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United States Patent Application Publication

20250253290

Kind Code

A1

Publication Date

August 07, 2025

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LOGIC DRIVE BASED ON CHIP SCALE PACKAGE COMPRISING STANDARDIZED COMMODITY PROGRAMMABLE LOGIC IC CHIP AND MEMORY IC CHIP

Abstract

A multi-chip package comprising an interconnection substrate; a first semiconductor IC chip over the interconnection substrate, wherein the first semiconductor IC chip comprises a first silicon substrate, a plurality of first metal vias passing through the first silicon substrate, a plurality of first transistors on a top surface of the first silicon substrate and a first interconnection scheme over the first silicon substrate, wherein the first interconnection scheme comprises a first interconnection metal layer over the first silicon substrate, a second interconnection metal layer over the first interconnection layer and the first silicon substrate and a first insulating dielectric layer over the first silicon substrate and between the first and second interconnection metal layers; a second semiconductor IC chip over and bonded to the first semiconductor IC chip; and a plurality of second metal vias over and coupling to the interconnection substrate, wherein the plurality of second metal vias are in a space extending from a sidewall of the first semiconductor IC chip.

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Family ID: 70460112

Appl. No.: 19/186646

Filed: April 23, 2025

Related U.S. Application Data

parent US continuation 18121873 20230315 parent-grant-document US 12327816 child US 19186646

parent US continuation 16671126 20191031 parent-grant-document US 11616046 child US 18121873

us-provisional-application US 62755415 20181102

Publication Classification

Int. Cl.: **H01L25/065** (20230101); **H01L23/00** (20060101); **H01L23/48** (20060101); **H01L23/498** (20060101); **H01L23/522** (20060101); **H01L23/528** (20060101); **H01L23/538** (20060101); **H01L25/00** (20060101); **H01L25/16** (20230101); **H01L25/18** (20230101); **H03K19/17704** (20200101); **H03K19/1776** (20200101); **H10B80/00** (20230101)

U.S. Cl.:

CPC **H01L25/0652** (20130101); **H01L23/481** (20130101); **H01L23/49816** (20130101); **H01L23/5226** (20130101); **H01L23/5283** (20130101); **H01L23/5286** (20130101); **H01L23/5386** (20130101); **H01L23/5389** (20130101); **H01L24/05** (20130101); **H01L24/13** (20130101); **H01L24/16** (20130101); **H01L24/29** (20130101); **H01L24/32** (20130101); **H01L24/73** (20130101); **H01L25/0657** (20130101); **H01L25/16** (20130101); **H01L25/18** (20130101); **H01L25/50** (20130101); **H03K19/17708** (20130101); **H03K19/1776** (20130101); **H10B80/00** (20230201); **H01L2224/0401** (20130101); **H01L2224/16225** (20130101); **H01L2224/32225** (20130101); **H01L2224/73204** (20130101); **H01L2225/06544** (20130101); **H01L2924/1431** (20130101)

Background/Summary

PRIORITY CLAIM [0001] This application is a continuation of application Ser. No. 18/121,873, filed Mar. 15, 2023, now pending, which is a continuation of application Ser. No. 16/671,126, filed Oct. 31, 2019, now patent Ser. No. 11/616,046, which claims priority benefits from U.S. provisional application No. 62/755,415, filed on Nov. 2, 2018 and entitled “LOGIC DRIVE BASED ON STANDARDIZED COMMODITY PROGRAMMABLE LOGIC/MEMORY SEMICONDUCTOR IC CHIP SCALE PACKAGES”, U.S. provisional application No. 62/882,941, filed on Aug. 5, 2019 and entitled “VERTICAL INTERCONNECT ELEVATOR BASED ON THROUGH SILICON VIAS”, and U.S. provisional application No. 62/891,386, filed on Aug. 25, 2019 and entitled “VERTICAL INTERCONNECT ELEVATOR BASED ON THROUGH SILICON VIAS”. The present application incorporates the foregoing disclosures herein by reference.

FIELD OF THE DISCLOSURE

[0002] The present invention relates to a logic package, logic package drive, logic device, logic module, logic drive, logic disk, logic disk drive, logic solid-state disk, logic solid-state drive, Field Programmable Gate Array (FPGA) logic disk, FPGA logic drive, or programmable logic drive (to be abbreviated as “logic drive” below, that is when “logic drive” is mentioned below, it means and reads as “logic package, logic package drive, logic device, logic module, logic drive, logic disk, logic disk drive, logic solid-state disk, logic solid-state drive, FPGA logic disk, FPGA logic drive, or programmable logic drive”) comprising plural programmable Field Programmable Gate Arrays/High Bandwidth Memory semiconductor IC chip Chip-Scale Packages (FPGA/HBM CSP) and one or plural non-volatile IC chips for field programming purposes, and more particularly to a standardized commodity logic drive formed by using plural standardized commodity FPGA/HBM

CSP (comprising FPGA IC chips and HBM IC chips) and one or plural non-volatile IC chip or chips, and to be used for different specific applications when field programmed or user programmed.

BRIEF DESCRIPTION OF THE RELATED ART

[0003] The Field Programmable Gate Array (FPGA) semiconductor integrated circuit (IC) has been used for development of new or innovated applications, or for small volume applications or business demands. When an application or business demand expands to a certain volume and extend to a certain time period, the semiconductor IC suppliers may usually implement the application in an Application Specific IC (ASIC) chip, or a Customer-Owned Tooling (COT) IC chip. The switch from the FPGA design to the ASIC or COT design is because the current FPGA IC chip, for a given application and compared with an ASIC or COT chip, (1) has a larger semiconductor chip size, lower fabrication yield, and higher fabrication cost, (2) consumes more power, (3) gives lower performance. When the semiconductor technology nodes or generations migrate, following the Moore's Law, to advanced nodes or generations (for example below 30 nm or 20 nm), the Non-Recurring Engineering (NRE) cost for designing an ASIC or COT chip increases greatly (more than US \$5M or even exceeding US \$10M, US \$20M, US \$50M or US \$100M). The cost of a photo mask set for an ASIC or COT chip at the 16 nm technology node or generation may be over US \$2M, US \$5M, or US \$10M. The high NRE cost in implementing the innovation or application using the advanced IC technology nodes or generations slows down or even stops the innovation or application using advanced and useful semiconductor technology nodes or generations. A new approach or technology is needed to inspire the continuing innovation and to lower down the barrier for implementing the innovation in the semiconductor IC chips.

SUMMARY OF THE DISCLOSURE

[0004] One aspect of the disclosure provides a standardized commodity logic drive in a multi-chip package comprising plural standardized commodity Field Programmable Gate Array/High Bandwidth Memory Chip-Scale Packages (FPGA/HBM CSP) and one or plural non-volatile IC chips for use in varieties of applications requiring logic, computing and/or processing functions by field programming; wherein the FPGA/HBM CSP is a Chip-Scale-Package (CSP) comprising a standard commodity FPGA IC chip and one HBM chip or a stacked package with plural HBM chips. Uses of the standardized commodity logic drive is analogues to uses of a standardized commodity data storage solid-state disk (drive), data storage hard disk (drive), data storage floppy disk, Universal Serial Bus (USB) flash drive, USB drive, USB stick, flash-disk, or USB memory, and differs in that the latter has memory functions for data storage, while the former has logic functions for processing and/or computing. Uses of the standardized commodity FPGA/HBM CSPs is analogues to uses of a standardized commodity data storage memory IC chips, for example, standard commodity DRAM chips or standard commodity NAND flash chips, and differs in that the latter has memory functions for data storage, while the former has logic functions for processing and/or computing.

[0005] Another aspect of the disclosure provides a method to reduce Non-Recurring Engineering (NRE) expenses for implementing an innovation and/or an application in semiconductor IC chips by using the standardized commodity logic drive comprising plural standardized commodity FPGA/HBM CSPs. A person, user, or developer with an innovation and/or an application concept or idea needs to purchase the standardized commodity logic drive and develops or writes software codes or programs to load into the standardized commodity logic drive to implement his/her innovation and/or application concept or idea; wherein said innovation and/or application (abbreviated as innovation) comprises (i) innovative algorithms and/or architectures of computing, processing, learning and/or inferencing, and/or (ii) innovative and/or specific applications. Compared to the implementation by developing a logic ASIC or COT IC chip, the NRE cost may be reduced by a factor of equal to or larger than 2, 5, 10, 30, 50 or 100 using the disclosed standardized commodity logic drive. For advanced semiconductor technology nodes or generations

(for example more advanced than or below 20 nm), the NRE cost for designing an ASIC or COT chip increases greatly, more than US \$5M or even exceeding US \$10M, US \$20M, US \$50M, or US \$100M. The cost of a photo mask set for an ASIC or COT chip at the 16 nm technology node or generation may be over US \$2M, US \$5M, or US \$10M. Implementing the same or similar innovation and/or application using the logic drive may reduce the NRE cost down to smaller than US \$10M or even less than US \$5M, US \$3M, US \$2M or US \$1M. The aspect of the disclosure inspires the innovation and lowers the barrier for implementing the innovation in IC chips designed and fabricated using an advanced IC technology node or generation, for example, a technology node or generation more advanced than or below 20 nm or 10 nm.

[0006] Another aspect of the disclosure provides a “public innovation platform” again for innovators to easily and cheaply implement or realize their innovation in semiconductor IC chips using advanced IC technology nodes more advanced than 20 nm, for example, using a technology node of 16 nm, 10 nm, 7 nm, 5 nm or 3 nm, by using logic drives; wherein said innovation comprises (i) innovative algorithms or architectures of computing, processing, learning and/or inferencing, and/or (ii) innovative and/or specific applications. In years of 1990's, innovators could implement their innovation by designing IC chips and fabricating the IC chips in a semiconductor manufacturing foundry fab using technology nodes at 1 μm , 0.8 μm , 0.5 μm , 0.35 μm , 0.18 μm or 0.13 μm , at a cost of about several hundred thousand US dollars. The semiconductor manufacturing foundry companies are productless companies and own semiconductor manufacturing fabs. They provide manufacturing services to their customers. The customers are fabless companies, which include (i) IC chip design companies designing and owning the IC chips, (ii) system companies designing and owning the systems, (iii) IC chip designing individuals designing and owning IC chips. The IC manufacturing foundry fab then was the “public innovation platform”. However, when IC technology nodes have migrated to a technology node more advanced than 20 nm, for example to the technology node of 16 nm, 10 nm, 7 nm, 5 nm or 3 nm IC technology nodes, only a few giant system or IC design companies, not the public innovators, can afford to use the semiconductor IC manufacturing foundry fab. It costs about or over 10 million US dollars to develop and implement an IC chip using these advanced technology nodes. The semiconductor IC manufacturing foundry fab is now not the “public innovation platform” anymore, they are becoming a “club innovation platform” for club innovators. The disclosed logic drives, comprising standard commodity FPGA IC chips, provides public innovators the “public innovation platform” to semiconductor IC industry again just as in 1990's. The innovators can implement or realize their innovation (algorithms, architectures and/or applications) by using the standard commodity of logic drives and writing software programs using common programing languages, for example, C, Java, C++, C#, Scala, Swift, Matlab, Assembly Language, Pascal, Python, Visual Basic, PL/SQL or JavaScript languages, at cost of less than 500K or 300K US dollars. The innovators can use their own standard commodity logic drives or they can rent standard commodity logic drives in data centers or clouds through networks.

[0007] Another aspect of the disclosure provides an innovation platform for an innovator, comprising: (a) multiple logic drives in a data center or a cloud, wherein multiple logic drives comprise plural standard commodity FPGA IC chips, in the FPGA/HBM CSPs, fabricated using a semiconductor IC process technology node more advanced than 20 nm technology node; (b) an innovator's device and multiple users' devices communicating with the multiple logic drives in the data center or the cloud through an internet or a network, wherein the innovator develops and writes software programs to implement his/her innovation (algorithms, architectures and/or applications) in a common programing language to program, through the internet or the network, the multiple logic drives in the data center or the cloud, wherein the common programing language comprises Java, C++, C#, Scala, Swift, Matlab, Assembly Language, Pascal, Python, Visual Basic, PL/SQL or JavaScript language; (c) after programming the logic drives, the innovator or the multiple users may use the programed logic drives for his/her or their innovations (algorithms,

architectures and/or applications) through the internet or the network; wherein said innovations comprise (i) innovative algorithms or architectures of computing, processing, learning and/or inferencing, and/or (ii) innovative and/or specific applications.

[0008] Another aspect of the disclosure provides a method to change the current logic ASIC or COT IC chip business into a commodity logic IC chip business, like the current commodity DRAM, or commodity flash memory IC chip business, by using the standardized commodity logic drive. Since the performance, power consumption, and engineering and manufacturing costs of the standardized commodity logic drive may be better or equal to that of the ASIC or COT IC chip for a same innovation (algorithms, architectures and/or applications), the standardized commodity logic drive may be used as an alternative for designing an ASIC or COT IC chip. The current logic ASIC or COT IC chip design, manufacturing and/or product companies (including fabless IC design and product companies, or IC foundry or contracted manufacturers (may be product-less), and/or vertically-integrated IC design, manufacturing and product (IDM) companies) may become companies like the current commodity DRAM, or flash memory IC chip design, manufacturing, and/or product companies; or like the current DRAM module design, manufacturing, and/or product companies; or like the current flash memory module, flash USB stick or drive, or flash solid-state drive or disk drive design, manufacturing, and/or product companies. The current logic ASIC or COT IC chip design and/or manufacturing companies (including fabless IC design and product companies, IC foundry or contracted manufacturers (may be product-less), vertically-integrated IC design, manufacturing and product companies) may become companies in the following business models: (1) designing, manufacturing, and/or selling the standard commodity FPGA IC chips or FPGA/HBM CSPs; and/or (2) designing, manufacturing, and/or selling the standard commodity logic drives. The business model is similar to the current commodity DRAM or flash memory chip and module business. A person, user, customer, or software developer, or algorithm/architecture/application developer may purchase the standardized commodity logic drive and write software codes to program them for his/her desired algorithms, architectures and/or applications, for example, in algorithms, architectures and/or applications of Artificial Intelligence (AI), machine learning, deep learning, big data, Internet Of Things (IoT), industry computers, Virtual Reality (VR), Augmented Reality (AR), self-drive or driver-less car, Graphic Processing (GP), Digital Signal Processing (DSP), Micro Controlling (MC), and/or Central Processing (CP). The logic drive may be programed to perform functions like a graphic chip, or a baseband chip, or an Ethernet chip, or a wireless (for example, 802.11ac) chip, or an AI chip. The logic drive may be alternatively programmed to perform functions of all or any combinations of functions of Artificial Intelligence (AI), machine learning, deep learning, big data, Internet Of Things (IoT), industry computers, Virtual Reality (VR), Augmented Reality (AR), car electronics, Graphic Processing (GP), Digital Signal Processing (DSP), Micro Controlling (MC), and/or Central Processing (CP). The logic drive may be field programmed as an accelerator for, for example, the AI functions, in the user-end, data center or cloud, in the algorithms, architectures and/or applications of training and/or inferring of the AI functions.

[0009] Another aspect of the disclosure provides a method to change the current logic ASIC or COT IC chip hardware business into a software business by using the standardized commodity logic drive. Since the performance, power consumption, and engineering and manufacturing costs of the standardized commodity logic drive may be better or equal to that of the ASIC or COT IC chip for a same innovation (algorithms, architectures and/or applications), the standardized commodity logic drive may be used as an alternative for designing an ASIC or COT IC chip. The current ASIC or COT IC chip design companies or suppliers may become software developers or suppliers; they may adapt the following business models: (1) become software companies to develop and sell software for their innovation (algorithms, architectures and/or applications), and let their customers or users to install software in the customers' or users' own standard commodity logic drive; and/or (2) still hardware companies by selling hardware without performing ASIC or

COT IC chip design and/or production. In the case (2), they may install their in-house developed software for the innovation (algorithms, architectures and/or applications) in the purchased standard commodity logic drive; and sell the program-installed logic drive to their customers or users. In both cases (1) and (2), either the customers/users or developers/companies may write software codes into the standard commodity logic drive (that is, loading the software codes in the standardized commodity logic drive) for their desired algorithms, architectures and/or applications, for example, in algorithms, architectures and/or applications of Artificial Intelligence (AI), machine learning, deep learning, big data, Internet Of Things (IoT), industry computers, car electronics, Virtual Reality (VR), Augmented Reality (AR), Graphic Processing, Digital Signal Processing, micro controlling, and/or Central Processing. The logic drive may be programed to perform functions like a graphic chip, or a baseband chip, or an Ethernet chip, or a wireless (for example, 802.11ac) chip, or an AI chip. The logic drive may be alternatively programmed to perform functions of all or any combinations of functions of Artificial Intelligence (AI), machine learning, deep learning, big data, Internet Of Things (IoT), industry computers, car electronics, Virtual Reality (VR), Augmented Reality (AR), car electronics, Graphic Processing (GP), Digital Signal Processing (DSP), Micro Controlling (MC), and/or Central Processing (CP).

[0010] Another aspect of the disclosure provides a method to change the current system design, manufactures and/or product business into a commodity system/product business, like current commodity DRAM, or flash memory business, by using the standardized commodity logic drive. The system, computer, processor, smart-phone, or electronic equipment or device may become a standard commodity hardware comprises mainly a memory drive and a logic drive. The memory drive may be a hard disk drive, a flash drive, and/or a solid-state drive. The logic drive in the aspect of the disclosure may have big enough or adequate number of inputs/outputs (I/Os) to support I/O ports for used for programming all or most applications. The logic drive may have I/Os to support required I/O ports for programming, for example, to perform all or any combinations of functions of Artificial Intelligence (AI), machine learning, deep learning, big data, Internet Of Things (IoT), industry computers, Virtual Reality (VR), Augmented Reality (AR), car electronics, Graphic Processing (GP), Digital Signal Processing (DSP), Micro Controlling (MC), and/or Central Processing (CP), and etc. The logic drive may comprise (1) programing or configuration I/Os for software, algorithm, architecture and/or application developers to load algorithm, architecture and/or application software or program codes to program or configure the logic drive, through I/O ports or connectors connecting or coupling to the I/Os of the logic drive; and (2) operation, execution or user I/Os for the users to operate, execute and perform their instructions, through I/O ports or connectors connecting or coupling to the I/Os of the logic drive; for example, generating a Microsoft Word file, or a PowerPoint presentation file, or an Excel file. The I/O ports or connectors connecting or coupling to the corresponding I/Os of the logic drive may comprise one or multiple (2, 3, 4, or more than 4) Universal Serial Bus (USB) ports, one or more IEEE 1394 ports, one or more Ethernet ports, one or more audio ports or serial ports, for example, RS-232 or COM (communication) ports, wireless transceiver I/Os, and/or Bluetooth transceiver I/Os, and etc. The I/O ports or connectors connecting or coupling to the corresponding I/Os of the logic drive may also comprise Serial Advanced Technology Attachment (SATA) ports, or Peripheral Components Interconnect express (PCIe) ports for communicating, connecting or coupling with or to the memory drive. The I/O ports or connectors may be placed, located, assembled, or connected on or to a substrate, film or board; for example, a Printed Circuit Board (PCB), a silicon substrate with interconnection schemes, a metal substrate with interconnection schemes, a glass substrate with interconnection schemes, a ceramic substrate with interconnection schemes, a flexible film with interconnection schemes. The logic drive is assembled on the substrate, film or board using solder bumps, or copper pillars or bumps, on or of the logic drive, similar to the flip-chip assembly of the chip packaging technology, or the Chip-On-Film (COF) assembly technology used in the LCD driver packaging technology. The system, computer, processor, smart-phone, or electronic

equipment or device design, manufacturing, and/or product companies may become companies to (1) design, manufacturing and/or sell the standard commodity hardware comprising a memory drive and a logic drive; in this case, the companies are still hardware companies; (2) develop system and algorithm, architecture and/or application software for users to install in the users' own standard commodity hardware; in this case, the companies become software companies; (3) install the third party's developed system and algorithm, architecture and/or application software or programs in the standard commodity hardware and sell the software-loaded hardware; and in this case, the companies are still hardware companies.

[0011] Another aspect of the disclosure provides a standard commodity FPGA IC chip for use in the standard commodity FPGA/HBM CSPs. The FPGA/HBM CSPs are used in the multi-chip packaged standard commodity logic drive. The standard commodity FPGA IC chip is designed, implemented and fabricated using an advanced semiconductor technology node or generation, for example more advanced than or equal to, or below or equal to 30 nm, 20 nm or 10 nm; with a chip size and manufacturing yield optimized with the minimum manufacturing cost for the used semiconductor technology node or generation. The standard commodity FPGA IC chip may have an area between 400 mm.sup.2 and 9 mm.sup.2, 225 mm.sup.2 and 9 mm.sup.2, 144 mm.sup.2 and 16 mm.sup.2, 100 mm.sup.2 and 16 mm.sup.2, 75 mm.sup.2 and 16 mm.sup.2, or 50 mm.sup.2 and 16 mm.sup.2. Transistors used in the advanced semiconductor technology node or generation may be a FIN Field-Effect-Transistor (FINFET), a FINFET on Silicon-On-Insulator (FINFET SOI), a Fully Depleted Silicon-On-Insulator (FDSOI) MOSFET, a Partially Depleted Silicon-On-Insulator (PDSOI) MOSFET or a conventional MOSFET. The standard commodity FPGA IC chip may only communicate directly with other chips in or of the logic drive only; its I/O circuits may require only small I/O drivers or receivers, and small or none Electrostatic Discharge (ESD) devices. The driving capability, loading, output capacitance, or input capacitance of I/O drivers or receivers, or I/O circuits may be between 0.05 pF and 2 pF or 0.05 pF and 1 pF; or smaller than 2 pF or 1 pF. The size of the ESD device may be between 0.01 pF and 2 pF or 0.01 pF and 1 pF; or smaller than 2 pF, 1 pF or 0.1 pF. For example, a bi-directional (or tri-state) I/O pad or circuit may comprise an ESD circuit, a receiver, and a driver, and has an input capacitance or output capacitance between 0.05 pF and 2 pF or 0.05 pF and 1 pF; or smaller than 2 pF or 1 pF. The smaller I/O circuits provide high performance and low power of the FPGA IC chips. All or most control and/or Input/Output (I/O) circuits or units (for example, the off-logic-drive I/O circuits, i.e., large I/O circuits, communicating with circuits or components external or outside of the logic drive) are outside of, or not included in, the standard commodity FPGA IC chip, but are included in another dedicated control chip, dedicated I/O chip, or dedicated control and I/O chip, packaged in the same logic drive. None or minimal area of the standard commodity FPGA IC chip is used for the control or I/O circuits, for example, less than 15%, 10%, 5%, 2%, 1%, 0.5% or 0.1% area is used for the control or IO circuits; or, none or minimal transistors of the standard commodity FPGA IC chip are used for the control or I/O circuits, for example, less than 15%, 10%, 5%, 2%, 1%, 0.5% or 0.1% of the total number of transistors are used for the control or I/O circuits; or all or most area of the standard commodity FPGA IC chip is used for (i) logic blocks or cells comprising logic gate arrays, computing units or operators, and/or Look-Up-Tables (LUTs) and multiplexers, and/or (ii) programmable interconnection. For example, greater than 85%, 90%, 95%, 98%, 99%, 99.5% or 99.9% area is used for logic blocks, and/or programmable interconnection; or, all or most transistors of the standard commodity FPGA IC chip are used for logic blocks, and/or programmable interconnection, for example, greater than 85%, 90%, 95%, 98%, 99%, 99.5% or 99.9% of the total number of transistors are used for logic blocks, and/or programmable interconnection. The area (mentioned above) of the standard commodity FPGA IC chip is measured without the seal ring and the dicing area of the chip; that means the area is only including an area upto the inner boundary of the seal ring. The standard repetitive arrays in the FPGA chip further improve the manufacturing yield of the FPGA chip. Since the FPGA IC chips are in the standard

common designs, a standard common design for the locations of the Through Silicon Vias (TSV) in the silicon substrate may be designed at fixed standard locations of the FPGA IC chip.

[0012] Another aspect of the disclosure provides a standard commodity FPGA IC chip for use in the FPGA/HBM CSPs. The FPGA/HBM CSPs are used in the multi-chip packaged standard commodity logic drive. The standard commodity FPGA chip comprises logic blocks or cells. The logic blocks or cells comprise (i) logic gate arrays comprising Boolean logic operators, for example, NAND, NOR, AND, and/or OR circuits; (ii) computing units comprising, for examples, adder, multiplication, and/or division circuits; (iii) Look-Up-Tables (LUTs) and multiplexers. The Boolean operators, the functions of logic gates, or computing, operations or processes may be carried out using the programmable wires or lines (the programmable metal interconnection wires or lines) on the FPGA IC chip; while certain Boolean operators, logic gates, or certain computing, operations or processes may be carried out using the fixed wires or lines (the metal interconnection wires or lines) on the FPGA IC chip. For example, the adder and/or multiplier may be designed and implemented by the fixed wires or lines (the fixed metal interconnection wires or lines) on the FPGA IC chip, for interconnecting logic circuits of the adder and/or multiplier. Alternatively, the Boolean operators, the functions of logic gates, or computing, operations or processes may be carried out using, for example, Look-Up-Tables (LUTs) and/or multiplexers. The LUTs store or memorize the processing or computing results of logic gates, computing results of calculations, decisions of decision-making processes, or results of operations, events or activities. The LUTs may store or memorize data or results in, for example, SRAM cells. One of the two latched nodes of the 4 latch transistors in the 5T or 6T SRAM cell is connected or coupled to the multiplexer. The stored data in the 5T or 6T SRAM cell is used for LUTs. When inputting a set of data, requests or conditions, a multiplexer is used to select the corresponding data (or results) stored or memorized in the LUTs, based on the inputted set of data, requests or conditions. As an example, a 4-input NAND gate may be implemented using an operator comprising LUTs and multiplexers as described below: There are 4 inputs for a 4-input NAND gate, and $2^{\sup.4}$ possible corresponding outputs (results) of the 4-input NAND gate. To carry out the same function of the 4-input NAND operation using LUTs and multiplexers, it may require circuits comprising: (i) a LUT for storing and memorizing the 16 possible corresponding outputs (results), (ii) a multiplexer designed and used for selecting the right (corresponding) output, based on a given 4-input control or instruction data set (for example, 1, 0, 0, 1); that is there are 16 input data (the memory stored data) and 4 control or instruction data for the multiplexer. An output is selected by the multiplexer from the 16 stored data based on 4 control or instruction data. In general, for a LUT and a multiplexer to carry out the same function as an operator NAND comprises n inputs, the LUT may be storing or memorizing $2^{\sup.n}$ corresponding data or results, and using the multiplexer to select a right (corresponding) output from the memorized $2^{\sup.n}$ corresponding data or results based on a given n -input control or instruction data set. The memorized $2^{\sup.n}$ corresponding data or results are memorized or stored in the $2^{\sup.n}$ memory cells, for example, $2^{\sup.n}$ memory cells of the 5T or 6T SRAM cells.

[0013] The programmable interconnections of the standard commodity FPGA chip comprise cross-point switches in the middle of interconnection metal lines or traces. For example, n metal lines or traces are connected to the input terminals of the cross-point switches, and m metal lines or traces are connected to the output terminals of the cross-point switches, and the cross-point switches are located between the n metal lines or traces and the m metal lines and traces. The cross-point switches are designed such that each of the n metal lines or traces may be programed to connect to anyone of the m metal lines or traces. Each of the cross-point switches may comprise, for example, a pass/no-pass circuit comprising a n -type and a p -type transistor, in pair, wherein one of the n metal lines or traces are connected to the connected source terminals of the n -type and p -type transistor pairs in the pass-no-pass circuit, while one of the m metal lines and traces are connected to the connected drain terminal of the n -type and p -type transistor pairs in the pass-no-pass circuit.

The connection or disconnection (pass or no pass) of the cross-point switch is controlled by the data (1 or 0) stored or latched in a SRAM cell. Since the standard commodity FPGA IC chip comprises mainly the regular and repeated gate arrays or blocks, LUTs and multiplexers, or programmable interconnection, just like standard commodity DRAM, or NAND flash IC chips, the manufacturing yield may be very high, for example, greater than 70%, 80%, 90% or 95% for a chip area greater than, for example, 50 mm.sup.2, or 80 mm.sup.2.

[0014] Alternatively, each of the cross-point switches may comprise, for example, a pass/no-pass circuit comprising a switching buffer, wherein the switching buffer comprises two-stages of inverters (buffer), a control N-MOS, and a control P-MOS. Wherein one of the n metal lines or traces is connected to the common (connected) gate terminal of an input-stage inverter of the buffer in the pass-no-pass circuit, while one of the m metal lines and traces is connected to the common (connected) drain terminal of output-stage inverter of buffer in the pass-no-pass circuit. The output-stage inverter is stacked with the control P-MOS at the top (between V.sub.cc and the source of the P-MOS of the output-stage inverter) and the control N-MOS at the bottom (between V.sub.ss and the source of the N-MOS of the output-stage inverter). The connection or disconnection (pass or no pass) of the cross-point switch is controlled by the data (0 or 1) stored in a 5T or 6T SRAM cell.

[0015] Alternatively, the cross-point switches may comprise, for example, multiplexers and switch buffers. The multiplexer selects one of the n inputting data from the n inputting metal lines based on the data stored in the 5T or 6T SRAM cells; and outputs the selected one of inputs to a switch buffer. The switch buffer passes or does not pass the output data from the multiplexer to one metal line connected to the output of the switch buffer based on the data stored in the 5T or 6T SRAM cells. The switch buffer comprises two-stages of inverters (buffer), a control N-MOS, and a control P-MOS. Wherein the selected data from the multiplexer is connected to the common (connected) gate terminal of input-stage inverter of the buffer, while one of the m metal lines or traces is connected to the common (connected) drain terminal of output-stage inverter of the buffer. The output-stage inverter is stacked with the control P-MOS at the top (between V.sub.cc and the source of the P-MOS of the output-stage inverter) and the control N-MOS at the bottom (between V.sub.ss and the source of the N-MOS of the output-stage inverter). The connection or disconnection of the switch buffer is controlled by the data (0 or 1) stored in the 5T or 6T SRAM cell.

[0016] The programmable interconnections of the standard commodity FPGA chip comprise a multiplexer in the middle of interconnection metal lines or traces. The multiplexer selects from n metal interconnection lines connected to the n inputs of the multiplexer, and coupled or connected to one metal interconnection line connected to the output of the multiplexer, based on the data stored or programmed in the 5T or 6T SRAM cells. For example, n=16, 4 bits of the 5T or 6T SRAM cells are required to select any one of the 16 metal interconnection lines connected to the 16 inputs of the multiplexer, and couple or connect the selected one to one metal interconnection line connected to the output of the multiplexer. The data from the selected one of 16 inputs is therefore coupled, passed, or connected to the metal line connected to the output of the multiplexer.

[0017] Another aspect of the disclosure provides the standard commodity logic drive in a multi-chip package comprising plural standard commodity FPGA/HBM CSPs and one or more non-volatile memory IC chips, for use in different applications requiring logic, computing and/or processing functions by field programming, wherein each of the plural standard commodity FPGA/HBM CSPs comprises (i) one standard commodity FPGA IC chip and (ii) one HBM chip mounted on the standard commodity FPGA IC chip or a stacked package with multiple HBM chips mounted on the standard commodity FPGA IC chip. Each of the plural standard commodity FPGA IC chips may have standard common features or specifications: (1) logic blocks including (i) system gates with the count greater than or equal to 2M, 10M, 20M, 50M or 100M, (ii) logic cells or elements with the count greater than or equal to 64K, 128K, 512K, 1M, 4M or 8M, (iii) hard macros, for example DSP slices, microcontroller macros, multiplexer macros, fixed-wired adders, and/or fixed-wired multipliers and/or (iv) blocks of memory with the bit count equal to or greater

than 1M, 10M, 50M, 100M, 200M or 500M bits. In some cases, the standard commodity FPGA IC chip may comprise logic blocks of system gates (as in (i)) and logic cells or elements but not hard macros as in (iii). The hard macros may be included in the other chips of the logic drive, for example, in the dedicated control chip, dedicated I/O chip, the dedicated control and I/O chip, IAC, or DPIIC chip of the logic drive. (2) the number of inputs to each of the logic blocks or operators: the number of inputs to each of the logic block or operator may be greater or equal to 4, 8, 16, 32, 64, 128, or 256; (3) the power supply voltage: the voltage may be between 0.2V and 2.5V, 0.2V and 2V, 0.2V and 1.5V, 0.1V and 1V, or 0.2V and 1V, or, smaller or lower than or equal to 2.5V, 2V, 1.8V, 1.5V or 1V; (4) the I/O pads, in terms of layout, location, number and function; (5) the Through Silicon Vias (TSVs) in the silicon substrate of the FPGA IC Chip, in terms of layout, location, number and function. Since the FPGA chips are standard commodity IC chips, the number of FPGA chip designs or products is reduced to a small number, therefore, the expensive photo masks or mask sets for fabricating the FPGA chips using advanced semiconductor nodes or generations are reduced to a few mask sets. For example, reduced down to between 3 and 20 mask sets, 3 and 10 mask sets, or 3 and 5 mask sets for a specific technology node or generation. The NRE and production expenses are therefore greatly reduced. With the few designs and products, the manufacturing processes may be tuned or optimized for the few chip designs or products, and resulting in very high manufacturing chip yields. This is similar to the current advanced standard commodity DRAM or NAND flash memory design and production. Furthermore, the chip inventory management becomes easy, efficient and effective; therefore, resulting in a shorter FPGA chip delivery time and becoming very cost-effective.

[0018] Another aspect of the disclosure provides the standard commodity logic drive in a multi-chip package comprising the plural standard commodity FPGA IC chips (in the FPGA/HBM CSPs) and one or more non-volatile memory IC chips, for use in different applications requiring logic, computing and/or processing functions by field programming, wherein the plural standard commodity FPGA IC chips, each is in the FPGA/HBM CSPs. Each of the plural standard commodity FPGA IC chips may have standard common features or specifications as described and specified above. Similar to standard commodity DRAM IC chips for use in a DRAM module, the standard commodity FPGA IC chips in the logic drive, each chip may further comprise some additional I/O pins or pads, for example: (1) one chip enable pin or pad, (2) two or more input selection pins or pads and/or (3) two or more output selection pins or pads. Each of the plural standard commodity FPGA IC chips may comprise, for example, 4 I/O ports, and each I/O port may comprise 64 bi-directional I/O circuits. The above additional I/O pins or pads are used to select one I/O port from the above 4 I/O ports for each of the standard commodity FPGA IC chips in the logic drive. The data, signal and/or power/ground bus in the interconnection schemes, for example, the FISIP and SISIP on or of interposer, for interconnecting two or more of the plural standard commodity FPGA IC chips in the logic drive also comprises a plurality of groups of bus lines or traces corresponding to the plurality of I/O ports, and each group of bus lines or traces may comprise n bus lines or traces, wherein n is equal to or greater than 4, 8, 16, 32, 64, 128, 256, 512, or 1024.

[0019] Another aspect of the disclosure provides the standard commodity logic drive in a multi-chip package comprising the plural standard commodity FPGA/HBM CSPs and one or more non-volatile memory IC chips, for use in different applications requiring logic, computing and/or processing functions by field programming, wherein each of the plural standard commodity FPGA/HBM CSPs comprises one standard commodity FPGA IC chip and one HBM chip mounted on the standard commodity FPGA IC chip or a stacked package with plural HBM chips mounted on the standard commodity FPGA IC chip. Each of the plural standard commodity FPGA IC chips may have standard common features or specifications as described and specified above. Each of the plural standard commodity FPGA IC chip may comprise multiple logic blocks, wherein each logic block may comprise, for example, (1) 1 to 16 of 8-by-8 adders, (2) 1 to 16 of 8-by-8 multipliers, (3)

256 to 2K of logic cells, wherein each logic cell comprises 1 register and 1 to 4 of LUTs (Look-Up-Tables), wherein each LUT comprises 4 to 256 bits of data or information. The above 1 to 16 of 8-by-8 adders and/or 1 to 16 of 8-by-8 multipliers may be designed and formed by fixed metal wires or lines (metal interconnection wires or lines) on each of the FPGA IC chips.

[0020] Another aspect of the disclosure provides the standard commodity logic drive in a multi-chip package comprising plural standard commodity FPGA/HBM CSPs and one or more non-volatile memory IC chips, for use in different algorithms, architectures and/or applications requiring logic, computing and/or processing functions by field programming, wherein each of the plural standard commodity FPGA/HBM CSPs comprises one standard commodity FPGA IC chip and one HBM chip mounted on the standard commodity FPGA IC chip or a stacked package with plural HBM chips mounted on the standard commodity FPGA IC chip. The standard commodity logic drive may have standard common features, counts or specifications: (1) logic blocks including (i) system gates with the count greater than or equal to 8M, 40M, 80M, 200M or 400M, (ii) logic cells or elements with the count greater than or equal to 256K, 512K, 2M, 4M, 16M or 32M, (iii) hard macros, for example DSP slices, microcontroller macros, multiplexer macros, fixed-wired adders, and/or fixed-wired multipliers and/or (iv) blocks of memory with the bit count equal to or greater than 4M, 40M, 200M, 400M, 800M or 2G bits; (2) the power supply voltage: the voltage may be between 0.1V and 12V, 0.1V and 7V, 0.1V and 3V, 0.1V and 2V, 0.1V and 1.5V, or 0.1V and 1V; (3) the I/O pads in the multi-chip package of the standard commodity logic drive, in terms of layout, location, number and function; wherein the logic drive may comprise the I/O pads, metal pillars or bumps connecting or coupling to one or multiple (2, 3, 4, or more than 4) Universal Serial Bus (USB) ports, one or more IEEE 1394 ports, one or more Ethernet ports, one or more audio ports or serial ports, for example, RS-232 or COM (communication) ports, wireless transceiver I/Os, and/or Bluetooth transceiver I/Os, and etc. The logic drive may also comprise the I/O pads, metal pillars or bumps connecting or coupling to Serial Advanced Technology Attachment (SATA) ports, or Peripheral Components Interconnect express (PCIe) ports for communicating, connecting or coupling with the memory drive. Since the logic drives are standard commodity products, the product inventory management becomes easy, efficient and effective, therefore resulting in a shorter logic drive delivery time and becoming cost-effective.

[0021] Another aspect of the disclosure provides the standard commodity logic drive in a multi-chip package further comprising a dedicated control chip. The dedicated control chip is designed, implemented and fabricated using varieties of semiconductor technology nodes or generations, including old or matured technology nodes or generations, for example, less advanced than or equal to, or above or equal to 40 nm, 50 nm, 90 nm, 130 nm, 250 nm, 350 nm, or 500 nm. The semiconductor technology node or generation used in the dedicated control chip is 1, 2, 3, 4, 5 or greater than 5 nodes or generations older, more matured or less advanced than that used in the standard commodity FPGA IC chips packaged in the same logic drive. Transistors used in the dedicated control chip may be a FINFET, a Fully Depleted Silicon-on-insulator (FDSOI) MOSFET, a Partially Depleted Silicon-on-insulator (PDSOI) MOSFET or a conventional MOSFET. Transistors used in the dedicated control chip may be different from that used in the standard commodity FPGA IC chips packaged in the same logic drive; for example, the dedicated control chip may use the conventional MOSFET, while the standard commodity FPGA IC chips packaged in the same logic drive may use the FINFET; or the dedicated control chip may use the Fully Depleted Silicon-on-insulator (FDSOI) MOSFET, while the standard commodity FPGA IC chips packaged in the same logic drive may use the FINFET. The dedicated control chip provides control functions of: (1) downloading programing codes from outside (of the logic drive) to the non-volatile IC chips in the logic drive; (2) downloading the programing codes from the non-volatile IC chips in the logic drive to the 5T or 6T SRAM cells of the programmable interconnection on the standard commodity FPGA chips. Alternatively, the programming codes from the non-volatile IC chips in the logic drive may go through a buffer or driver in or of the dedicated control chip before

getting into the 5T or 6T SRAM cells of the programmable interconnection on the standard commodity FPGA chips. The buffer in or of the dedicated control chip may latch the data from the non-volatile chips and increase the bit-width of the data. For example, the data bit-width (in a SATA standard) from the non-volatile chips is 1 bit, the buffer may latch the 1 bit data in each of the multiple SRAM cells in the buffer, and output the data stored or latched in the multiple SRAM cells in parallel and simultaneously to increase the data bit-width; for example, equal to or greater than 4, 8, 16, 32, or 64 data bit-width. For another example, the data bit-width (in a PCIe standard) from the non-volatile chips is 32 bits, the buffer may increase the data bit-width to equal to or greater than 64, 128, or 256 data bit-width. The driver in or of the dedicated control chip may amplify the data signals from the non-volatile chips; (3) inputting/outputting signals for a user application; (4) power management; (5) downloading data from the non-volatile IC chips in the logic drive to the 5T or 6T SRAM cells of the LUTs on the standard commodity FPGA chips. Alternatively, the data from the non-volatile IC chips in the logic drive may go through a buffer or driver in or of the dedicated control chip before getting into the 5T or 6T SRAM cells of LUTs on the standard commodity FPGA chips. The buffer in or of the dedicated control chip may latch the data from the non-volatile chips and increase the bit-width of the data. For example, the data bit-width (in a SATA standard) from the non-volatile chips is 1 bit, the buffer may latch the 1 bit data in each of the multiple SRAM cells in the buffer, and output the data stored or latched in the multiple SRAM cells in parallel and simultaneously to increase the data bit-width; for example, equal to or greater than 4, 8, 16, 32, or 64 data bit-width. For another example, the data bit-width (in a PCIe standard) from the non-volatile chips is 32 bits, the buffer may increase the data bit-width to equal to or greater than 64, 128, or 256 data bit-width. The driver in or of the dedicated control chip may amplify the data signals from the non-volatile chips.

[0022] Another aspect of the disclosure provides the standard commodity logic drive in a multi-chip package further comprising a dedicated I/O chip. The dedicated I/O chip is designed, implemented and fabricated using varieties of semiconductor technology nodes or generations, including old or matured technology nodes or generations, for example, a semiconductor node or generation less advanced than or equal to, or above or equal to 40 nm, 50 nm, 90 nm, 130 nm, 250 nm, 350 nm, or 500 nm. The semiconductor technology node or generation used in the dedicated I/O chip is 1, 2, 3, 4, 5 or greater than 5 nodes or generations older, more matured or less advanced than that used in the standard commodity FPGA IC chips packaged in the same logic drive. Transistors used in the dedicated I/O chip may be a Fully Depleted Silicon-on-insulator (FDSOI) MOSFET, a Partially Depleted Silicon-on-insulator (PDSOI) MOSFET or a conventional MOSFET. Transistors used in the dedicated I/O chip may be different from that used in the standard commodity FPGA IC chips packaged in the same logic drive; for example, the dedicated I/O chip may use the conventional MOSFET, while the standard commodity FPGA IC chips packaged in the same logic drive may use the FINFET; or the dedicated I/O chip may use the Fully Depleted Silicon-on-insulator (FDSOI) MOSFET, while the standard commodity FPGA IC chips packaged in the same logic drive may use the FINFET. The power supply voltage used in the dedicated I/O chip may be greater than or equal to 1.5V, 2.0 V, 2.5V, 3 V, 3.5V, 4V, or 5V, while the power supply voltage used in the standard commodity FPGA IC chips packaged in the same logic drive may be smaller than or equal to 2.5V, 2V, 1.8V, 1.5V, or 1 V. The power supply voltage used in the dedicated I/O chip may be different from that used in the standard commodity FPGA IC chips packaged in the same logic drive; for example, the dedicated I/O chip may use a power supply of 4V, while the standard commodity FPGA IC chips packaged in the same logic drive may use a power supply voltage of 1.5V; or the dedicated I/O chip may use a power supply of 2.5V, while the standard commodity FPGA IC chips packaged in the same logic drive may use a power supply of 0.75V. The gate oxide (physical) thickness of the Field-Effect-Transistors (FETs) may be thicker than or equal to 5 nm, 6 nm, 7.5 nm, 10 nm, 12.5 nm, or 15 nm, while the gate oxide (physical) thickness of FETs used in the standard commodity FPGA IC chips packaged in the same

logic drive may be thinner than 4.5 nm, 4 nm, 3 nm or 2 nm. The gate oxide (physical) thickness of FETs used in the dedicated I/O chip may be different from that used in the standard commodity FPGA IC chips packaged in the same logic drive; for example, the dedicated I/O chip may use a gate oxide (physical) thickness of FETs of 10 nm, while the standard commodity FPGA IC chips packaged in the same logic drive may use a gate oxide (physical) thickness of FETs of 3 nm; or the dedicated I/O chip may use a gate oxide (physical) thickness of FETs of 7.5 nm, while the standard commodity FPGA IC chips packaged in the same logic drive may use a gate oxide (physical) thickness of FETs of 2 nm. The dedicated I/O chip provides inputs and outputs, and ESD protection for the logic drive. The dedicated I/O chip provides (i) large drivers or receivers, or I/O circuits for communicating with external or outside (of the logic drive) circuits, and (ii) small drivers or receivers, or I/O circuits for communicating with chips in or of the logic drive. The large drivers or receivers, or I/O circuits for communicating with external or outside (of the logic drive) circuits have driving capability, loading, output capacitance or input capacitance larger or bigger than that of the small drivers or receivers, or I/O circuits for communicating with chips in or of the logic drive. The driving capability, loading, output capacitance, or input capacitance of the large I/O drivers or receivers, or I/O circuits for communicating with external or outside (of the logic drive) circuits may be between 2 pF and 100 pF, 2 pF and 50 pF, 2 pF and 30 pF, 2 pF and 20 pF, 2 pF and 15 pF, 2 pF and 10 pF, or 2 pF and 5 pF; or larger than 2 pF, 5 pF, 10 pF, 15 pF or 20 pF. The driving capability, loading, output capacitance, or input capacitance of the small I/O drivers or receivers, or I/O circuits for communicating with chips in or of the logic drive may be between 0.1 pF and 10 pF, 0.1 pF and 5 pF, 0.1 pF and 2 pF, or 0.1 pF and 1 pF; or smaller than 10 pF, 5 pF, 3 pF, 2 pF or 1 pF. The size of ESD protection device on the dedicated I/O chip is larger than that on other standard commodity FPGA IC chips in the same logic drive. The size of the ESD device in the large I/O circuits may be between 0.5 pF and 20 pF, 0.5 pF and 15 pF, 0.5 pF and 10 pF 0.5 pF and 5 pF or 0.5 pF and 2 pF; or larger than 0.5 pF, 1 pF, 2 pF, 3 pF, 5 pF or 10 pF. For example, a bi-directional (or tri-state) I/O pad or circuit may be used for the large I/O drivers or receivers, or I/O circuits for communicating with external or outside (of the logic drive) circuits, and may comprise an ESD circuit, a receiver, and a driver, and may have an input capacitance or output capacitance between 2 pF and 100 pF, 2 pF and 50 pF, 2 pF and 30 pF, 2 pF and 20 pF, 2 pF and 15 pF, 2 pF and 10 pF, or 2 pF and 5 pF; or larger than 2 pF, 5 pF, 10 pF, 15 pF or 20 pF. For example, a bi-directional (or tri-state) I/O pad or circuit may be used for the small I/O drivers or receivers, or I/O circuits for communicating with chips in or of the logic drive, and may comprise an ESD circuit, a receiver, and a driver, and may have an input capacitance or output capacitance between 0.1 pF and 10 pF, 0.1 pF and 5 pF, 0.1 pF and 2 pF, or 0.1 pF and 1 pF; or smaller than 10 pF, 5 pF, 3 pF, 2 pF or 1 pF.

[0023] The dedicated I/O chip (or chips) in the multi-chip package of the standard commodity logic drive may comprise a buffer and/or driver circuits for (1) downloading the programing codes from the non-volatile IC chips in the logic drive to the 5T or 6T SRAM cells of the programmable interconnection on the standard commodity FPGA chips. The programming codes from the non-volatile IC chips in the logic drive may go through a buffer or driver in or of the dedicated I/O chip before getting into the 5T or 6T SRAM cells of the programmable interconnection on the standard commodity FPGA chips. The buffer in or of the dedicated I/O chip may latch the data from the non-volatile chips and increase the bit-width of the data. For example, the data bit-width (in a SATA standard) from the non-volatile chips is 1 bit, the buffer may latch the 1 bit data in each of the multiple SRAM cells in the buffer, and output the data stored or latched in the multiple SRAM cells in parallel and simultaneously to increase the data bit-width; for example, equal to or greater than 4, 8, 16, 32, or 64 data bit-width. For another example, the data bit-width (in a PCIe standard) from the non-volatile chips is 32 bits, the buffer may increase the data bit-width to equal to or greater than 64, 128, or 256 data bit-width. The driver in or of the dedicated I/O chip may amplify the data signals from the non-volatile chips; (2) downloading data from the non-volatile IC chips in

the logic drive to the 5T or 6T SRAM cells of the LUTs on the standard commodity FPGA chips. The data from the non-volatile IC chips in the logic drive may go through a buffer or driver in or of the dedicated I/O chip before getting into the 5T or 6T SRAM cells of LUTs on the standard commodity FPGA chips. The buffer in or of the dedicated I/O chip may latch the data from the non-volatile chips and increase the bit-width of the data. For example, the data bit-width (in a SATA standard) from the non-volatile chips is 1 bit, the buffer may latch the 1 bit data in each of the multiple SRAM cells in the buffer, and output the data stored or latched in the multiple SRAM cells in parallel and simultaneously to increase the data bit-width; for example, equal to or greater than 4, 8, 16, 32, or 64 data bit-width. For another example, the data bit-width (in a PCIe standard) from the non-volatile chips is 32 bits, the buffer may increase the data bit-width to equal to or greater than 64, 128, or 256 data bit-width. The driver in or of the dedicated I/O chip may amplify the data signals from the non-volatile chips.

[0024] The dedicated I/O chip (or chips) in the multi-chip package of the standard commodity logic drive may comprise I/O circuits or pads (or micro copper pillars or bumps) for connecting or coupling to one or multiple (2, 3, 4, or more than 4) Universal Serial Bus (USB) ports, one or more IEEE 1394 ports, one or more Ethernet ports, one or more audio ports or serial ports, for example, RS-232 or COM (communication) ports, wireless transceiver I/Os, and/or Bluetooth transceiver I/Os, and etc. The dedicated I/O chip may also comprise I/O circuits or pads (or micro copper pillars or bumps) for connecting or coupling to Serial Advanced Technology Attachment (SATA) ports, or Peripheral Components Interconnect express (PCIe) ports for communicating, connecting or coupling with the memory drive.

[0025] Another aspect of the disclosure provides the standard commodity logic drive in a multi-chip package comprising plural standard commodity FPGA/HBM CSPs and one or more non-volatile IC chips, for use in different applications requiring logic, computing and/or processing functions by field programming; wherein the one or more non-volatile memory IC chips comprises a NAND flash chip or chips, in a bare-die format or in a multi-chip flash package format. Each of the one or more NAND flash chips may has a standard memory density, capacity or size of greater than or equal to 64 Mb, 512 Mb, 1 Gb, 4 Gb, 16 Gb, 64 Gb, 128 Gb, 256 Gb, or 512 Gb, wherein “b” is bits. The NAND flash chip may be designed and fabricated using advanced NAND flash technology nodes or generations, for example, more advanced than or equal to 45 nm, 28 nm, 20 nm, 16 nm, and/or 10 nm, wherein the advanced NAND flash technology may comprise Single Level Cells (SLC) or multiple level cells (MLC) (for example, Double Level Cells DLC, or triple Level cells TLC), and in a 2D-NAND or a 3D NAND structure. The 3D NAND structures may comprise multiple stacked layers or levels of NAND cells, for example, greater than or equal to 4, 8, 16, 32, 72 stacked layers or levels of NAND cells.

[0026] Another aspect of the disclosure provides the standard commodity logic drive in a multi-chip package comprising plural standard commodity FPGA/HBM CSPs and one or more non-volatile IC chips, for use in different applications requiring logic, computing and/or processing functions by field programming; wherein the one or more non-volatile memory IC chips comprises a NAND flash chip or chips, in a bare-die format or in a multi-chip flash package format. The standard commodity logic drive may have a standard non-volatile memory density, capacity or size of greater than or equal to 8 MB, 64 MB, 128 GB, 512 GB, 1 GB, 4 GB, 16 GB, 64 GB, 256 GB, or 512 GB, wherein “B” is bytes, each byte has 8 bits.

[0027] Another aspect of the disclosure provides the standard commodity logic drive in a multi-chip package comprising the plural standard commodity FPGA/HBM CSPs, the dedicated I/O chip, the dedicated control chip and the one or more non-volatile memory IC chips, for use in different applications requiring logic, computing and/or processing functions by field programming. The communication between the chips of the logic drive and the communication between each chip of the logic drive and the external or outside (of the logic drive) circuits are described as follows: (1) the dedicated I/O chip communicates directly with the other chip or chips of the logic drive, and

also communicates directly with the external or outside circuits (of the logic drive). The dedicated I/O chip comprises two types of I/O circuits; one type having large driving capability, loading, output capacitance or input capacitance for communicating directly with the external or outside circuits of the logic drive, and the other type having small driving capability, loading, output capacitance or input capacitance for communicating directly with the other chip or chips of the logic drive; (2) each of the plural FPGA IC chips (in the FPGA/HBM CSPs) only communicates directly with the other chip or chips of the logic drive, but does not communicate directly and/or does not communicate with the external or outside circuits (of the logic drive); wherein an I/O circuit of one of the plural FPGA IC chips may communicate indirectly with the external or outside circuits (of the logic drive) by going through an I/O circuit of the dedicated I/O chip; wherein the driving capability, loading, output capacitance or input capacitance of the I/O circuit of the dedicated I/O chip is significantly larger or bigger than that of the I/O circuit of the one of the plural FPGA IC chips, wherein the I/O circuit (for example, the input or output capacitance is smaller than 2 pF) of the one of the plural FPGA IC chips is connected or coupled to the large or big I/O circuit (for example, the input or output capacitance is larger than 3 pF) of the dedicated I/O chip for communicating with the external or outside circuits of the logic drive; (3) the dedicated control chip only communicates directly with the other chip or chips of the logic drive, but does not communicate directly and/or does not communicate with the external or outside circuits (of the logic drive); wherein an I/O circuit of the dedicated control chip may communicate indirectly with the external or outside circuits (of the logic drive) by going through an I/O circuit of the dedicated I/O chip; wherein the driving capability, loading, output capacitance or input capacitance of the I/O circuit of the dedicated I/O chip is significantly larger or bigger than that of the I/O circuit of the dedicated control chip. Alternatively, wherein the dedicated control chip may communicate directly with the other chip or chips of the logic drive, and may also communicate directly with the external or outside circuits (of the logic drive), wherein the dedicated control chip comprises both small and large I/O circuits for these two types of communication, respectively; (4) each of the one or more non-volatile memory IC chips only communicates directly with the other chip or chips of the logic drive, but does not communicate directly and/or does not communicate with the external or outside circuits (of the logic drive); wherein an I/O circuit of the one or more non-volatile memory IC chips may communicate indirectly with the external or outside (of the logic drive) by going through an I/O circuit of the dedicated I/O chip; wherein the driving capability, loading, output capacitance or input capacitance of the I/O circuit of the dedicated I/O chip is significantly larger or bigger than that of the I/O circuit of the one or more non-volatile memory IC chips. Alternatively, wherein the one or more non-volatile memory IC chips may communicate directly with the other chip or chips of the logic drive, and may also communicate directly with the external or outside circuits (of the logic drive), wherein the one or more non-volatile memory IC chips comprises both small and large I/O circuits for these two types of communication, respectively. In the above, “Object X communicates directly with Object Y” means the Object X (for example, a first chip of the logic drive) communicates or couples electrically and directly with the Object Y without going through or passing through any other chip or chips of the logic drive. In the above, “Object X does not communicate directly with Object Y” means the Object X (for example, a first chip of or in the logic drive) may communicate or couple electrically but indirectly with the Object Y by going through or passing through any other chip or chips of the logic drive. “Object X does not communicate with Object Y” means the Object X (for example, a first chip of the logic drive) does not communicate or couple electrically and directly, and does not communicate or couple electrically and indirectly with the Object Y.

[0028] Another aspect of the disclosure provides the standard commodity logic drive in a multi-chip package further comprising a dedicated control and I/O chip. The dedicated control and I/O chip provides the functions of the dedicated control chip and the dedicated I/O chip, as described in the above paragraphs, in one chip.

[0029] Another aspect of the disclosure provides a development kit or tool for a user or developer to implement an innovation or an application using the standard commodity logic drive. The user or developer with innovation or application concept or idea may purchase the standard commodity logic drive and use the corresponding development kit or tool to develop or to write software codes or programs to load into the non-volatile memory of the standard commodity logic drive for implementing his/her innovation or application concept or idea.

[0030] Another aspect of the disclosure provides a logic drive in a multi-chip package format further comprising an Innovated ASIC or COT (abbreviated as IAC below) chip for Intellectual Property (IP) circuits, Application Specific (AS) circuits, analog circuits, mixed-mode signal circuits, Radio-Frequency (RF) circuits, and/or transmitter, receiver, transceiver circuits, etc. The IAC chip is designed, implemented and fabricated using varieties of semiconductor technology nodes or generations, including old or matured technology nodes or generations, for example, less advanced than or equal to, or above or equal to 40 nm, 50 nm, 90 nm, 130 nm, 250 nm, 350 nm or 500 nm. Alternatively, the advanced semiconductor technology nodes or generations, such as more advanced than or equal to, or below or equal to 40 nm, 20 nm or 10 nm, may be used for the IAC chip. The semiconductor technology node or generation used in the IAC chip is 1, 2, 3, 4, 5 or greater than 5 nodes or generations older, more matured or less advanced than that used in the standard commodity FPGA IC chips packaged in the same logic drive. Transistors used in the IAC chip may be a FINFET, a Fully Depleted Silicon-on-insulator (FDSOI) MOSFET, a Partially Depleted Silicon-On-Insulator (PDSOI) MOSFET or a conventional MOSFET. Transistors used in the IAC chip may be different from that used in the standard commodity FPGA IC chips packaged in the same logic drive; for example, the IAC chip may use the conventional MOSFET, while the standard commodity FPGA IC chips packaged in the same logic drive may use the FINFET; or the IAC chip may use the Fully Depleted Silicon-on-insulator (FDSOI) MOSFET, while the standard commodity FPGA IC chips packaged in the same logic drive may use the FINFET. Since the IAC chip in this aspect of disclosure may be designed and fabricated using older or less advanced technology nodes or generations, for example, less advanced than or equal to, or more mature than, 20 nm or 30 nm, and for example using the technology node of 22 nm, 28 nm, 40 nm, 90 nm, 130 nm, 180 nm, 250 nm, 350 nm, or 500 nm, its NRE cost is cheaper than or less than that of the current or conventional ASIC or COT chip designed and fabricated using an advanced IC technology node or generation, for example, more advanced than or below 20 nm or 10 nm, and for example using the technology node of 16 nm, 14 nm, 12 nm, 10 nm, 7 nm, 5 nm or 3 nm. The NRE cost for designing a current or conventional ASIC or COT chip using an advanced IC technology node or generation, for example, more advanced than or below 20 nm or 10 nm, may be more than US \$5M, US \$10M, US \$20M or even exceeding US \$50M, or US \$100M. The cost of a photo mask set for an ASIC or COT chip at the 16 nm technology node or generation is over US \$2M, US \$5M, or US \$10M. Implementing the same or similar innovation and/or application using the logic drive including the IAC chip designed and fabricated using older or less advanced technology nodes or generations may reduce NRE cost down to less than US \$10M, US \$7M, US \$5M, US \$3M or US \$1M. Compared to the implementation by developing the current conventional logic ASIC or COT IC chip, the NRE cost of developing the IAC chip for the same or similar innovation and/or application may be reduced by a factor of larger than 2, 5, 10, 20, or 30. The innovators therefor can cheaply and easily implement their innovation by (i) designing the IAC chip using older and more mature technology nodes, for example, 40 nm or more mature than or equal to 20 nm; and (ii) using standard commodity FPGA IC chips packaged in a same logic drive, wherein the standard commodity FPGA IC chips are fabricated using advanced technology nodes, for example, 7 nm node, more advanced than 20 nm or more advanced than 7 nm.

[0031] Another aspect of the disclosure provides a method to change the logic ASIC or COT IC chip hardware business into a mainly software business by using the logic drive. Since the performance, power consumption and engineering and manufacturing costs of the logic drive may

be better or equal to the current conventional ASIC or COT IC chip for a same or similar innovation or application, the current ASIC or COT IC chip design companies or suppliers may become mainly software developers, while only designing the IAC chip, as described above, using older or less advanced semiconductor technology nodes or generations. In this aspect of disclosure, they may (1) design and own the IAC chip; (2) purchase from a third party the standard commodity FPGA chips and standard commodity non-volatile memory chips in the bare-die or packaged format; (3) design and fabricate (may outsource the manufacturing to a third party of the manufacturing provider) the logic drive including their own IAC chip, and the purchased third party's standard commodity FPGA chips and standard commodity non-volatile memory chips; (3) install in-house developed software for the innovation or application in the non-volatile memory IC chip or chips in the logic drive; and/or (4) sell the program-installed logic drive to their customers. In this case, they still sell hardware without performing the expensive ASIC or COT IC chip design and production using advanced semiconductor technology nodes, for example, nodes or generations more advanced than or below 30 nm, 20 nm or 10 nm. They may write software codes to program the logic drive comprising the plural of standard commodity FPGA chips for their desired applications, for example, in applications of Artificial Intelligence (AI), machine learning, deep learning, big data, Internet Of Things (IoT), industry computing, Virtual Reality (VR), Augmented Reality (AR), car electronics, Graphic Processing (GP), Digital Signal Processing (DSP), Micro Controlling (MC), and/or Central Processing (CP).

[0032] Another aspect of the disclosure provides the logic drive in a multi-chip package comprising plural standard commodity FPGA/HBM CSPs and one or more non-volatile IC chips, further comprising processing and/or computing IC chips, for example, one or plural Central Processing Unit (CPU) chips, one or plural Graphic Processing Unit (GPU) chips, one or plural Digital Signal Processing (DSP) chips, one or plural Tensor Processing Unit (TPU) chips, and/or one or plural Application Processing Unit (APU) chips, designed, implemented and fabricated using an advanced semiconductor technology node or generation, for example more advanced than or equal to, or below or equal to 50 nm, 30 nm, 20 nm or 10 nm, which may be the same as, one generation or node less advanced than, or one generation or node more advanced than that used for the FPGA IC chips in the same logic drive. Alternatively, the logic drive may comprise the combination of the plural processing and/or computing IC chips: (1) plural GPU chips, for example 2, 3, 4 or more than 4 GPU chips, (2) one or plural CPU chips and/or one or plural GPU chips, (3) one or plural CPU chips and/or one or plural DSP chips, (3) one or plural CPU chips, one or plural GPU chips and/or one or plural DSP chips, (4) one or plural CPU chips and/or one or plural TPU chips, or, (5) one or plural CPU chips, one or plural DSP chips and/or one or plural TPU chips. In all of the above alternatives, the logic drive may comprise one or plural of the processing and/or computing IC chips, and one or plural high speed, wide bit-width and high bandwidth cache SRAM chips or DRAM IC chips (HBM) for high speed parallel processing and/or computing. For example, the logic drive may comprise plural GPU chips, for example 2, 3, 4 or more than 4 GPU chips, and plural high speed, wide bit-width and high bandwidth cache SRAM chips or DRAM IC chips (HBM). The communication between one of GPU chips and one of SRAM or DRAM IC chips may be with data bit-width of equal or greater than 64, 128, 256, 512, 1024, 2048, 4096, 8K, or 16K. For another example, the logic drive may comprise plural TPU chips, for example 2, 3, 4 or more than 4 TPU chips, and plural high speed, wide bit-width and high bandwidth cache SRAM chips or DRAM IC chips. The communication between one of TPU chips and one of SRAM or DRAM IC chips may be with data bit-width of equal or greater than 64, 128, 256, 512, 1024, 2048, 4096, 8K, or 16K.

[0033] The communication, connection, or coupling between one of logic, processing and/or computing chips (for example, FPGA, CPU, GPU, DSP, APU, TPU, and/or ASIC chips) and one of high speed, wide bit-width and high bandwidth SRAM, DRAM or NVM RAM (for example, MRAM, RRAM) chips, through the FISIP and/or SISIP of the interposer to be described and

specified below, may be the same or similar as that between internal circuits in a same chip. Alternatively, the communication, connection, or coupling between one of logic, processing and/or computing chips (for example, FPGA, CPU, GPU, DSP, APU, TPU, and/or ASIC chips) and one of high speed, wide bit-width and high bandwidth SRAM, DRAM or NVM RAM chips, through the FISIP and/or SISIP of the interposer, may be using small I/O drivers and/or receivers on both logic, processing and/or computing chips and SRAM, DRAM or NVM RAM chips. The driving capability, loading, output capacitance, or input capacitance of the small I/O drivers or receivers, or I/O circuits may be between 0.01 pF and 10 pF, 0.05 pF and 5 pF, 0.01 pF and 2 pF, or 0.01 pF and 1 pF; or smaller than 10 pF, 5 pF, 3 pF, 2 pF, 1 pF, 0.5 pF or 0.1 pF. For example, a bi-directional (or tri-state) I/O pad or circuit may be used for the small I/O drivers or receivers, or I/O circuits for communicating between high speed, wide bit-width and high bandwidth logic and memory chips in the logic drive, and may comprise an ESD circuit, a receiver, and a driver, and may have an input capacitance or output capacitance between 0.01 pF and 10 pF, 0.05 pF and 5 pF, 0.01 pF and 2 pF, 0.01 pF and 1 pF; or smaller than 10 pF, 5 pF, 3 pF, 2 pF, 1 pF, or 0.5 pF or 0.1 pF.

[0034] The processing and/or computing IC chip or chips in the logic drive provide fixed-metal-line (non-field-programmable) interconnects for (non-field-programmable) functions, processors and operations. The standard commodity FPGA IC chips provide (1) programmable-metal-line (field-programmable) interconnects for (field-programmable) logic functions, processors and operations and (2) fixed-metal-line (non-field-programmable) interconnects for (non-field-programmable) logic functions, processors and operations. Once the programmable-metal-line interconnects in or of the FPGA IC chips are programmed, the programmed interconnects together with the fixed interconnects in or of the FPGA chips provide some specific functions for some given applications. The operational FPGA chips may operate together with the processing and/or computing IC chip or chips in the same logic drive to provide flexibility, programmability and powerful functions and operations in applications, for example, Artificial Intelligence (AI), machine learning, deep learning, big data, Internet Of Things (IoT), industry computing, Virtual Reality (VR), Augmented Reality (AR), driverless car electronics, Graphic Processing (GP), Digital Signal Processing (DSP), Micro Controlling (MC), and/or Central Processing (CP).

[0035] Another aspect of the disclosure provides the standard commodity FPGA IC chip for use in the FPGA/HBM CSPs. The FPGA/HBM CSPs are used in the multi-chip packaged logic drive. The standard commodity FPGA chip is designed, implemented and fabricated using an advanced semiconductor technology node or generation, for example more advanced than or below 20 nm or 10 nm. The standard commodity FPGA IC chips comprising Through Silicon Vias (TSV) in the silicon substrates. The standard commodity FPGA IC chips with TSVs are fabricated by the following process steps:

[0036] (1) Providing a semiconductor substrate (for example, a silicon substrate), or a Silicon-On-Insulator (SOI) substrate, with the substrate in the wafer form, and with a wafer size, for example 8", 12" or 18" in the diameter. Through Silicon Vias (TSVs) are first formed in the silicon substrate. Transistors are then formed in or on the silicon substrate, and/or on or at the surface of the substrate by a wafer process. Wherein the transistors are formed in the advanced semiconductor technology node or generation may be a FINFET, a FINFET on Silicon-on-insulator (FINFET SOI), a Fully Depleted Silicon-on-insulator (FDSOI) MOSFET, a Partially Depleted Silicon-on-insulator (PDSOI) MOSFET or a conventional MOSFET.

[0037] The TSVs in the substrate are formed by the following process steps: (a) depositing a masking insulting layer on the silicon wafer, for example, a thermally grown silicon oxide SiO₂ and/or a CVD silicon nitride Si₃N₄; (b) photoresist depositing, patterning and then etching the masking insulting layer to form holes or openings in it; (c) using the masking insulting layer as an etching mask to etch the silicon wafer and forming holes in the silicon wafer at the locations of holes or openings in the masking insulting layer. The hole in the silicon wafer has a depth between 10 μm and 100 μm, or 20 μm and 60 μm; and with a diameter or size of the hole

between 2 μm and 60 μm , or 5 μm and 20 μm . Note that the hole is not completely through the silicon substrate here; it becomes a through silicon via when the backside silicon is partially removed to expose the bottom surface of the metal via in the later processes; (d) removing the remaining masking insulating layer, then forming an insulating lining layer on the sidewall of the hole. The insulating lining layer may be, for example, a thermally grown silicon oxide SiO_2 and/or a CVD silicon nitride Si_3N_4 ; (e) forming metal via by filling the hole with metal. The damascene copper process, as mentioned above, is used to form the metal via in the hole. In the damascene copper process for forming the metal vias, an adhesion metal layer is deposited, followed by depositing an electroplating seed layer, and then electroplating a copper layer. The electroplating copper process is performed on the whole wafer until the hole is completely filled. The un-wanted metal stack of electroplating copper, seed layer and adhesion layer outside the via is then removed by a CMP process. The processes and materials in the damascene process for forming the metal vias are the same as described and specified in the above.

[0038] (2) Forming a First Interconnection Scheme in, on or of the Chip (FISC) over the substrate and on or over a layer comprising transistors, by a wafer process. The FISC comprises multiple interconnection metal layers, with an inter-metal dielectric layer between each of the multiple interconnection metal layers. The FISC structure may be formed by performing a single damascene copper process and/or a double damascene copper process, and using Chemical Mechanical Polishing process (CMP). The FISC may comprise 4 to 15 layers, or 6 to 12 layers of interconnection metal layers.

[0039] The metal lines or traces in the FISC are coupled or connected to the underlying transistors. The thickness of the metal lines or traces of the FISC, either formed by the single-damascene process or by the double-damascene process, is, for example, between 3 nm and 500 nm, or between 10 nm and 1,000 nm, or, thinner than or equal to 5 nm, 10 nm, 30 nm, 50 nm, 100 nm, 200 nm, 300 nm, 500 nm, or 1,000 nm. The width of the metal lines or traces of the FISC is, for example, between 3 nm and 500 nm, or between 10 nm and 1,000 nm, or, narrower than 5 nm, 10 nm, 20 nm, 30 nm, 70 nm, 100 nm, 300 nm, 500 nm or 1,000 nm. The thickness of the inter-metal dielectric layer has a thickness, for example, between 3 nm and 500 nm, or between 10 nm and 1,000 nm, or thinner than 5 nm, 10 nm, 30 nm, 50 nm, 100 nm, 200 nm, 300 nm, 500 nm or 1,000 nm. The metal lines or traces of the FISC may be used for the programmable interconnection.

[0040] (3) Depositing a passivation layer on or over the whole wafer and on or over the FISC structure. The passivation is used for protecting the transistors and the FISC structure from water moisture or contamination from the external environment, for example, sodium mobile ions. The passivation comprises a mobile ion-catching layer or layers, for example, SiN , SiON , and/or SiCN layer or layers. The total thickness of the mobile ion catching layer or layers is thicker than or equal to 100 nm, 150 nm, 200 nm, 300 nm, 450 nm, or 500 nm. Openings in the passivation layer may be formed to expose the top surface of the top-most interconnection metal layer of the FISC, and for forming metal vias in the passivation openings in the following processes later.

[0041] (4) Forming a Second Interconnection Scheme in, on or of the Chip (SISC) on or over the FISC structure. The SISC comprises multiple interconnection metal layers, with an inter-metal dielectric layer between each of the multiple interconnection metal layers. A polymer material may be used for the inter-metal dielectric layer, for example, polyimide, BenzoCycloButene (BCB), parylene, epoxy-based material or compound, photo epoxy SU-8, elastomer or silicone. The material used for the inter-metal dielectric layer of SISC comprises organic material, for example, a polymer, or material compounds comprising carbon. The SISC may comprise 2 to 6, or 3 to 5 layers of interconnection metal layers. The metal lines or traces of the interconnection metal layers of the SISC have the adhesion layer (Ti or TiN , for example) and the copper seed layer only at the bottom, but not at the sidewalls of the metal lines or traces. The metal lines or traces of the interconnection metal layers of FISC have the adhesion layer (Ti or TiN , for example) and the copper seed layer at both the bottom and the sidewalls of the metal lines or traces.

[0042] The SISC interconnection metal lines or traces are coupled or connected to the FSIC interconnection metal lines or traces, or to transistors in the chip, through metal vias in openings of the passivation layer. The thickness of the metal lines or traces of SISC is between, for example, 0.3 μm and 20 μm , 0.5 μm and 10 μm , 1 μm and 5 μm , 1 μm and 10 μm , or 2 μm and 10 μm ; or thicker than or equal to 0.3 μm , 0.5 μm , 0.7 μm , 1 μm , 1.5 μm , 2 μm or 3 μm . The width of the metal lines or traces of SISC is between, for example, 0.3 μm and 20 μm , 0.5 μm and 10 μm , 1 μm and 5 μm , 1 μm and 10 μm , or 2 μm and 10 μm ; or wider than or equal to 0.3 μm , 0.5 μm , 0.7 μm , 1 μm , 1.5 μm , 2 μm or 3 μm . The thickness of the inter-metal dielectric layer has a thickness between, for example, 0.3 μm and 20 μm , 0.5 μm and 10 μm , 1 μm and 5 μm , or 1 μm and 10 μm ; or thicker than or equal to 0.3 μm , 0.5 μm , 0.7 μm , 1 μm , 1.5 μm , 2 μm or 3 μm . The metal lines or traces of SISC may be used for the programmable interconnection.

[0043] (5) Forming micro copper pads for flipchip assembly by exposing top surfaces of the top-most interconnection metal layer in the openings of the top-most insulating dielectric layer of SISC. Alternatively, micro copper pads, pillars or bumps may have solder caps

[0044] The height of the micro pillars or bumps is between, for example, 3 μm and 60 μm , 5 μm and 50 μm , 5 μm and 40 μm , 5 μm and 30 μm , 5 μm and 20 μm , 5 μm and 15 μm , or 3 μm and 10 μm , or greater than or equal to 30 μm , 20 μm , 15 μm , 5 μm or 3 μm . The largest dimension in a cross-section of the micro pillars or bumps (for example, the diameter of a circle shape, or the diagonal length of a square or rectangle shape) is between, for example, 3 μm and 60 μm , 5 μm and 50 μm , 5 μm and 40 μm , 5 μm and 30 μm , 5 μm and 20 μm , 5 μm and 15 μm , or 3 μm and 10 μm , or smaller than or equal to 60 μm , 50 μm , 40 μm , 30 μm , 20 μm , 15 μm or 10 μm . The space between a micro pillar or bump to its nearest neighboring pillar or bump is between, for example, 3 μm and 60 μm , 5 μm and 50 μm , 5 μm and 40 μm , 5 μm and 30 μm , 5 μm and 20 μm , 5 μm and 15 μm , or 3 μm and 10 μm , or smaller than or equal to 60 μm , 50 μm , 40 μm , 30 μm , 20 μm , 15 μm or 10 μm .

[0045] Another aspect of the disclosure provides an HBM Stacked Chip Scale Package (HBM SCSP). The HBM Stacked Chip Scale Package (HBM SCSP) comprises an ASIC or logic IC chip and plural High Bandwidth Memory IC chips (HBM, for example, DRAM IC chips) stacked assembled on the ASIC or logic IC chip. The ASIC or logic IC chip and the plural DRAM IC chips, each has Through Silicon Vias (TSVs) in its silicon substrate for use in electrical communication with the other chip or chips staked assembled in the HBM SCSP. One HBM SCSP may comprise 2, 4, 8, 16, 24, 32 HBM DRAM IC chips, or a equal to or greater than 2, 4, 8, 16, 32 HBM DRAM IC chips. Each HBM DRAM IC chip may have the memory density of 512 Mb, 1 Gb, 4 Gb, 8 Gb, 16 Gb, 32 Gb, 64 Gb, or equal to or greater than 256 Mb, 1 Gb, 8 Gb, 16 Gb, wherein b is bit. The HBM DRAM IC chips may be with data bit-width of equal or greater than 64, 128, 256, 512, 1024, 2048, 4096, 8K, or 16K. The HBM DRAM IC chips are designed with small I/O drivers or receivers, or I/O circuits with small driving capability, wherein the loading, output capacitance, or input capacitance may be between 0.05 pF and 2 pF, or 0.05 pF and 1 pF, or smaller than 2 pF or 1 pF. The ASIC or logic IC chip is used for buffers, DRAM memory controls, or interface circuits, and may be located at the bottom of HBM SCSP package. The HBM SCSP packages have solder bumps or copper pillars at the bottom of the HBM SCSP packages. The HBM SCCSP and the HBM DRAM IC chips are designed in a standard common specification and feature physically and functionally.

[0046] Another aspect of the disclosure provides a method of forming the standard commodity FPGA/HBM CSPs for use in the logic drive; wherein each of the plural standard commodity FPGA/HBM CSPs comprises one standard commodity FPGA IC chip and one HBM chip mounted on the standard commodity FPGA IC chip or a stacked package with plural HBM chips (HBM SCSP) mounted on the standard commodity FPGA IC chip. The standard commodity FPGA IC chips and the HBM chip or the stacked package with plural HBM DRAM IC chips (HBM SCSP) are described and specified in above. The process steps for forming the FPGA/HBM CSPs are

described as below:

[0047] (1) Performing flip-chip assembling, bonding or packaging: (a) First providing the wafers with standard commodity FPGA IC chips as described and specified above, wherein the standard commodity FPGA IC chips comprising the TSVs, transistors, FISC, the SISC, micro copper pads, bumps or pillars, and providing HBM DRAM IC chips or HBM SCSP packages; then flip-chip assembling, bonding or packaging the HBM DRAM IC chips or HBM SCSP packages to and on the FPGA wafer. The FPGA wafer is formed as described and specified above. The HBM DRAM IC chips or HBM SCSP packages to be assembled, bonded or packaged to the FPGA wafer are described and specified above. The method of solder reflow flip-chip bonding may be used for the assembling, bonding or packaging the HBM DRAM IC chips or HBM SCSP packages to the FPGA wafer. All HBM DRAM IC chips or HBM SCSP packages to be flip-chip packaged in the FPGA wafer comprise solder bumps or copper pillars on the top surfaces thereof. Here, for the HBM SCSPs, the ASIC or logic chips are at the bottoms of the stacks. The copper pads may be provided and exposed at the top surface of the FPGA wafer for flip-chip assembly. Alternatively, solder bumps and micro-pillars on the top surface of the FPGA wafer may be used for flip-chip assembly. The top surfaces of solder bumps or micro copper pillars are at a level above a level of the top surface of the top-most insulating dielectric layer of the FPGA IC chips with a height of, for example, between 3 μm and 120 μm , 5 μm and 75 μm , 5 μm and 50 μm , 5 μm and 25 μm , 5 μm and 15 μm , or 3 μm and 10 μm , or greater than or equal to 30 μm , 20 μm , 15 μm , or 3 μm . Alternatively, thermal compression bonding may be used for the assembling, bonding or packaging the HBM DRAM IC chips or HBM SCSP packages to the FPGA wafer. Alternatively, the oxide-to-oxide metal-to-metal direct bonding may be used for the assembling, bonding or packaging the HBM DRAM IC chips or HBM SCSP packages to the FPGA wafer; (b) The HBM DRAM IC chips or HBM SCSP packages are flip-chip assembled, bonded or packaged on or to corresponding micro copper pads, bumps or pillar on or of the FPGA wafer with the side or surface of the FPGA wafer with transistors faced up, using solder reflow bonding, thermal compression bonding or oxide-to-oxide metal-to-metal direct bonding. The backside of the silicon substrate of the HBM DRAM IC chip or HBM SCSP package (the side or surface without transistors) is faced up; (c) for the solder reflow bonding or thermal compression bonding, filling the gaps between the FPGA wafer and the HBM DRAM IC chips or HBM SCSP packages (and between micro solder bumps or copper pillars of the HBM DRAM IC chips or HBM SCSP packages and the FPGA wafer) with an underfill material by, for example, a dispensing method using a dispenser. The underfill material comprises epoxy resins or compounds, and can be cured at temperature equal to or above 100° C., 120° C., or 150° C.

[0048] (2) Applying a material, resin, or compound to fill the gaps or spaces between HBM DRAM IC chips or HBM SCSP packages and cover the backside surfaces of HBM DRAM IC chips or HBM SCSP packages by methods, for example, spin-on coating, screen-printing, dispensing or molding in the wafer format. The molding method includes the compress molding (using top and bottom pieces of molds) or the casting molding (using a dispenser). The material, resin, or compound used may be a polymer material includes, for example, polyimide, BenzoCycloButene (BCB), parylene, epoxy-based material or compound, photo epoxy SU-8, elastomer, or silicone. The polymer may be, for example, photosensitive polyimide/PBO PIMEL™ supplied by Asahi Kasei Corporation, Japan; or epoxy-based molding compounds, resins or sealants provided by Nagase ChemteX Corporation, Japan. The material, resin or compound is applied (by coating, printing, dispensing or molding) on or over the FPGA wafer and on or over the backside of the HBM DRAM IC chips or HBM SCSP packages to a level to: (i) fill gaps or spaces between HBM DRAM IC chips or HBM SCSP packages, (ii) cover the top-most backside surface of the HBM DRAM IC chips or HBM SCSP packages. The material, resin or compound may be cured or cross-linked by raising a temperature to a certain temperature degree, for example, at or higher than or equal to 50° C., 70° C., 90° C., 100° C., 125° C., 150° C., 175° C., 200° C., 225° C., 250° C., 275° C.

C. or 300° C. The material may be polymer or molding compound. Applying a CMP, polishing or grinding process to planarize the surface of the applied material, resin or compound. Optionally, the CMP, or grinding process is performed until a level where the backside surfaces of all HBM DRAM IC chips or HBM SCSP packages are fully exposed.

[0049] (3) Thinning the FPGA wafer to expose the surfaces of the through silicon metal vias (TSVs) at the backside of the FPGA wafer. A wafer thinning process, for example, a CMP process, a polishing process or a wafer backside grinding process, may be performed to remove a portion of the wafer to make the wafer thinner, in a wafer process, to expose the surfaces of the through silicon metal vias (TSVs) at the backside of the FPGA wafer.

[0050] The interconnection metal lines or traces of the FISC and/or SISC of the FPGA chips for the logic drive may: (a) comprise a first interconnection net or scheme of metal lines or traces in or of the FISC and/or SISC of a FPGA IC chip for connecting or coupling the transistors, a second interconnection net or scheme of metal lines or traces and/or the micro copper pillars or bumps of the FPGA IC chip. The first interconnection net or scheme of metal lines or traces in or of the FISC and/or SISC may be connected to the circuits or components outside or external to the logic drive through TSVs in the substrate of the FPGA chips. The first interconnection net or scheme may be connected or coupled to the HBM DRAM IC chip or HBM SCSP package on or over the FPGA chip. The first interconnection net or scheme of metal lines or traces in or of the FISC and/or SISC may be a net or scheme for signals, or the power or ground supply; (b) comprise direct and vertical connection between the FPGA chip and the HBM DRAM IC chip or HBM SCSP package by using the stacked metal vias/metal layer in the FISC and SISC. The solder bumps or copper pillars of the HBM DRAM IC chip or HBM SCSP package are flipchip bonded to the copper pads, solder bumps or copper pillars of the FPGA IC chip, wherein the copper pads, solder bumps or copper pillars are directly over the stacked vias/metal layers of FISC and/or SISC of the FPGA IC chip. The direct vertical connects provide high bandwidth, high speed and wide bit width between the FPGA chip and the HBM DRAM IC chip or HBM SCSP package. The HBM DRAM IC chip or HBM SCSP package may communicate with the FPGA IC chip with data bit-width of equal to or greater than 64, 128, 256, 512, 1024, 2048, 4096, 8K, or 16K. The HBM DRAM IC chip or HBM SCSP package and the FPGA IC chip are both designed with small I/O drivers or receivers, or I/O circuits with small driving or receiving capability for high speed communication therebetween, wherein the driving or receiving capability has the loading, output capacitance, or input capacitance of between 0.05 pF and 2 pF, or 0.05 pF and 1 pF, or smaller than 2 pF or 1 pF.

(4) Forming Metal Pillars or Bumps on or Under the Exposed Bottom Surfaces of the TSVs in the Silicon substrate of the FPGA wafer.

[0051] Copper pillars or bumps may be formed on or under the exposed bottom surfaces of the TSVs. For the description purpose, the wafer or panel is turned upside down, with the FPGA wafer at the top and the HBM DRAM IC chip or HBM SCSP package at the bottom. The frontside (the side with the transistors) of the FPGA chips are now facing down, the molding compound and the backside of the HBM DRAM IC chip or HBM SCSP package are now at the bottom. The copper pillars or bumps are formed by performing an emboss copper process. The copper pillars or bumps are used for next level packaging on an interposer.

[0052] (5) Separating, cutting or dicing the finished FPGA wafer, including separating, cutting or dicing through materials or structures between two neighboring HBM DRAM IC chips or HBM SCSP packages. The material (for example, polymer) filling gaps or spaces between two neighboring HBM DRAM IC chip or HBM SCSP package is separated, cut or diced to form individual unit of FPGA/HBM CSPs.

[0053] Another aspect of the disclosure provides an interposer for flip-chip assembly or packaging in forming the multi-chip package of the logic drive. The multi-chip package is based on multiple-Chips-On-an-Interposer (COIP) flip-chip packaging method. The interposer or substrate in the COW multi-chip package comprises: (1) high density interconnects for fan-out and interconnection

between IC chips flip-chip-assembled, bonded or packaged on or over the interposer, (2) micro metal pads, bumps or pillars on or over the high density interconnects, (3) deep vias or shallow vias in the interposer. The IC chips or packages to be flip-chip assembled, bonded or packaged, to the interposer include the chips or packages mentioned, described and specified above: the standard commodity FPGA/HBM CSPs chips, the non-volatile chips or packages, the dedicated control chip, the dedicated I/O chip, the dedicated control and I/O chip, IAC chip, and/or processing and/or computing IC chip, for example CPU, GPU, DSP, TPU, or APU chip. The process steps for forming the interposer of the logic drive are as follows:

[0054] (1) Providing a substrate. The substrate may be in a wafer format (with 8", 12" or 18" in diameter), or, in a panel format in the square or rectangle format (with a width or a length greater than or equal to 20 cm, 30 cm, 50 cm, 75 cm, 100 cm, 150 cm, 200 cm or 300 cm). The material of the substrate may be silicon, metal, ceramics, glass, steel, plastics, polymer, epoxy-based polymer, or epoxy-based compound. As an example, a silicon wafer may be used as a substrate in forming a silicon interposer.

[0055] (2) forming through silicon vias in the substrate. Silicon wafer is used as an example in forming the metal vias in the substrate. The bottom surface metal vias in the silicon wafer are exposed in the final product of the logic drive, therefore, the metal vias become through vias, and the through vias are the Trough-Silicon-Vias (TSVs).

[0056] (3) Forming a First Interconnection Scheme on or of the Interposer (FISIP). The metal lines or traces and the metal vias of the FISIP are formed by the single damascene copper processes or the double damascene copper processes as described or specified above in forming the metal lines or traces and metal vias in the FISC of FPGA IC chips. The FISIP may comprise 2 to 10 layers, or 3 to 6 layers of interconnection metal layers. The metal lines or traces of the interconnection metal layers of FISIP have the adhesion layer (Ti or TiN, for example) and the copper seed layer at both the bottom and the sidewalls of the metal lines or traces.

[0057] The metal lines or traces in the FISIP are coupled or connected to the micro copper bumps or pillars of the IC chips in or of the logic drive, and/or coupled or connected to the TSVs in the substrate of the interposer. The thickness of the metal lines or traces of the FISIP, either formed by the single-damascene process or by the double-damascene process, is, for example, between 3 nm and 500 nm, between 10 nm and 1,000 nm, or between 10 nm and 2,000 nm, or, thinner than or equal to 50 nm, 100 nm, 200 nm, 300 nm, 500 nm, 1,000 nm, 1,500 nm or 2,000 nm. The minimum width of the metal lines or traces of the FISIP is, for example, equal to or smaller than 50 nm, 100 nm, 150 nm, 200 nm, 300 nm, 500 nm, 1,000 nm, 1,500 nm or 2,000 nm. The minimum space between two neighboring metal lines or traces of the FISIP is, for example, equal to or smaller than 50 nm, 100 nm, 150 nm, 200 nm, 300 nm, 500 nm, 1,000 nm, 1,500 nm or 2,000 nm. The minimum pitch of the metal lines or traces of the FISIP is, for example, equal to or smaller than 100 nm, 200 nm, 300 nm, 400 nm, 600 nm, 1,000 nm, 3,000 nm or 4,000 nm. The thickness of the inter-metal dielectric layer has a thickness, for example, between 3 nm and 500 nm, between 10 nm and 1,000 nm, or between 10 nm and 2,000 nm, or, thinner than or equal to 50 nm, 100 nm, 200 nm, 300 nm, 500 nm, 1,000 nm or 2,000 nm. The metal lines or traces of the FISIP may be used as the programmable interconnection.

[0058] (4) Forming a Second Interconnection Scheme of the Interposer (SISIP) on or over the FISIP structure. The SISIP comprises multiple interconnection metal layers, with an inter-metal dielectric layer between each of the multiple interconnection metal layers. The metal lines or traces and the metal vias are formed by the emboss copper processes as described or specified above in forming the metal lines or traces and metal vias in the SISC of FPGA IC chips. The SISIP may comprise 1 to 5 layers, or 1 to 3 layers of interconnection metal layers. Alternatively, the SISIP on or of the interposer may be omitted, and the COIP only has FISIP interconnection scheme on the substrate of the interposer. Alternatively, the FISIP on or of the interposer may be omitted, and the COIP only has SISIP interconnection scheme on the substrate of the interposer.

[0059] The thickness of the metal lines or traces of SISIP is between, for example, 0.3 μm and 20 μm , 0.5 μm and 10 μm , 1 μm and 5 μm , 1 μm and 10 μm , or 2 μm and 10 μm ; or thicker than or equal to 0.3 μm , 0.5 μm , 0.7 μm , 1 μm , 1.5 μm , 2 μm or 3 μm . The width of the metal lines or traces of SISIP is between, for example, 0.3 μm and 20 μm , 0.5 μm and 10 μm , 1 μm and 5 μm , 1 μm and 10 μm , or 2 μm and 10 μm ; or wider than or equal to 0.3 μm , 0.5 μm , 0.7 μm , 1 μm , 1.5 μm , 2 μm or 3 μm . The thickness of the inter-metal dielectric layer has a thickness between, for example, 0.3 μm and 20 μm , 0.5 μm and 10 μm , 1 μm and 5 μm , or 1 μm and 10 μm ; or thicker than or equal to 0.3 μm , 0.5 μm , 0.7 μm , 1 μm , 1.5 μm , 2 μm or 3 μm . The metal lines or traces of SISIP may be used as the programmable interconnection.

[0060] (5) Forming micro copper pads, pillars or bumps (i) on the top surface of the top-most interconnection metal layer of SISIP, exposed in openings in the topmost insulating dielectric layer of the SISIP, or (ii) on the top surface of the top-most interconnection metal layer of FISIP, exposed in openings in the topmost insulating dielectric layer of the FISIP in the case wherein the SISIP is omitted. An emboss copper process, as described and specified in above paragraphs, is performed to form the micro copper pillars or bumps on or over the interposer.

[0061] The height of the micro pads, pillars or bumps on or over the interposer is between, for example, 1 μm and 60 μm , 5 μm and 50 μm , 5 μm and 40 μm , 5 μm and 30 μm , 5 μm and 20 μm , 1 μm and 15 μm , or 1 μm and 10 μm , or smaller than or equal to 60 μm , 50 μm , 40 μm , 30 μm , 20 μm , 15 μm , 10 μm or 5 μm . The largest dimension in a cross-section of the micro pillars or bumps (for example, the diameter of a circle shape, or the diagonal length of a square or rectangle shape) is between, for example, 1 μm and 60 μm , 5 μm and 50 μm , 5 μm and 40 μm , 5 μm and 30 μm , 5 μm and 20 μm , 1 μm and 15 μm , or 1 μm and 10 μm , or smaller than or equal to 60 μm , 50 μm , 40 μm , 30 μm , 20 μm , 15 μm , 10 μm or 5 μm . The space between a micro pillar or bump to its nearest neighboring pillar or bump is between, for example, 1 μm and 60 μm , 5 μm and 50 μm , 5 μm and 40 μm , 5 μm and 30 μm , 5 μm and 20 μm , 1 μm and 15 μm , or 1 μm and 10 μm , or smaller than or equal to 60 μm , 50 μm , 40 μm , 30 μm , 20 μm , 15 μm , 10 μm or 5 μm .

[0062] Another aspect of the disclosure provides a method for forming the logic drive in a COIP multi-chip package using an interposer comprising the FISIP, the SISIP, micro copper pads, bumps or pillars and TSVs based on a flip-chip assembled multi-chip packaging technology and process. The process steps for forming the COW multi-chip packaged logic drive are described as below:

[0063] (1) Performing flip-chip assembling, bonding or packaging: (a) First providing the interposer comprising the FISIP, the SISIP, micro copper pads, bumps or pillars and TSVs, and IC chips or packages; then flip-chip assembling, bonding or packaging the IC chips or packages to and on the interposer. The interposer is formed as described and specified above. The IC chips or packages to be assembled, bonded or packaged to the interposer include the chips or packages mentioned, described and specified above: the standard commodity the standard commodity FPGA/HBM CSPs, the non-volatile chips or packages, the dedicated control chip, the dedicated I/O chip, the dedicated control and I/O chip, IAC chip and/or computing and/or processing IC chips, for example, CPU, GPU, DSP, TPU, APU chips. All chips or packages to be flip-chip packaged in the logic drives comprise micro copper pillars or bumps with solder caps on the top surface of the chips; (b) The chips or packages are flip-chip assembled, bonded or packaged on or to corresponding micro copper pads, bumps or pillar on or of the interposer with the side or surface of the chip with transistors faced down or with the frontside of the CSP faced down, by the solder reflow bonding or the thermal compression bonding. The backside of the silicon substrate of the chips or the CSPs (the side or surface without transistors) is faced up; (c) Filling the gaps or spaces between the interposer and the IC chips or packages (and between micro copper bumps or pillars of the IC chips and the interposer) with an underfill material by, for example, a dispensing method using a dispenser.

[0064] (2) Applying a material, resin, or compound to fill the gaps or spaces between chips or packages and cover the backside surfaces of chips or packages by methods, for example, spin-on

coating, screen-printing, dispensing or molding in the wafer or panel format. The molding method includes the compress molding (using top and bottom pieces of molds) or the casting molding (using a dispenser). The material, resin, or compound used may be a polymer material includes, for example, polyimide, BenzoCycloButene (BCB), parylene, epoxy-based material or compound, photo epoxy SU-8, elastomer, or silicone. The polymer may be, for example, photosensitive polyimide/PBO PIMEL™ supplied by Asahi Kasei Corporation, Japan; or epoxy-based molding compounds, resins or sealants provided by Nagase ChemteX Corporation, Japan. The material, resin or compound is applied (by coating, printing, dispensing or molding) on or over the interposer and on or over the backside of the chips or packages to a level to: (i) fill gaps or spaces between chips or packages, (ii) cover the top-most backside surface of the chips or packages. The material, resin or compound may be cured or cross-linked by raising a temperature to a certain temperature degree, for example, at or higher than or equal to 50° C., 70° C., 90° C., 100° C., 125° C., 150° C., 175° C., 200° C., 225° C., 250° C., 275° C. or 300° C. The material may be polymer or molding compound. Applying a CMP, polishing or grinding process to planarize the surface of the applied material, resin or compound. Optionally, the CMP, or grinding process is performed until a level where the backside surfaces of all IC chips or packages are fully exposed.

[0065] (3) Thinning the interposer to expose the surfaces of the metal through vias (TSVs) at the backside of the interposer. A wafer or panel thinning process, for example, a CMP process, a polishing process or a wafer backside grinding process, may be performed to remove portion of the wafer or panel to make the wafer or panel thinner, in a wafer or panel process, to expose the surfaces of the metal through vias (TSVs) at the backside of the interposer.

[0066] The interconnection metal lines or traces of the FISIP and/or SISIP of the interposer for the logic drive may: (a) comprise an interconnection net or scheme of metal lines or traces in or of the FISIP and/or SISIP of the logic drive for connecting or coupling the transistors, the FISC, the SISC and/or the micro copper pillars or bumps of a first FPGA IC chip of a first standard commodity FPGA/HBM CSPs chip in the logic drive to the transistors, the FISC, the SISC and/or the micro copper pillars or bumps of a second FPGA IC chip of a second standard commodity FPGA/HBM CSPs chip packaged in the same logic drive. This interconnection net or scheme of metal lines or traces in or of the FISIP and/or SISIP may be connected to the circuits or components outside or external to the logic drive through TSVs in the substrate of the interposer. This interconnection net or scheme of metal lines or traces in or of the FISIP and/or SISIP may be a net or scheme for signals, or the power or ground supply; (b) comprise an interconnection net or scheme of metal lines or traces in or of the FISIP and/or SISIP of the logic drive connecting to multiple micro copper pillars or bumps of an IC chip or CSP in or of the logic drive. This interconnection net or scheme of metal lines or traces in or of the FISIP and/or SISIP may be connected to the circuits or components outside or external to the logic drive through the TSVs in the substrate of the interposer. This interconnection net or scheme of metal lines or traces in or of the FISIP and/or SISIP may be a net or scheme for signals, or the power or ground supply; (c) comprise interconnection metal lines or traces in or of the FISIP and/or SISIP of the logic drive for connecting or coupling to the circuits or components outside or external to the logic drive, through one or more of the TSVs in the substrate of the interposer. The interconnection metal lines or traces in or of the FISIP and/or SISIP may be used for signals, power or ground supplies. In this case, for example, the one or a plurality of the TSVs in the substrate of the interposer may be connected to the I/O circuits of, for example, the dedicated I/O chip of the logic drive. The I/O circuits in this case may be a large I/O circuit, for example, a bi-directional (or tri-state) I/O pad or circuit, comprising an ESD circuit, a receiver, and a driver, and may have an input capacitance or output capacitance between 2 pF and 100 pF, 2 pF and 50 pF, 2 pF and 30 pF, 2 pF and 20 pF, 2 pF and 15 pF, 2 pF and 10 pF, or 2 pF and 5 pF; or larger than 2 pF, 5 pF, 10 pF, 15 pF or 20 pF; (d) comprise an interconnection net or scheme of metal lines or traces in or of the FISIP and/or SISIP of the logic drive used for connecting the transistors, the FISC, the SISC and/or the micro copper pillars

or bumps of a first standard commodity FPGA IC chip of a first FPGA/HBM CSP of the logic drive to the transistors, the FISC, the SISC and/or the micro copper pillars or bumps of a second FPGA IC chip of a second FPGA/HBM CSP packaged in the logic drive; but not connected to the circuits or components outside or external to the logic drive. That is, no TSV in the substrate of the interposer of the logic drive is connected to the interconnection net or scheme of metal lines or traces in or of the FISIP and/or SISIP. In this case, the interconnection net or scheme of metal lines or traces in or of the FISIP and/or SISIP may be connected or coupled to the off-chip I/O circuits of the first FPGA chips of the first FPGA/HBM CSP packaged in the logic drive. The I/O circuit in this case may be a small I/O circuit, for example, a bi-directional (or tri-state) I/O pad or circuit, comprising an ESD circuit, a receiver, and/or a driver, and may have an input capacitance or output capacitance between 0.05 pF and 2 pF, or 0.05 pF and 1 pF; or smaller than 2 pF or 1 pF.

[0067] (4) Forming metal pillars or bumps, for example solder bumps, on or under the exposed bottom surfaces of the TSVs. The solder bumps may be located at the frontside (bottom side, the interposer is at bottom of the logic drive) surface of the logic drive package with a layout in a Ball-Grid-Array (BGA), having the solder bumps at the peripheral area used for the signal I/Os, and the solder bumps at or near the central area used for the Power/Ground (P/G) I/Os. The signal bumps at the peripheral area may form ring or rings along the edges of the logic driver package, with 1 ring, or 2, 3, 4, 5, 6 rings. The pitches of the signal I/Os in the peripheral area may be smaller than that of the P/G I/Os at or near the central area of the logic drive package.

[0068] (5) Separating, cutting or dicing the finished wafer or panel, including separating, cutting or dicing through materials or structures between two neighboring logic drives. The material (for example, polymer) filling gaps or spaces between two neighboring logic drives is separated, cut or diced to form individual unit of logic drives.

[0069] Another aspect of the disclosure provides the standard commodity COP multi-chip packaged logic drive. The standard commodity COIP logic drive may be in a shape of square or rectangle, with a certain widths, lengths and thicknesses. An industry standard may be set for the shape and dimensions of the logic drive. For example, the standard shape of the COIP-multi-chip packaged logic drive may be a square, with a width greater than or equal to 4 mm, 7 mm, 10 mm, 12 mm, 15 mm, 20 mm, 25 mm, 30 mm, 35 mm or 40 mm, and having a thickness greater than or equal to 0.03 mm, 0.05 mm, 0.1 mm, 0.3 mm, 0.5 mm, 1 mm, 2 mm, 3 mm, 4 mm, or 5 mm.

Alternatively, the standard shape of the COP-multi-chip packaged logic drive may be a rectangle, with a width greater than or equal to 3 mm, 5 mm, 7 mm, 10 mm, 12 mm, 15 mm, 20 mm, 25 mm, 30 mm, 35 mm or 40 mm, and a length greater than or equal to 5 mm, 7 mm, 10 mm, 12 mm, 15 mm, 20 mm, 25 mm, 30 mm, 35 mm, 40 mm, 45 mm or 50 mm; and having a thickness greater than or equal to 0.03 mm, 0.05 mm, 0.1 mm, 0.3 mm, 0.5 mm, 1 mm, 2 mm, 3 mm, 4 mm, or 5 mm. Furthermore, the metal bumps or pillars on or under the interposer in the logic drive may be in a standard footprint, for example, in an area array of $M \times N$ with a standard dimension of pitch and space between neighboring two metal bumps or pillars. The locations of metal bumps or pillars are also at standard locations.

[0070] Another aspect of the disclosure provides the logic drive comprising plural single-layer-packaged logic drives; and each of the plural single-layer-packaged logic drives in a multiple-chip package is as described and specified above. The plural single-layer-packaged logic drives, for example, 2, 3, 4, 5, 6, 7, 8 or greater than 8 single-layer-packaged logic drives, may be, for example, (1) flip-package assembled, in a same plane, on a printed circuit board (PCB), high-density fine-line PCB, Ball-Grid-Array (BGA) substrate, or flexible circuit film or tape; or (2) stack assembled using the Package-on-Package (POP) assembling technology; that is assembling one single-layer-packaged logic drive on top of the other single-layer-packaged logic drive. The POP assembling technology may apply, for example, the Surface Mount Technology (SMT).

[0071] Another aspect of the disclosure provides a method for a single-layer-packaged logic drive suitable for the stacked POP assembling technology. The single-layer-packaged logic drive for use

in the POP package assembling are fabricated as the same as the process steps and specifications of the COW multi-chip packaged logic drive as described in the above paragraphs, except for forming Through-Package-metal-Vias, Through-Polymer-metal-Vias, Through-Polymer-metal-posts, or Through-Polymer-metal-pillars (all are abbreviated as TPVs) in the gaps or spaces between chips or packages in or of the logic drive, and/or in the peripheral area of the logic drive package and outside the edges of chips or packages in or of the logic drive. The TPVs are used for connecting or coupling circuits or components at the frontside (bottom) of the logic drive to that at the backside (top) of the logic drive, the frontside (bottom) is the side with the interposer or substrate. The TPVs may be used for power supply or as power ground connection. The TPVs may be used as the thermal connection. The single-layer-packaged logic drive with TPVs for use in the stacked logic drive may be in a standard format or having standard sizes. For example, the single-layer-packaged logic drive may be in a shape of square or rectangle, with a certain widths, lengths and thicknesses. An industry standard may be set for the shape and dimensions of the single-layer-packaged logic drive. For example, the standard shape of the single-layer-packaged logic drive may be a square, with a width greater than or equal to 4 mm, 7 mm, 10 mm, 12 mm, 15 mm, 20 mm, 25 mm, 30 mm, 35 mm or 40 mm, and having a thickness greater than or equal to 0.03 mm, 0.05 mm, 0.1 mm, 0.3 mm, 0.5 mm, 1 mm, 2 mm, 3 mm, 4 mm, or 5 mm. Alternatively, the standard shape of the single-layer-packaged logic drive may be a rectangle, with a width greater than or equal to 3 mm, 5 mm, 7 mm, 10 mm, 12 mm, 15 mm, 20 mm, 25 mm, 30 mm, 35 mm or 40 mm, and a length greater than or equal to 5 mm, 7 mm, 10 mm, 12 mm, 15 mm, 20 mm, 25 mm, 30 mm, 35 mm, 40 mm, 45 mm or 50 mm; and having a thickness greater than or equal to 0.03 mm, 0.05 mm, 0.1 mm, 0.3 mm, 0.5 mm, 1 mm, 2 mm, 3 mm, 4 mm, or 5 mm. The logic drive with TPVs is formed by forming another set of copper pillars, posts or bumps on or of the interposer using the embossing copper electroplating process as described above, wherein the height of copper bump, post or pillar is taller than that of the micro copper pad, bump or pillar on the SISIP and/or FISIP used for the flip-chip assembly (flip-chip micro copper pads, pillars or bumps) on or of the interposer.

[0072] The wafer or panel of the interposer, with the FISIP, SISIP, flip-chip micro copper pads, pillars and the tall copper pillars, posts or bumps (TPVs), are then used for flip-chip assembling or bonding the IC chips or packages to the flip-chip micro copper pads, pillars or bumps on or of the interposer for forming a logic drive. The process steps for forming the logic drive with TPVs are the same as described and specified above, including the process steps of flip-chip assembly or bonding, underfill, molding, molding compound planarization, silicon interposer thinning and formation of metal pads, pillars or bumps on or under the interposer.

[0073] Another aspect of the disclosure provides a method for forming a stacked logic driver, for an example, by the following process steps: (i) providing a first single-layer-packaged logic drive, either separated or still in the wafer or panel format, with its copper pillars or bumps, or solder bumps faced down, and with the exposed copper pads of TPVs faced up (the interposer are at the bottom of the logic drive); (ii) Package-On-Package (POP) stacking assembling, by surface-mounting and/or flip-package methods, a second separated single-layer-packaged logic drive on top of the provided first single-layer-packaged logic drive. The surface-mounting process is similar to the Surface-Mount Technology (SMT) used in the assembly of components on or to the Printed Circuit Boards (PCB), by first printing solder or solder cream, or flux on the copper pads (top surfaces) of the TPVs, and then flip-package assembling, connecting or coupling the copper pillars or bumps, or solder bumps on or of the second separated single-layer-packaged logic drive to the solder or solder cream or flux printed copper pads of TPVs of the first single-layer-packaged logic drive. The flip-package process is performed, similar to the Package-On-Package technology (POP) used in the IC stacking-package technology, by flip-package assembling, connecting or coupling the copper pillars or bumps, or solder bumps on or of the second separated single-layer-packaged logic drive to the copper pads of or on TPVs of the first single-layer-packaged logic drive. An underfill material may be filled in the gaps or spaces between the first and second single-

layer-packaged logic drivers. A third separated single-layer-packaged logic drive may be flip-package assembled, connected or coupled to the exposed copper pads of or on TPVs of the second single-layer-packaged logic drive. The Package-On-Package stacking assembling process may be repeated for assembling more separated single-layer-packaged logic drives (for example, up to more than or equal to a $n^{\text{sup.th}}$ separated single-layer-packaged logic drive, wherein n is greater than or equal to 2, 3, 4, 5, 6, 7, 8) to form the finished stacking logic drive. When the first single-layer-packaged logic drives are in the separated format, they may be first flip-package assembled to a carrier or substrate, for example a PCB, or a BGA (Ball-Grid-Array) substrate, and then performing the POP processes, in the carrier or substrate format, to form stacked logic drives, and then cutting, dicing the carrier or substrate to obtain the separated finished stacked logic drives. When the first single-layer-packaged logic drives are still in the wafer or panel format, the wafer or panel may be used directly as the carrier or substrate for performing POP stacking processes, in the wafer or panel format, for forming the stacked logic drivers. The wafer or panel is then cut or diced to obtain the separated stacked finished logic drives.

[0074] Another aspect of the disclosure provides a method for a single-layer-packaged logic drive suitable for the stacked POP assembling technology. The single-layer-packaged logic drive for use in the POP package assembling are fabricated as the same process steps and specifications of the COIP multi-chip packages described in the above paragraphs, except for forming a Backside metal Interconnection Scheme at the backside of the single-layer-packaged logic drive (abbreviated as BISD in below) and Through-Package-metal-Vias, Through-Polymer-metal-Vias, Through-Polymer-metal-posts, or Through-Polymer-metal-pillars (all are abbreviated as TPVs) in the gaps or spaces between chips or packages in or of the logic drive, and/or in the peripheral area of the logic drive package and outside the edges of chips or packages in or of the logic drive (the interposer is at the bottom of the logic drive). The BISD may comprise metal lines, traces, or planes in multiple interconnection metal layers, and is formed on or over (i) the backside of the IC chips or packages (the interposer is at the bottom of the logic drive), (ii) the molding compound after the process step of planarization of the molding compound, and (iii) the exposed top surfaces of the TPVs. The BISD provides additional interconnection metal layer or layers at the backside of the logic drive package, and provides copper pads, copper pillars or solder bumps in an area array at the backside of the single-layer-packaged logic drive, including at locations vertically over the IC chips or packages of the logic drive (the interposer is at the bottom of the logic drive). The TPVs are used for connecting or coupling circuits or components (for example, the FISIP and/or SISIP) of the interposer of the logic drive to that (for example, the BISD) at the backside of the logic drive package. The TPVs may be used for power supply or as power or ground connection. The TPVs may be used as the thermal connection. The single-layer-packaged logic drive with TPVs and BISD for use in the stacked logic drive may be in a standard format or having standard sizes. For example, the single-layer-packaged logic drive may be in a shape of square or rectangle, with a certain widths, lengths and thicknesses; and/or with a standard layout of the locations of the copper pads, copper pillars or solder bumps on or over the BISD. An industry standard may be set for the shape and dimensions of the single-layer-packaged logic drive. For example, the standard shape of the single-layer-packaged logic drive may be a square, with a width greater than or equal to 4 mm, 7 mm, 10 mm, 12 mm, 15 mm, 20 mm, 25 mm, 30 mm, 35 mm or 40 mm, and having a thickness greater than or equal to 0.03 mm, 0.05 mm, 0.1 mm, 0.3 mm, 0.5 mm, 1 mm, 2 mm, 3 mm, 4 mm, or 5 mm. Alternatively, the standard shape of the single-layer-packaged logic drive may be a rectangle, with a width greater than or equal to 3 mm, 5 mm, 7 mm, 10 mm, 12 mm, 15 mm, 20 mm, 25 mm, 30 mm, 35 mm or 40 mm, and a length greater than or equal to 5 mm, 7 mm, 10 mm, 12 mm, 15 mm, 20 mm, 25 mm, 30 mm, 35 mm, 40 mm, 45 mm or 50 mm; and having a thickness greater than or equal to 0.03 mm, 0.05 mm, 0.1 mm, 0.3 mm, 0.5 mm, 1 mm, 2 mm, 3 mm, 4 mm, or 5 mm. The logic drive with the BISD is formed by forming metal lines, traces, or planes on multiple interconnection metal layers on or over the backside of the IC chips or packages (the

interposer is at the bottom of the logic drive), the molding compound, and the exposed top surfaces of the TPVs, after the process step of planarization of the molding compound. The top-most interconnection metal layer of the BISD is covered with a top-most insulating dielectric layer of the BISD. Forming copper pads, solder bumps, copper pillars on or over the top-most metal layer of BISD exposed in openings in the top-most insulating dielectric layer of BISD using emboss copper process as described and specifies in above. The locations of the copper pads, copper pillars or solder bumps are on or over: (a) the gaps or spaces between chips or packages in or of the logic drive; (b) peripheral area of the logic drive and outside the edges of chips or packages in or of the logic drive; (c) and/or vertically over the backside of the IC chips or packages. The BISD may comprise 1 to 6 layers, or 2 to 5 layers of interconnection metal layers. The interconnection metal lines, traces or planes of the BISD have the adhesion layer (Ti or TiN, for example) and the copper seed layer only at the bottom, but not at the sidewalls of the metal lines or traces. The interconnection metal lines or traces of FISC and FISIP have the adhesion layer (Ti or TiN, for example) and the copper seed layer at both the bottom and the sidewalls of the metal lines or traces. [0075] The thickness of the metal lines, traces or planes of the BISD is between, for example, 0.3 μm and 40 μm , 0.5 μm and 30 μm , 1 μm and 20 μm , 1 μm and 15 μm , 1 μm and 10 μm , or 0.5 μm to 5 μm , or thicker than or equal to 0.3 μm , 0.7 μm , 1 μm , 2 μm , 3 μm , 5 μm , 7 μm or 10 μm . The width of the metal lines or traces of the BISD is between, for example, 0.3 μm and 40 μm , 0.5 μm and 30 μm , 1 μm and 20 μm , 1 μm and 15 μm , 1 μm and 10 μm , or 0.5 μm to 5 μm , or wider than or equal to 0.3 μm , 0.7 μm , 1 μm , 2 μm , 3 μm , 5 μm , 7 μm or 10 μm . The thickness of the inter-metal dielectric layer of the BISD is between, for example, 0.3 μm and 50 μm , 0.3 μm and 30 μm , 0.5 μm and 20 μm , 1 μm and 10 μm , or 0.5 μm and 5 μm , or thicker than or equal to 0.3 μm , 0.5 μm , 0.7 μm , 1 μm , 1.5 μm , 2 μm , 3 μm or 5 μm . The planes in a metal layer of interconnection metal layers of the BISD may be used for the power, ground planes of a power supply, and/or used as heat dissipaters or spreaders for the heat dissipation or spreading; wherein the metal thickness may be thicker, for example, between 5 μm and 50 μm , 5 μm and 30 μm , 5 μm and 20 μm , or 5 μm and 15 μm ; or thicker than or equal to 5 μm , 10 μm , 20 μm , or 30 μm . The power, ground plane, and/or heat dissipater or spreader may be layout as interlaced or interleaved shaped structures in a plane of an interconnection metal layer of the BISD; or may be layout in a fork shape.

[0076] The BISD interconnection metal lines or traces of the single-layer-packaged logic drive are used: (a) for connecting or coupling the copper pads, copper pillars or solder bumps at the backside (top side, the interposer is at the bottom of the logic drive) surface of the single-layer-packaged logic drive to their corresponding TPVs; and through the corresponding TPVs, the copper pads, copper pillars or solder bumps at the backside surface of the single-layer-packaged logic drive are connected or coupled to the metal lines or traces of the FISIP and/or SISIP of the interposer; and further through the micro copper pillars or bumps, the SISC, and the FISC of the IC chips for connecting or coupling to the transistors; (b) for connecting or coupling the copper pads, copper pillars or solder bumps at the backside (top side, the interposer is at the bottom of the logic drive) surface of the single-layer-packaged logic drive to their corresponding TPVs; and through the corresponding TPVs, the copper pads, copper pillars or solder bumps at the backside surface of the single-layer-packaged logic drive are connected or coupled to the metal lines or traces of the FISIP and/or SISIP of the interposer, and are further through TSVs for connecting or coupling to copper pads, metal bumps or pillars, for example, solder bumps, copper pillars or gold bumps at the frontside (bottom side, the interposer is at the bottom of the logic drive) surface of the single-layer-packaged logic drive. Therefore, the copper pads, copper pillars or solder bumps at the backside (top side, the interposer is at the bottom of the logic drive) of the single-layer-packaged logic drive are connected or coupled to the copper pads, metal pillars or bumps at the frontside (bottom side, the interposer is at the bottom of the logic drive) of the single-layer-packaged logic drive; (c) for connecting or coupling copper pads, copper pillars or solder bumps vertically over a backside of a first of a first FPGA/HBM CSP (top side, the interposer is at the bottom of the logic drive) of the

single-layer-packaged logic drive to copper pads, copper pillars or solder bumps vertically over a second FPGA/HBM CSP (top side, the interposer is at the bottom of the logic drive) of the single-layer-packaged logic drive by using an interconnection net or scheme of metal lines or traces in or of the BISD. The interconnection net or scheme may be connected or coupled to TPVs of the single-layer-packaged logic drive; (d) for connecting or coupling a first copper pad, copper pillar or solder bump vertically over a of a FPGA/HBM CSP of the single-layer-packaged logic drive to a second copper pad, copper pillar or solder bump vertically over the same of the FPGA/HBM CSP by using an interconnection net or scheme of metal lines or traces in or of the BISD. The interconnection net or scheme may be connected or coupled to the TPVs of the single-layer-packaged logic drive; (e) for the power or ground planes and/or heat dissipaters or spreaders.

[0077] Another aspect of the disclosure provides a method for forming a stacked logic drive using the single-layer-packaged logic drive with the BISD and TPVs. The stacked logic drive may be formed using the same or similar process steps, as described and specified above; for an example, by the following process steps: (i) providing a first single-layer-packaged logic drive with both TPVs and the BISD, either separated or still in the wafer or panel format, and with its copper pillars or bumps, solder bumps, or gold bumps, on or under the TSVs, faced down, and with the exposed copper pads, copper pillars, or solder bumps, on or over the BISD, on its upside; (ii) Package-On-Package (POP) stacking assembling, by surface-mounting and/or flip-package methods, a second separated single-layer-packaged logic drive (also with both TPVs and the BISD) on top of the provided first single-layer-packaged logic drive. The surface-mounting process is similar to the Surface-Mount Technology (SMT) used in the assembly of components on or to the Printed Circuit Boards (PCB), by, for example, first printing solder or solder cream, or flux on the surfaces of the exposed copper pads, and then flip-package assembling, connecting or coupling the copper pillars or bumps, solder bumps, or gold bumps on or of the second separated single-layer-packaged logic drive to the solder or solder cream or flux printed surfaces of the exposed copper pads of the first single-layer-packaged logic drive. The flip-package process is performed, similar to the Package-On-Package technology (POP) used in the IC stacking-package technology, by flip-package assembling, connecting or coupling the copper pillars or bumps, solder bumps, or gold bumps on or of the second separated single-layer-packaged logic drive to the surfaces of copper pads of the first single-layer-packaged logic drive. Note that the copper pillars or bumps, solder bumps, or gold bumps on or of the second separated single-layer-packaged logic drive bonded to the surfaces of copper pads of the first single-layer-packaged logic drive may be located vertically over or above locations where IC chips or packages are placed in the first single-layer-packaged logic drive; and that the copper pillars or bumps, solder bumps, or gold bumps on or of the second separated single-layer-packaged logic drive bonded to the surfaces of copper pads of the first single-layer-packaged logic drive may be located vertically under or below locations where IC chips or packages are placed in the second single-layer-packaged logic drive. An underfill material may be filled in the gaps between the first and the second single-layer-packaged logic drivers. A third separated single-layer-packaged logic drive (also with both TPVs and the BISD) may be flip-package assembled, connected or coupled to the copper pads (on or over the BISD) of the second single-layer-packaged logic drive. The Package-On-Package stacking assembling process may be repeated for assembling more separated single-layer-packaged logic drives (for example, up to more than or equal to a $n^{\text{sup.th}}$ separated single-layer-packaged logic drive, wherein n is greater than or equal to 2, 3, 4, 5, 6, 7, 8) to form the finished stacking logic drive. When the first single-layer-packaged logic drives are in the separated format, they may be first flip-package assembled to a carrier or substrate, for example a PCB, or a BGA (Ball-Grid-Array) substrate, and then performing the POP processes, in the carrier or substrate format, to form stacked logic drives, and then cutting, dicing the carrier or substrate to obtain the separated finished stacked logic drives. When the first single-layer-packaged logic drives are still in the wafer or panel format, the wafer or panel may be used directly as the carrier or substrate for performing POP stacking processes, in the wafer or panel format, for

forming the stacked logic drives. The wafer or panel is then cut or diced to obtain the separated stacked finished logic drives.

[0078] Another aspect of the disclosure provides varieties of interconnection alternatives for the TPVs of a single-layer-packaged logic drive: (a) the TPV may be designed and formed as a through via by stacking the TPV directly over the stacked metal layers/vias of SISIP and/or FISIP and directly over the TSV in the interposer or substrate. The TSV is now used as a through via for connecting a single-layer-packaged logic drive above the single-layer-packaged logic drive, and a single-layer-packaged logic drive below the single-layer-packaged logic drive; without connecting or coupled to the FISIP, the SISIP or micro copper pillars or bumps on or of any IC chip of the single-layer-packaged logic drive. In this case, a stacked structure is formed, from top to bottom: (i) copper pad, copper pillar or solder bump; (ii) stacked interconnection layers and metal vias in the dielectric layer of the BISD; (iii) the TPV; (iv) stacked interconnection layers and metal vias in the dielectric layer of the FISIP and/or SISIP; (v) TSV in the interposer or substrate; (vi) copper pad, metal bump, solder bump, copper pillar, or gold bump on or under bottom surface of the TSV. Alternatively, the stacked TPV/metal layers and vias/TSV may be used as power, ground or thermal conduction via; (b) the TPV is stacked as a through TPV as in (a), but is connected or coupled to the FISIP, the SISIP and/or micro copper pillars or bumps on or of one or plural IC chips or packages of the single-layer-packaged logic drive, through the metal lines or traces of the FISIP and/or FISIP. Alternatively, the stacked TPV/metal layers and vias/TSV may be used as power, ground or thermal conduction via; (c) the TPV is only stacked at the top portion, but not at the bottom portion. In this case, a structure for the TPV connection is formed, from top to bottom: (i) copper pad, copper pillar or solder bump; (ii) stacked interconnection layers and metal vias in the dielectric layer of the BISD; (iii) the TPV; (iv) the bottom of the TPV is connected or coupled to the FISIP, the SISIP or micro copper pillars or bumps on or of one or plural IC chips or packages of the single-layer-packaged logic drive, through the interconnection metal layers and metal vias in the dielectric layer of the SISIP and/or FISIP. Wherein (1) a copper pad, metal bump, solder bumps, copper pillar or gold bump, directly under the bottom of the TPV, is not connected or coupled to the TPV; (2) a copper pad, metal bump, solder bump, copper pillar or gold bump on and under the interposer connected or coupled to the bottom of the TPV (through FISIP and/or SISIP) is at a location not vertically under the bottom of the TPV; (d) a structure for the TPV connection is formed, from top to bottom: (i) a copper pad, copper pillar or solder bump (on the BISD) connected or coupled to the top surface of the TPV, and may be at a location vertically over the backside of the IC chips or packages; (ii) the copper pad, copper pillar or solder bump (on the BISD) is connected or coupled to the top surface of the TPV (which is located between the gaps or spaces of chips or packages, or at the peripheral area where no chip or package is placed) through the interconnection metal layers and metal vias in the dielectric layer of the BISD; (iii) the TPV; (iv) the bottom of the TPV is connected or coupled to the FISIP, the SISIP, or the micro copper pillars or bumps on or of one or plural IC chips or packages of the single-layer-packaged logic drive through the interconnection metal layers and metal vias in the dielectric layer of the SISIP and/or FISIP; (v) TSV (in the interposer or substrate) and a metal pad, pillar or bump (on or under the TSV) connected or coupled to the bottom of the TPV, wherein the TSV or the metal pad, bump or pillar may be at a location not vertically under the bottom of the TPV, while may be at a location vertically under the frontside of the IC chips or packages; (e) a structure for the TPV connection is formed, from top to bottom: (i) a copper pad, copper pillar or solder bump (on the BISD) vertically over the backside of an IC chip or packages of the single-layer-packaged logic drive; (ii) the copper pad, copper pillar or solder bump on the BISD is connected or coupled to the top surface of the TPV (which is located between the gaps or spaces of chips or packages, or at the peripheral area where no chip or package is placed) through the interconnection metal layers and metal vias in the dielectric layer of the BISD; (iii) the TPV; (iv) the bottom of the TPV is connected or coupled to the FISIP, the SISIP of interposer, and/or micro copper pillars or bumps, SISC, or FISC on or of

one or plural IC chips or packages of the single-layer-packaged logic drive through the interconnection metal layers and metal vias in the dielectric layer of the SISIP and/or FISIP. Wherein no TSV (in the interposer or substrate) and no metal pad, pillar or bump (on or under the TSV) are connected or coupled to the bottom of the TPV.

[0079] Another aspect of the disclosure provides an interconnection net or scheme of metal lines or traces in or of the FISIP and/or SISIP of the single-layer-packaged logic drive used for connecting or coupling the transistors, the FISC, the SISC and/or the micro copper pillars or bumps of an FPGA IC chip of the FPGA/HBM CSP packaged in the single-layer-packaged logic drive, but the interconnection net or scheme is not connected or coupled to the circuits or components outside or external to the single-layer-packaged logic drive. That is, no metal pads, pillars or bumps (copper pads, pillars or bumps, solder bumps, or gold bumps) on or under the interposer of the single-layer-packaged logic drive is connected to the interconnection net or scheme of metal lines or traces in or of the FISIP and/or SISIP, and no copper pads, copper pillars or solder bumps on or over the BISD is connected or coupled to the interconnection net or scheme of metal lines or traces in or of the FISIP and/or SISIP.

[0080] Another aspect of the disclosure provides the logic drive in a multi-chip package format further comprising one or plural Dedicated Programmable Interconnection IC (DPIIC) chip or chips. The DPIIC chip comprises 5T or 6T SRAM cells and cross-point switches, and is used for programming the interconnection between circuits or interconnections of two different standard commodity FPGA chips in the FPGA/HBM CSP. The programmable interconnections comprise interconnection metal lines or traces on, over or of the interposer (the FISIP and/or SISIP) between the standard commodity FPGA chips of the FPGA/HBM CSP, with cross-point switch circuits (on the DPIIC chip) in the middle of interconnection metal lines or traces of the FISIP and/or SISIP. For example, n metal lines or traces of the FISIP and/or SISIP are input to a cross-point switch circuit on the DPIIC chip, and m metal lines or traces of the FISIP and/or SISIP are output from the cross-point switch circuit. The cross-point switch circuit on the DPIIC chip is designed such that each of the n metal lines or traces of the FISIP and/or SISIP can be programed to connect to anyone of the m metal lines or traces of the FISIP and/or SISIP. The cross-point switch circuit may be controlled by the programming code stored in, for example, an SRAM cell in or of the DPIIC chip. The SRAM cell may comprise 6-Transistors (6T), with two transfer (write) transistors and 4 data-latch transistors. The two transfer (write) transistors are used for writing the programing code or data into the two storage or latch nodes of the 4 data-latch transistors. Alternatively, the SRAM cell may comprise 5-Transistors (5T), with a transfer (write) transistor and 4 data-latch transistors. The transfer (write) transistor is used for writing the programing code or data into the two storage or latch nodes of the 4 data-latch transistors. The stored (programming) data in the 5T or 6T SRAM cell is used to program the connection or not-connection of metal lines or traces of the FISIP and/or SISIP. The cross-point switches are the same as that described in the standard commodity FPGA IC chips of the FPGA/HBM CSP. The details of various types of cross-point switches are as specified or described in the paragraphs of FPGA IC chips of the FPGA/HBM CSP. The DPIIC chip comprises 5T or 6T SRAM cells and cross-point switches used for programmable interconnection of metal lines or traces of the FISIP and/or SISIP between the standard commodity FPGA chips in the logic drive. Alternatively, the DPIIC chip comprising 5T or 6T SRAM cells and cross-point switches may be used for programmable interconnection of metal lines or traces of the FISIP and/or SISIP between the standard commodity FPGA chips of the FPGA/HBM CSP and the TPVs (for example, the bottom surfaces of the TPVs) in the logic drive, in the same or similar method as described above. The stored (programming) data in the 5T or 6T SRAM cell (on the DPIIC chip) is used to program the connection or not-connection between (i) a first metal line, trace, or net of the FISIP and/or SISIP, connecting to one or more micro copper pillars or bumps on or over one or plural the IC chips of the logic drive, and/or to one or plural metal pads, pillars or bumps on or under the TSVs of the interposer, and (ii) a second metal line, trace or net of the FISIP and/or

SISIP, connecting or coupling to a TPV (for example, the bottom surface of the TPV), in a same or similar method described above. With this aspect of disclosure, TPVs are programmable; in other words, this aspect of disclosure provides programmable TPVs. The programmable TPVs may, alternatively, use the programmable interconnection, comprising 5T or 6T SRAM cells and cross-point switches, on or of the FPGA IC chips of the FPGA/HBM CSP in or of the logic drive.

[0081] A programmable TSV may be achieved by having 5T or 6T SRAM cells and cross-point switches on the DPIIC chip in the middle between (i) a first interconnection line, trace or net (of FISIP and/or SISIP) connected or coupled to one or plural micro copper pillars or bumps of an IC chip or package (therefor to the metal lines or traces of the SISC and/or the FISC, and/or the transistors) of the logic drive, and (ii) a second interconnection line, trace or net (of FISIP and/or SISIP) connected or coupled to a metal pad, pillar or bump on or under the TSV of the interposer of the logic drive. The programmable TSVs may, alternatively, use the programmable interconnection, comprising 5T or 6T SRAM cells and cross-point switches, on or of the FPGA IC chips of the FPGA/HBM CSP in or of the logic drive. The metal pads, pillars or bumps on or under the TSVs of the interposer of the logic drive become programmable using the programmable TSVs.

[0082] When a metal pad, bump or pillar (on or over the BISD) at the backside of the logic drive is connected to the programmable TPV, the copper pad, copper pillar or solder bump (on or over the BISD) becomes a programmable metal bump or pillar (on or over the BISD). The programmable metal pad, bump or pillar (on or over the BISD) at the backside of the logic drive may be connected or coupled to, by programming and through the programmable TPV, wherein the programmable TPV is achieved as described above. The programmable metal pad, bump or pillar (on or over the BISD) at the backside of the logic drive may, alternatively, use the programmable interconnection, comprising 5T or 6T SRAM cells and cross-point switches, on or of the FPGA IC chips of the FPGA/HBM CSP in or of the logic drive.

[0083] The DPIIC chip is designed, implemented and fabricated using varieties of semiconductor technology nodes or generations, including old or matured technology nodes or generations, for example, a semiconductor node or generation less advanced than or equal to, or above or equal to 35 nm, 40 nm, 50 nm, 90 nm, 130 nm, 250 nm, 350 nm, 500 nm, or alternatively including advanced semiconductor technology nodes or generations, for example, a semiconductor node or generation more advanced than or equal to, or below or equal to 30 nm, 20 nm or 10 nm. The semiconductor technology node or generation used in the DPIIC chip is 1, 2, 3, 4, 5 or greater than 5 nodes or generations older, more matured or less advanced than that used in the standard commodity FPGA IC chips of the FPGA/HBM CSP packaged in the same logic drive. Transistors used in the DPIIC chip may be a FINFET, a Fully Depleted Silicon-on-insulator (FDSOI) MOSFET, a Partially Depleted Silicon-on-insulator (PDSOI) MOSFET or a conventional MOSFET. Transistors used in the DPIIC chip may be different from that used in the standard commodity FPGA IC chips of the FPGA/HBM CSP packaged in the same logic drive; for example, the DPIIC chip may use the conventional MOSFET, while the standard commodity FPGA IC chips of the FPGA/HBM CSP packaged in the same logic drive may use the FINFET; or the DPIIC chip may use the Fully Depleted Silicon-On-Insulator (FDSOI) MOSFET, while the standard commodity FPGA IC chips of the FPGA/HBM CSP packaged in the same logic drive may use the FINFET.

[0084] Another aspect of the disclosure provides a standardized interposer, in the wafer form or panel form in the stock or in the inventory for use in the later processing in forming the standard commodity logic drive, as described and specified above. The standardized interposer comprises a fixed physical layout or design of the TSVs in the interposer; and a fixed design and layout of the TPVs on or over the interposer if included in the interposer. The locations or coordinates of the TSVs and the TPVs in or on the interposer are the same or of certain types of standards of layouts and designs for the standard interposers. For example, connection schemes between TSVs and the TPVs, are the same for each of the standard commodity interposers. Furthermore, the design or

interconnection of the FISIP and/or SISIP, and the layout or coordinates of the micro copper pads, pillars or bumps on or over the SISIP and/or FISIP are the same or of certain types of standards of layouts and designs for the standard interposers. The standard commodity interposer in the stock or inventory is then used for forming the standard commodity logic drive by the process described and specified above, including process steps: (1) flip-chip assembling or bonding the IC chips or packages on or to the standard interposer; (2) Applying a material, resin, or compound to fill the gaps or spaces between chips or packages and cover the backside surfaces of IC chips or packages by methods, for example, spin-on coating, screen-printing, dispensing or molding in the wafer or panel format. Applying a CMP process, polishing process, or backside grinding process to planarize the surface of the applied material, resin or compound to a level where the top surfaces of all bumps or pillars (TPVs) on or of the interposers and the backside of IC chips are fully exposed; (3) forming the BISD; and (4) forming the metal pads, pillars or bumps on or over the BISD. The standard commodity interposer or substrates with a fixed layout or design may be used and customized, by software coding or programming, using the programmable TPVs, and/or programmable metal pads, pillars or bumps on or under the interposer (programmable TSVs) as described and specified above, for different applications. As described above, the data installed or programed in the 5T or 6T SRAM cells of the DPIIC chips may be used for programmable TPVs and/or programmable metal pads, pillars or bumps under the TSVs of the interposer (programmable TSVs). The data installed or programed in the 5T or 6T SRAM cells of the FPGA chips of the FPGA/HBM CSP may be alternatively used for programmable TPVs and/or programmable metal pads, pillars or bumps on or under the interposer (programmable TSVs).

[0085] Another aspect of the disclosure provides the standardized commodity logic drive (for example, the single-layer-packaged logic drive) with a fixed design, layout or footprint of (i) the metal pads, pillars or bumps (copper pillars or bumps, solder bumps or gold bumps) on or under the TSVs of the interposer, and (ii) copper pads, copper pillars or solder bumps (on or over the BISD) on the backside (top side, the interposer is at bottom of the logic drive) of the standard commodity logic drive. The standardized commodity logic drive may be used, customized for different applications by software coding or programming, using the programmable metal pads, pillars or bumps on or under the TSVs of the interposer, and/or using programmable copper pads, copper pillars or bumps, or solder bumps on or over the BISD (through programmable TPVs), as described and specified above, for different applications. As described above, the codes of the software programs are loaded, installed or programed in the 5T or 6T SRAM cells of the DPIIC chip for controlling cross-point switches of the DPIIC chip in or of the standard commodity logic drive for different varieties of applications. Alternatively, the codes of the software programs are loaded, installed or programed in the 5T or 6T SRAM cells of one of the FPGA IC chips of the FPGA/HBM CSP, in or of the logic drive in or of the standard commodity logic drive, for controlling cross-point switches of the FPGA IC chip of the FPGA/HBM CSP for different varieties of applications. Each of the standard commodity logic drives with the same design, layout or footprint of the metal pads, pillars or bumps on or under the TSVs of the interposer, and the copper pads, copper pillars or bumps, or solder bumps on or over the BISD may be used for different applications, purposes or functions, by software coding or programming, using the programmable metal pads, pillars or bumps on or under the TSVs of the interposer, and/or programmable copper pads, copper pillars or bumps, or solder bumps on or over the BISD (through programmable TPVs) of the logic drive.

[0086] Another aspect of the disclosure provides the logic drive, either in the single-layer-packaged or in a stacked format, comprising IC chips, logic blocks (comprising LUTs, cross-point switches, multiplexers, switch buffers, logic circuits, switch buffers, logic gates, and/or computing circuits) and/or memory cells or arrays, immersing in a super-rich interconnection scheme or environment. The logic blocks (comprising LUTs, cross-point switches, multiplexers, logic circuits, logic gates, and/or computing circuits) and/or memory cells or arrays of each of the multiple standard

commodity FPGA IC chips of the FPGA/HBM CSP (and/or other IC chips in the single-layer-packaged or in a stacked logic drive) are immersed in a programmable 3D Immersive IC Interconnection Environment (IIIE). The programmable 3D IIIE on, in, or of the logic drive package provides the super-rich interconnection scheme or environment, comprising (1) the FISC, the SISC and micro copper pillars or bumps on, in or of the IC chips, (2) the FISIP and/or SISIP, TPVs, micro copper pillars or bumps, and TSVs of the interposer or substrate, (3) metal pads, pillars or bumps on or under the TSVs of the interposer, (4) the BISD, and (5) copper pads, copper pillars or bumps, or solder bumps on or over the BISD. The programmable 3D IIIE provides a programmable 3-Dimension (3D) super-rich interconnection scheme or system: (1) the FISC, the SISC, the FISIP and/or SISIP, and/or the BISD provide the interconnection scheme or system in the x-y directions for interconnecting or coupling the logic blocks and/or memory cells or arrays in or of a same FPGA IC chip of the FPGA/HBM CSP, or in or of different FPGA chips of the FPGA/HBM CSP in or of the single-layer-packaged logic drive. The interconnection of metal lines or traces in the interconnection scheme or system in the x-y directions is programmable; (2) The metal structures including (i) metal vias in the FISC and SISC, (ii) micro pillars or bumps on the SISC, (iii) metal vias in the FISIP and SISIP, (iv) micro pillars or bumps on the SISIP, (v) TSVs, (vi) metal pads, pillars or bumps on or under the TSVs of the interposer, (vii) TPVs, (viii) metal vias in the BISD, and/or (ix) copper pads, copper pillars or bumps, or solder bumps on or over the BISD, provide the interconnection scheme or system in the z direction for interconnecting or coupling the logic blocks, and/or memory cells or arrays in or of different FPGA chips of the FPGA/HBM CSP in or of different single-layer-packaged logic drives stacking-packaged in the stacked logic drive. The interconnection of the metal structures in the interconnection scheme or system in the z direction is also programmable. The programmable 3D IIIE provides an almost unlimited number of the transistors or logic blocks, interconnection metal lines or traces, and memory cells/switches at an extremely low cost. The programmable 3D IIIE similar or analogous to the human brain: (i) transistors and/or logic blocks (comprising logic gates, logic circuits, computing operators, computing circuits, LUTs, and/or cross-point switches) are similar or analogous to the neurons (cell bodies) or the nerve cells; (ii) the metal lines or traces of the FISC and/or the SISC are similar or analogous to the dendrites connecting to the neurons (cell bodies) or nerve cells. The micro pillars or bumps connecting to the receivers for the inputs of the logic blocks (comprising, for example, logic gates, logic circuits, computing operators, computing circuits, LUTs, and/or cross-point switches) in or of the FPGA IC chips of the FPGA/HBM CSP are similar or analogous to the post-synaptic cells at the ends of the dendrites; (iii) the long distance connects formed by metal lines or traces of the FISC, the SISC, the FISIP and/or SISIP, and/or the BISD, and the metal vias, metal pads, pillars or bumps, including the micro copper pillars or bumps on the SISC, TSVs, metal pads, pillars or bumps on or under the TSVs of the interposer, TPVs, and/or copper pads, copper pads, pillars or bumps, or solder bumps on or over the BISD, are similar or analogous to the axons connecting to the neurons (cell bodies) or nerve cells. The micro pillars or bumps connecting the drivers or transmitters for the outputs of the logic blocks (comprising, for example, logic gates, logic circuits, computing operators, computing circuits, LUTs, and/or cross-point switches) in or of the FPGA IC chips of the FPGA/HBM CSP are similar or analogous to the pre-synaptic cells at the axons' terminals.

[0087] Another aspect of the disclosure provides a Fan-Out Interconnection Technology (FOIT) for making or fabricating the logic drive based on a multi-chip packaging technology and process. The Fan-Out Interconnection Technology (FOIT) is a multichip packaging technology based on fan-out interconnection or Re-Distribution Layer (RDL) for interconnecting chips or packages in the logic drive. The FOIT logic drive may be formed by three methods: (A) Chip-First by placing chips or packages first in the process: (i) chip faced up, (ii) chip face down; (B) RDL-First by forming the RDL layer first and then flip-chip assembling the chips on the RDL. The three methods differ in process sequence, yet result in a similar structure. The process steps of method (A) (i) are described

as below:

[0088] (1) Providing a chip carrier, holder, molder or substrate, and IC chips or packages; then placing, fixing or attaching the IC chips or packages to and on the carrier, holder, molder or substrate. The carrier, holder, molder or substrate may be in a wafer format (with 8", 12" or 18" in diameter), or, in a panel format in the square or rectangle format (with a width or a length greater than or equal to 20 cm, 30 cm, 50 cm, 75 cm, 100 cm, 150 cm, 200 cm or 300 cm). The material of the chip carrier, holder, molder or substrate may be silicon, metal, ceramics, glass, steel, plastics, polymer, epoxy-based polymer, or epoxy-based compound. The IC chips or packages to be placed, fixed or attached to the carrier, holder, molder or substrate include the chips or packages mentioned, described and specified above: the standard commodity DRAM IC chips or FPGA/HBM CSP packages, the non-volatile chips or packages, the dedicated control chip, the dedicated I/O chip, the dedicated control and I/O chip, IAC, DPIIC chip and/or computing and/or processing IC chips, for example, CPU, GPU, DSP, TPU, APU chips. The chips or CSPs are placed, held, fixed or attached on or to the carrier, holder, molder or substrate with the side or surface of the chip with transistors faced up or with the frontside of the CSP faced up. The backside of the silicon substrate of the chips (the side or surface without transistors or the backside of the CSP) is faced down and is placed, fixed, held or attached on or to the carrier, holder, molder or substrate.

[0089] ((2) Applying a material, resin, or compound to fill the gaps or spaces between chips or packages and cover the surfaces of chips or packages by methods, for example, spin-on coating, screen-printing, dispensing or molding in the wafer or panel format. The molding method includes the compress molding (using top and bottom pieces of molds) or the casting molding (using a dispenser). The material, resin, or compound used may be a polymer material includes, for example, polyimide, BenzoCycloButene (BCB), parylene, epoxy-based material or compound, photo epoxy SU-8, elastomer, or silicone. The polymer may be, for example, photosensitive polyimide/PBO PIMEL.sup.Th supplied by Asahi Kasei Corporation, Japan; or epoxy-based molding compounds, resins or sealants provided by Nagase ChemteX Corporation, Japan. The material, resin or compound is applied (by coating, printing, dispensing or molding) on or over the carrier, holder, molder or substrate and on or over the chips or packages to a level to: (i) fill gaps or spaces between chips or packages, (ii) cover the top-most surface of the chips or packages, (iii) fill gaps or spaces between micro copper pillars or bumps on or of the chips or packages, (iv) cover top surfaces of the micro copper pillars or bumps on or of the chips or packages. Applying a CMP, polishing or grinding process to planarize the surface of the applied material, resin or compound to a level where the top surfaces of all micro bumps or pillars on or of the chips or packages are fully exposed. The chip carrier, holder, molder or substrate may be then (i) removed after the CMP, polishing or grinding process mentioned above, and before forming a Top Interconnection Scheme in, on or of the logic drive (TISD) to be described below; (ii) kept during the following fabrication process steps to be performed later, and removed after all fabrication process steps for making or fabricating the logic drive at the wafer or panel format are finished; or (iii) kept as part of the separated finished final logic drive product. A process, for example, a CMP process, a polishing process, or a wafer backside grinding process, may be performed for removing the chip carrier, holder, molder or substrate. Alternatively, a wafer or panel thinning process, for example, a CMP process, a polishing process or a wafer backside grinding process, may be performed to remove portion of the wafer or panel to make the wafer or panel thinner, in a wafer or panel process, after the wafer or panel process steps are all finished, and before the wafer or panel is separated, cut or diced into individual unit of the logic drive. EiOC (3) Forming a Top Interconnection Scheme in, on or of the logic drive (TISD) on or over the planarized material, resin or compound and on or over the exposed top surfaces of the micro pillars or bumps by a wafer or panel processing. The TISD comprises multiple metal layers, with inter-metal dielectric layers between each of the multiple metal layers, and may, optionally, comprise an insulating dielectric layer on the planarized

material, resin or compound layer, and between the bottom-most interconnection metal layer of the TISD and the planarized material, resin or compound layer. The metal lines or traces of the interconnection metal layers of the TISD are over the chips and extend horizontally across the edges of the chips or packages, in other words, the metal lines or traces are running through and over gaps or spaces between chips or packages of the logic drive. The metal lines or traces of the interconnection metal layers of the TISD are connecting or coupling circuits of two or more chips or packages of the logic drive. The TISD comprises multiple electroplated copper layers formed by the emboss copper processes and multiple inter-metal dielectric insulating polymer layers. A polymer material may be used for the insulating dielectric polymer layer of the TISD, for example, polyimide, BenzoCycloButene (BCB), parylene, epoxy-based material or compound, photo epoxy SU-8, elastomer, or silicone.

[0090] The TISD interconnection metal lines or traces have the same specification as that of the SISIP of the interposer in the COIP packaging and have functions of that of FISIP/SISIP of the interposer in the COW packaging.

[0091] (4) Forming copper pillars or solder bumps on or over the top-most insulating dielectric layer of the TISD, and the exposed top surfaces of the top-most interconnection metal layer of the TISD in openings of the top-most insulating dielectric layer of the TISD, by performing an emboss copper process, as described above.

[0092] (5) Separating, cutting or dicing the finished wafer or panel, including separating, cutting or dicing through materials or structures between two neighboring logic drives. The material (for example, polymer) filling gaps or spaces between two neighboring logic drives is separated, cut or diced to form individual unit of logic drives.

[0093] The logic drive formed by the FOIT multi-chip packaging can further include Through-Package-metal-Vias, Through-Polymer-metal-Vias, Through-Polymer-metal-posts or Through-Polymer-metal-pillars (TPVs) and/or Backside Interconnection Scheme of logic drive (BISD), which are similar or the same as TPVs or BISD in the COW logic drive. The functions and specifications of the TPVs and BISD of FOIT logic drives are the same as that specified in the COIP logic drives.

[0094] All specifications, functions, purposes of the structures and designs of the COIP logic drives described above can be applied to the corresponding structures or designs in the FOIT structures.

[0095] Another aspect of the disclosure provides a method for forming the logic drive in a Chip-On-Interconnection-Substrate (COIS) multi-chip package using an Interconnection Substrate (IS) comprising the interconnection Schemes of the Printed Circuit Board (PCB) substrate or Ball Grid Array (BGA) substrate and silicon Fineline Interconnection Bridges (FIB) embedded in it. The FIB is used for high speed, high density interconnection between IC chips or CSPs flipchip assembled on the IS substrate. The FIBs comprise First Interconnection Schemes on the substrates of FIBs (FISIB) and/or Second Interconnection Schemes on the substrates of FIBs (SISIB). The description, fabrication processes, specifications and features of the FISIB is as described and specified above in the FISIP of the interposers, and the description, fabrication processes, specifications and features of the SISIB is as described and specified above in the SISIP of the interposers. The FIBs are then embedded in the IS. The IS is formed by the PCB or BGA processes, for example, semi-additive process using laminated dielectric insulating layers and copper foils. The dielectric insulating layers may comprise FR4 (a composite material composed of woven fiberglass cloth with an epoxy resin binder) or BT (Bismaleimide Triazine Resin).

[0096] The COIS packages are the same as the COIP package except that Interconnection Substrates are used instead of the Interposers (IP). The interconnection schemes of IS comprises the interconnection Schemes of the Printed Circuit Board (PCB) substrate or Ball Grid Array (BGA) substrate and silicon Fineline Interconnection Bridges (FIB) embedded in it, wherein FIB comprise the FISIB and/or SISIB. The purposes and functions of the interconnection schemes of the ISs are same as interconnection schemes (FISIP and/or SISIP) of the interposers. The IC chips

or CSP packages to be assembled, bonded or packaged to the IS include the chips or CSP packages mentioned, described and specified above: the standard commodity DRAM IC chips or FPGA/HBM CSP packages, the non-volatile chips or packages, the dedicated control chip, the dedicated I/O chip, the dedicated control and I/O chip, IAC chip, DPIIC chip and/or computing and/or processing IC chips, for example, CPU, GPU, DSP, TPU. APU chips.

[0097] The logic drive formed by the COIS multi-chip packaging can further include Through-Package-metal-Vias, Through-Polymer-metal-Vias, Through-Polymer-metal-posts or Through-Polymer-metal-pillars (TPVs) and/or Backside Interconnection Scheme of logic drive (BISD), which are similar or the same as TPVs or BISD in the COIP logic drive. The functions and specifications of the TPVs and BISD of COIS logic drives are the same as that specified in the COIP logic drives.

[0098] All specifications, functions, purposes of the structures and designs of the COIP logic drives described above can be applied to the corresponding structures or designs in the COIS structures.

[0099] These, as well as other components, steps, features, benefits, and advantages of the present application, will now become clear from a review of the following detailed description of illustrative embodiments, the accompanying drawings, and the claims.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0100] The drawings disclose illustrative embodiments of the present application. They do not set forth all embodiments. Other embodiments may be used in addition or instead. Details that may be apparent or unnecessary may be omitted to save space or for more effective illustration.

Conversely, some embodiments may be practiced without all of the details that are disclosed. When the same reference number or reference indicator appears in different drawings, it may refer to the same or like components or steps.

[0101] Aspects of the disclosure may be more fully understood from the following description when read together with the accompanying drawings, which are to be regarded as illustrative in nature, and not as limiting. The drawings are not necessarily to scale, emphasis instead being placed on the principles of the disclosure. In the drawings:

[0102] FIGS. 1A and 1B are circuit diagrams illustrating first and second types of SRAM cells in accordance with an embodiment of the present application.

[0103] FIGS. 2A-2C are circuit diagrams illustrating first, second and third types of pass/no-pass switches in accordance with an embodiment of the present application.

[0104] FIGS. 3A and 3B are circuit diagrams illustrating first and second types of cross-point switches composed of multiple pass/no-pass switches in accordance with an embodiment of the present application.

[0105] FIG. 4 is a circuit diagram illustrating a multiplexer in accordance with an embodiment of the present application.

[0106] FIG. 5A is a circuit diagram of a large I/O circuit in accordance with an embodiment of the present application.

[0107] FIG. 5B is a circuit diagram of a small I/O circuit in accordance with an embodiment of the present application.

[0108] FIG. 6A is a schematic view showing a block diagram of a programmable logic cell in accordance with an embodiment of the present application.

[0109] FIG. 6B is a block diagram illustrating a computation operator in accordance with an embodiment of the present application.

[0110] FIG. 6C shows a truth table for a logic operator as seen in FIG. 6B.

[0111] FIG. 6D is a block diagram illustrating a programmable logic block for a standard

commodity FPGA IC chip in accordance with an embodiment of the present application.

[0112] FIG. 7 is a circuit diagram illustrating programmable interconnects programmed by a third type of cross-point switch in accordance with an embodiment of the present application.

[0113] FIG. 8A is a schematically top view showing a block diagram of a standard commodity FPGA IC chip in accordance with an embodiment of the present application.

[0114] FIG. 8B is a top view showing a layout of a standard commodity FPGA IC chip in accordance with an embodiment of the present application.

[0115] FIG. 9 is a schematically top view showing a block diagram of a dedicated programmable interconnection (DPI) integrated-circuit (IC) chip in accordance with an embodiment of the present application.

[0116] FIGS. 10A-10D are schematically top views showing multiple arrangements for semiconductor chips packaged in various types of standard commodity logic drives in accordance with multiple embodiments of the present application.

[0117] FIG. 11 is a block diagram showing interconnection between chips in a standard commodity logic drive in accordance with an embodiment of the present application.

[0118] FIG. 12 is a block diagram illustrating multiple control buses for one or more standard commodity FPGA IC chips and multiple data buses for an expandable logic scheme based on one or more standard commodity FPGA IC chips and high bandwidth memory (HBM) IC chips in accordance with an embodiment the present application.

[0119] FIG. 13 is a block diagrams showing architecture of programming and operation in a standard commodity FPGA IC chip in accordance with an embodiment of the present application.

[0120] FIGS. 14A-14F are schematically cross-sectional views showing various types of semiconductor chips in accordance with an embodiment of the present application.

[0121] FIGS. 15A and 15B are schematically cross-sectional views showing various types of memory modules in accordance with an embodiment of the present application.

[0122] FIGS. 16A and 16B are schematically cross-sectional views showing a process of bonding a thermal compression bump to a thermal compression pad in accordance with an embodiment of the present application.

[0123] FIGS. 16C and 16D are schematically cross-sectional views showing a direct bonding process in accordance with an embodiment of the present application.

[0124] FIGS. 17A-17G are schematic views showing a process for forming first and second types of operation modules, i.e., FPGA/HBM stacked 3D chip scale packages (CSP), in accordance with an embodiment of the present application.

[0125] FIGS. 18A and 18B are schematically cross-sectional views showing a process of bonding a thermal compression bump to a thermal compression pad in accordance with an embodiment of the present application.

[0126] FIGS. 19A-19G are cross-sectional views showing a process for fabricating first and second types of operation modules, i.e., FPGA/HBM stacked 3D chip scale packages (CSP), in accordance with another embodiment of the present application.

[0127] FIGS. 20A and 20B are schematically cross-sectional views showing various types of interposers in accordance with multiple embodiments of the present application.

[0128] FIGS. 21A-21E are cross-sectional views showing a process for fabricating a first type of chip/module-on-interposer package in accordance with an embodiment of the present application.

[0129] FIG. 21F is a cross-sectional view showing a package-on-package (POP) assembly for a first type of chip/module-on-interposer package in accordance with an embodiment of the present application.

[0130] FIG. 21G is a schematically cross-sectional view showing a third type of chip/module-on-interposer package in accordance with an embodiment of the present application.

[0131] FIG. 21H is a schematically cross-sectional view showing a fifth type of chip/module-on-interposer package in accordance with an embodiment of the present application.

[0132] FIG. **21I** is a cross-sectional view showing a package-on-package (POP) assembly for a fifth type of chip/module-on-interposer package in accordance with an embodiment of the present application.

[0133] FIGS. **22A** and **22B** are schematically cross-sectional views showing a process of bonding a thermal compression bump to a thermal compression pad in accordance with an embodiment of the present application.

[0134] FIGS. **22C** and **22D** are schematically cross-sectional views showing a process of bonding a thermal compression bump to a thermal compression pad in accordance with an embodiment of the present application.

[0135] FIGS. **23A-23E** are cross-sectional views showing a process for fabricating a second type of chip/module-on-interposer package in accordance with various embodiments of the present application.

[0136] FIG. **23F** is a cross-sectional view showing a package-on-package (POP) assembly for a second type of chip/module-on-interposer package in accordance with an embodiment of the present application.

[0137] FIG. **23G** is a schematically cross-sectional view showing a fourth type of chip/module-on-interposer package in accordance with an embodiment of the present application.

[0138] FIG. **23H** is a schematically cross-sectional view showing a sixth type of chip/module-on-interposer package in accordance with an embodiment of the present application.

[0139] FIG. **23I** is a cross-sectional view showing a package-on-package (POP) assembly for a sixth type of chip/module-on-interposer package in accordance with an embodiment of the present application.

[0140] FIG. **24** is a schematically cross-sectional view showing a standard commodity logic drive in accordance with another embodiment of the present application.

[0141] FIG. **25** is a schematically cross-sectional view showing a standard commodity logic drive in accordance with another embodiment of the present application.

[0142] While certain embodiments are depicted in the drawings, one skilled in the art will appreciate that the embodiments depicted are illustrative and that variations of those shown, as well as other embodiments described herein, may be envisioned and practiced within the scope of the present application.

DETAILED DESCRIPTION OF THE DISCLOSURE

[0143] Illustrative embodiments are now described. Other embodiments may be used in addition or instead. Details that may be apparent or unnecessary may be omitted to save space or for a more effective presentation. Conversely, some embodiments may be practiced without all of the details that are disclosed.

Specification for Static Random-Access Memory (SRAM) Cells

(1) First type of Volatile Storage Unit

[0144] FIG. **1A** is a circuit diagram illustrating a first type of volatile storage unit in accordance with an embodiment of the present application. Referring to FIG. **1A**, a first type of volatile storage unit **398** may have a memory unit **446**, i.e., static random-access memory (SRAM) cell, composed of 4 data-latch transistors **447** and **448**, that is, two pairs of a P-type MOS transistor **447** and N-type MOS transistor **448** both having respective drain terminals coupled to each other, respective gate terminals coupled to each other and respective source terminals coupled to the voltage V_{cc} of power supply and to the voltage V_{ss} of ground reference. The gate terminals of the P-type and N-type MOS transistors **447** and **448** in the left pair are coupled to the drain terminals of the P-type and N-type MOS transistors **447** and **448** in the right pair, acting as a first output point of the memory unit **446** for a first data output Out1 of the memory unit **446**. The gate terminals of the P-type and N-type MOS transistors **447** and **448** in the right pair are coupled to the drain terminals of the P-type and N-type MOS transistors **447** and **448** in the left pair, acting as a second output point of the memory unit **446** for a second data output Out2 of the memory unit **446**.

[0145] Referring to FIG. 1A, the first type of volatile storage unit **398** may further include two switches or transfer (write) transistor **449**, such as N-type or P-type MOS transistors, a first one of which has a gate terminal coupled to a word line **451** and a channel having a terminal coupled to a bit line **452** and another terminal coupled to the drain terminals of the P-type and N-type MOS transistors **447** and **448** in the left pair and the gate terminals of the P-type and N-type MOS transistors **447** and **448** in the right pair, and a second one of which has a gate terminal coupled to the word line **451** and a channel having a terminal coupled to a bit-bar line **453** and another terminal coupled to the drain terminals of the P-type and N-type MOS transistors **447** and **448** in the right pair and the gate terminals of the P-type and N-type MOS transistors **447** and **448** in the left pair. A logic level on the bit line **452** is opposite a logic level on the bit-bar line **453**. The switch **449** may be considered as a programming transistor for writing a programming code or data into storage nodes of the 4 data-latch transistors **447** and **448**, i.e., at the drains and gates of the 4 data-latch transistors **447** and **448**. The switches **449** may be controlled via the word line **451** to turn on connection from the bit line **452** to the drain terminals of the P-type and N-type MOS transistors **447** and **448** in the left pair and the gate terminals of the P-type and N-type MOS transistors **447** and **448** in the right pair via the channel of the first one of the switches **449**, and thereby the logic level on the bit line **452** may be reloaded into the conductive line between the gate terminals of the P-type and N-type MOS transistors **447** and **448** in the right pair and the conductive line between the drain terminals of the P-type and N-type MOS transistors **447** and **448** in the left pair. Further, the bit-bar line **453** may be coupled to the drain terminals of the P-type and N-type MOS transistors **447** and **448** in the right pair and the gate terminals of the P-type and N-type MOS transistors **447** and **448** in the left pair via the channel of the second one of the switches **449**, and thereby the logic level on the bit line **453** may be reloaded into the conductive line between the gate terminals of the P-type and N-type MOS transistors **447** and **448** in the left pair and the conductive line between the drain terminals of the P-type and N-type MOS transistors **447** and **448** in the right pair. Thus, the logic level on the bit line **452** may be registered or latched in the conductive line between the gate terminals of the P-type and N-type MOS transistors **447** and **448** in the right pair and in the conductive line between the drain terminals of the P-type and N-type MOS transistors **447** and **448** in the left pair; a logic level on the bit line **453** may be registered or latched in the conductive line between the gate terminals of the P-type and N-type MOS transistors **447** and **448** in the left pair and in the conductive line between the drain terminals of the P-type and N-type MOS transistors **447** and **448** in the right pair.

(2) Second type of Volatile Storage Unit

[0146] FIG. 1B is a circuit diagram illustrating a second type of volatile storage unit in accordance with an embodiment of the present application. Referring to FIG. 1B, a second type of volatile storage unit **398** may have the memory unit **446**, i.e., static random-access memory (SRAM) cell, as illustrated in FIG. 1A. The second type of volatile storage unit **398** may further have a switch or transfer (write) transistor **449**, such as N-type or P-type MOS transistor, having a gate terminal coupled to a word line **451** and a channel having a terminal coupled to a bit line **452** and another terminal coupled to the drain terminals of the P-type and N-type MOS transistors **447** and **448** in the left pair and the gate terminals of the P-type and N-type MOS transistors **447** and **448** in the right pair. The switch **449** may be considered as a programming transistor for writing a programming code or data into storage nodes of the 4 data-latch transistors **447** and **448**, i.e., at the drains and gates of the 4 data-latch transistors **447** and **448**. The switch **449** may be controlled via the word line **451** to turn on connection from the bit line **452** to the drain terminals of the P-type and N-type MOS transistors **447** and **448** in the left pair and the gate terminals of the P-type and N-type MOS transistors **447** and **448** in the right pair via the channel of the switch **449**, and thereby a logic level on the bit line **452** may be reloaded into the conductive line between the gate terminals of the P-type and N-type MOS transistors **447** and **448** in the right pair and the conductive line between the drain terminals of the P-type and N-type MOS transistors **447** and **448** in the left pair. Thus, the

logic level on the bit line **452** may be registered or latched in the conductive line between the gate terminals of the P-type and N-type MOS transistors **447** and **448** in the right pair and in the conductive line between the drain terminals of the P-type and N-type MOS transistors **447** and **448** in the left pair; a logic level, opposite to the logic level on the bit line **452**, may be registered or latched in the conductive line between the gate terminals of the P-type and N-type MOS transistors **447** and **448** in the left pair and in the conductive line between the drain terminals of the P-type and N-type MOS transistors **447** and **448** in the right pair.

Specification for Pass/No-Pass Switches

(1) First Type of Pass/No-Pass Switch

[0147] FIG. 2A is a circuit diagram illustrating a first type of pass/no-pass switch in accordance with an embodiment of the present application. Referring to FIG. 2A, a first type of pass/no-pass switch **258** may include an N-type metal-oxide-semiconductor (MOS) transistor **222** and a P-type metal-oxide-semiconductor (MOS) transistor **223** coupling in parallel to each other. Each of the N-type and P-type metal-oxide-semiconductor (MOS) transistors **222** and **223** of the first type of pass/no-pass switch **258** may be configured to form a channel having an end at a node N21 of the pass/no-pass switch **258** and the other opposite end at a node N22 of the pass/no-pass switch **258**. Thereby, the first type of pass/no-pass switch **258** may be set to turn on or off connection between its nodes N21 and N22. The first type of pass/no-pass switch **258** may further include an inverter **533** configured to invert its data input at its input point coupling to a gate terminal of the N-type MOS transistor **222** and a node SC-3 as its data output at its output point coupling to a gate terminal of the P-type MOS transistor **223**.

(2) Second Type of Pass/No-Pass Switch

[0148] FIG. 2B is a circuit diagram illustrating a second type of pass/no-pass switch in accordance with an embodiment of the present application. Referring to FIG. 2B, a second type of pass/no-pass switch **258** may be a multi-stage tri-state buffer **292**, i.e., switch buffer, having a pair of a P-type MOS transistor **293** and N-type MOS transistor **294** in each stage, both having respective drain terminals coupling to each other and respective source terminals configured to couple to the voltage Vcc of power supply and to the voltage Vss of ground reference. In this case, the multi-stage tri-state buffer **292** is two-stage tri-state buffer, i.e., two-stage inverter buffer, having two pairs of the P-type MOS transistor **293** and N-type MOS transistor **294** in the two respective stages, i.e., first and second stages. The P-type MOS and N-type MOS transistors **293** and **294** in the pair in the first stage may have gate terminals at a node N21 of the pass/no-pass switch **258**. The drain terminals of the P-type MOS and N-type MOS transistors **293** and **294** in the pair in the first stage may couple to each other and to gate terminals of the P-type MOS and N-type MOS transistors **293** and **294** in the pair in the second stage, i.e., output stage. The P-type MOS and N-type MOS transistors **293** and **294** in the pair in the second stage, i.e., output stage, may have drain terminals couple to each other at a node N22 of the pass/no-pass switch **258**.

[0149] Referring to FIG. 2B, the second type of pass/no-pass switch **258** may further include a switching mechanism configured to enable or disable the multi-stage tri-state buffer **292**, wherein the switching mechanism may be composed of (1) a control P-type MOS transistor **295** having a source terminal coupling to the voltage Vcc of power supply and a drain terminal coupling to the source terminals of the P-type MOS transistors **293** in the first and second stages, (2) a control N-type MOS transistor **296** having a source terminal coupling to the voltage Vss of ground reference and a drain terminal coupling to the source terminals of the N-type MOS transistors **294** in the first and second stages and (3) an inverter **297** configured to invert a data input SC-4 of the pass/no-pass switch **258** at an input point of the inverter **297** coupling to a gate terminal of the control N-type MOS transistor **296** as a data output of the inverter **297** at an output point of the inverter **297** coupling to a gate terminal of the control P-type MOS transistor **295**.

[0150] For example, referring to FIG. 2B, when the pass/no-pass switch **258** has the data input SC-4 at a logic level of “1” to turn on the pass/no-pass switch **258**, the pass/no-pass switch **258** may

amplify its data input and pass its data input from its input point at the node N21 to its output point at its node N22 as its data output. When the pass/no-pass switch 258 has the data input SC-4 at a logic level of “0” to turn off the pass/no-pass switch 258, the pass/no-pass switch 258 may neither pass data from its node N21 to its node N22 nor pass data from its node N22 to its node N21.

(3) Third Type of Pass/No-Pass Switch

[0151] FIG. 2C is a circuit diagram illustrating a third type of pass/no-pass switch in accordance with an embodiment of the present application. For an element indicated by the same reference number shown in FIGS. 2B and 2C, the specification of the element as seen in FIG. 2C may be referred to that of the element as illustrated in FIG. 2B. Referring to FIG. 2C, a third type of pass/no-pass switch 258 may include a pair of multi-stage tri-state buffers 292, i.e., switch buffers, as illustrated in FIG. 2B. The P-type and N-type MOS transistors 293 and 294 in the first stage in the left one of the multi-stage tri-state buffers 292 in the pair may have their gate terminals at a node N21 of the pass/no-pass switch 258, which couples to the drain terminals of the P-type and N-type MOS transistors 293 and 294 in the second stage, i.e., output stage, in the right one of the multi-stage tri-state buffers 292 in the pair. The P-type and N-type MOS transistors 293 and 294 in the first stage in the right one of the multi-stage tri-state buffers 292 in the pair may have gate terminals at a node N22 of the pass/no-pass switch 258, which couples to the drain terminals of the P-type and N-type MOS transistors 293 and 294 in the second stage, i.e., output stage, in the left one of the multi-stage tri-state buffers 292 in the pair. For the left one of the multi-stage tri-state buffers 292 in the pair, its inverter 297 is configured to invert a data input SC-5 of the pass/no-pass switch 258 at an input point of its inverter 297 coupling to the gate terminal of its control N-type MOS transistor 296 as a data output of its inverter 297 at an output point of its inverter 297 coupling to the gate terminal of its control P-type MOS transistor 295. For the right one of the multi-stage tri-state buffers 292 in the pair, its inverter 297 is configured to invert a data input SC-6 of the pass/no-pass switch 258 at an input point of its inverter 297 coupling to the gate terminal of its control N-type MOS transistor 296 as a data output of its inverter 297 at an output point of its inverter 297 coupling to the gate terminal of its control P-type MOS transistor 295.

[0152] For example, referring to FIG. 2C, when the pass/no-pass switch 258 has the data input SC-5 at a logic level of “1” to turn on the left one of the multi-stage tri-state buffers 292 in the pair and the pass/no-pass switch 258 has the data input SC-6 at a logic level of “0” to turn off the right one of the multi-stage tri-state buffers 292 in the pair, the third type of pass/no-pass switch 258 may amplify its data input and pass its data input from its input point at its node N21 to its output point at its node N22 as its data output. When the pass/no-pass switch 258 has the data input SC-5 at a logic level of “0” to turn off the left one of the multi-stage tri-state buffers 292 in the pair and the pass/no-pass switch 258 has the data input SC-6 at a logic level of “1” to turn on the right one of the multi-stage tri-state buffers 292 in the pair, the third type of pass/no-pass switch 258 may amplify its data input and pass its data input from its input point at its node N22 to its output point at its node N21 as its data output. When the pass/no-pass switch 258 has the data input SC-5 at a logic level of “1” to turn on the left one of the multi-stage tri-state buffers 292 in the pair and the pass/no-pass switch 258 has the data input SC-6 at a logic level of “1” to turn on the right one of the multi-stage tri-state buffers 292 in the pair, the third type of pass/no-pass switch 258 may either amplify its data input and pass its data input from its input point at its node N21 to its output point at its node N22 as its data output or amplify its data input and pass its data input from its input point at its node N22 to its output point at its node N21 as its data output.

Specification for Cross-Point Switches Constructed from Pass/No-Pass Switches

(1) First Type of Cross-Point Switch

[0153] FIG. 3A is a circuit diagram illustrating a first type of cross-point switch composed of four pass/no-pass switches in accordance with an embodiment of the present application. Referring to FIG. 3A, four pass/no-pass switches **258**, each of which may be one of the first and third types of pass/no-pass switches **258** as illustrated in FIGS. 2A and 2C respectively, may compose a first type of cross-point switch **379**. The first type of cross-point switch **379** may have four terminals N23-N26 each configured to be switched to couple to another one of its four terminals N23-N26 via two of its four pass/no-pass switches **258**. The first type of cross-point switch **379** may have a central node configured to couple to its four terminals N23-N26 via its four respective pass/no-pass switches **258**. Each of the pass/no-pass switches **258** may have one of the nodes N21 and N22 coupling to one of the four terminals N23-N26 and the other one of the nodes N21 and N22 coupling to the central node of the first type of cross-point switch **379**. For example, the first type of cross-point switch **379** may be switched to pass data from its terminal N23 to its terminal N24 via top and left ones of its four pass/no-pass switches **258**, to its terminal N25 via top and bottom ones of its four pass/no-pass switches **258** and/or to its terminal N26 via top and right ones of its four pass/no-pass switches **258**.

(2) Second Type of Cross-Point Switch

[0154] FIG. 3B is a circuit diagram illustrating a second type of cross-point switch composed of six pass/no-pass switches in accordance with an embodiment of the present application. Referring to FIG. 3B, six pass/no-pass switches **258**, each of which may be one of the first and three types of pass/no-pass switches as illustrated in FIGS. 2A and 2C respectively, may compose a second type of cross-point switch **379**. The second type of cross-point switch **379** may have four terminals N23-N26 each configured to be switched to couple to another one of its four terminals N23-N26 via one of its six pass/no-pass switches **258**. Each of the pass/no-pass switches **258** may have one of the nodes N21 and N22 coupling to one of the four terminals N23-N26 and the other one of the nodes N21 and N22 coupling to another one of the four terminals N23-N26. For example, the second type of cross-point switch **379** may be switched to pass data from its terminal N23 to its terminal N24 via a first one of its six pass/no-pass switches **258** between its terminals N23 and N24, to its terminal N25 via a second one of its six pass/no-pass switches **258** between its terminals N23 and N25 and/or to its terminal N26 via a third one of its six pass/no-pass switches **258** between its terminals N23 and N26.

Specification for Multiplexer (MUXER)

[0155] FIG. 4 is a circuit diagram illustrating a multiplexer in accordance with an embodiment of the present application. Referring to FIG. 4, a multiplexer (MUXER) **211** may have a first set of two input points arranged in parallel for a first input data set, e.g., A0 and A1, and a second set of four input points arranged in parallel for a second input data set, e.g., D0, D1, D2 and D3. The multiplexer (MUXER) **211** may select a data input, e.g., D0, D1, D2 or D3, from its second input data set at a second set of its input points as a data output Dout at its output point based on its first input data set, e.g., A0 and A1, at a first set of its input points.

[0156] Referring to FIG. 4, the multiplexer **211** may include multiple stages of switch buffers, e.g., two stages of switch buffers **217** and **218**, coupling to each other or one another stage by stage. For more elaboration, the multiplexer **211** may include four switch buffers **217** in two pairs in the first stage, i.e., input stage, arranged in parallel, each having a first input point for a first data input associated with data A1 of the first input data set of the multiplexer **211** and a second input point for a second data input associated with data, e.g., D0, D1, D2 or D3, of the second input data set of the multiplexer **211**. Said each of the four switch buffers **217** in the first stage may be switched on or off to pass or not to pass its second data input from its second input point to its output point in accordance with its first data input at its first input point. The multiplexer **211** may include an inverter **207** having an input point for the data A1 of the first input data set of the multiplexer **211**, wherein the inverter **207** is configured to invert the data A1 of the first input data set of the

multiplexer **211** as a data output at an output point of the inverter **207**. One of the two switch buffers **217** in each pair in the first stage may be switched on, in accordance with the first data input at its first input point coupling to one of the input and output points of the inverter **207**, to pass the second data input from its second input point to its output point as a data output of said pair of switch buffers **217** in the first stage; the other one of the switch buffers **217** in said each pair in the first stage may be switched off, in accordance with the first data input at its first input point coupling to the other one of the input and output points of the inverter **207**, not to pass the second data input from its second input point to its output point. The output points of the two switch buffers **217** in said each pair in the first stage may couple to each other. For example, a top one of the two switch buffers **217** in a top pair in the first stage may have its first input point coupling to the output point of the inverter **207** and its second input point for its second data input associated with data **D0** of the second input data set of the multiplexer **211**; a bottom one of the two switch buffers **217** in the top pair in the first stage may have its first input point coupling to the input point of the inverter **207** and its second input point for its second data input associated with data **D1** of the second input data set of the multiplexer **211**. The top one of the two switch buffers **217** in the top pair in the first stage may be switched on in accordance with its first data input at its first input point to pass its second data input from its second input point to its output point as a data output of the top pair of switch buffers **217** in the first stage; the bottom one of the two switch buffers **217** in the top pair in the first stage may be switched off in accordance with its first data input at its first input point not to pass its second data input from its second input point to its output point. Thereby, each of the two pairs of switch buffers **217** in the first stage may be switched in accordance with its two first data inputs at its two first input points coupling to the input and output points of the inverter **207** respectively to pass one of its two second data inputs from one of its two second input points to its output point coupling to a second input point of one of the switch buffers **218** in the second stage, i.e., output stage, as a data output of said each of the two pairs of switch buffers **217** in the first stage.

[0157] Referring to FIG. 4, the multiplexer **211** may include a pair of two switch buffers **218** in the second stage, i.e., output stage, arranged in parallel, each having a first input point for a first data input associated with data **A0** of the first input data set of the multiplexer **211** and a second input point for a second data input associated with the data output of one of the two pairs of switch buffers **217** in the first stage. Said each of the two switch buffers **218** in the pair in the second stage, i.e., output stage, may be switched on or off to pass or not to pass its second data input from its second input point to its output point in accordance with its first data input at its first input point. The multiplexer **211** may include an inverter **208** having an input point for the data **A0** of the first input data set of the multiplexer **211**, wherein the inverter **208** is configured to invert the data **A0** of the first input data set of the multiplexer **211** as its data output at an output point of the inverter **208**. One of the two switch buffers **218** in the pair in the second stage, i.e., output stage, may be switched on, in accordance with the first data input at its first input point coupling to one of the input and output points of the inverter **208**, to pass the second data input from its second input point to its output point as a data output of said pair of switch buffers **218** in the second stage; the other one of the two switch buffers **218** in the pair in the second stage, i.e., output stage, may be switched off, in accordance with the first data input at its first input point coupling to the other one of the input and output points of the inverter **208**, not to pass the second data input from its second input point to its output point. The output points of the two switch buffers **218** in the pair in the second stage, i.e., output stage, may couple to each other. For example, a top one of the two switch buffers **218** in the pair in the second stage, i.e., output stage, may have its first input point coupling to the output point of the inverter **208** and its second input point for its second data input associated with the data output of the top one of the two pairs of switch buffers **217** in the first stage; a bottom one of the two switch buffers **218** in the pair in the second stage, i.e., output stage, may have its first input point coupling to the input point of the inverter **208** and its second input point for its second

data input associated with the data output of the bottom one of the two pairs of switch buffers **217** in the first stage. The top one of the two switch buffers **218** in the pair in the second stage, i.e., output stage, may be switched on in accordance with its first data input at its first input point to pass its second data input from its second input point to its output point as a data output of the pair of switch buffers **218** in the second stage; the bottom one of the two switch buffers **218** in the pair in the second stage, i.e., output stage, may be switched off in accordance with its first data input at its first input point not to pass its second data input from its second input point to its output point. Thereby, the pair of switch buffers **218** in the second stage, i.e., output stage, may be switched in accordance with its two first data inputs at its two first input points coupling to the input and output points of the inverter **207** respectively to pass one of its two second data inputs from one of its two second input points to its output point as a data output of the pair of switch buffers **218** in the second stage, i.e., output stage.

[0158] Referring to FIG. **4**, the second type of pass/no-pass switch or switch buffer **292** as seen in FIG. **2B** may be provided to couple to the output point of the pair of switch buffers **218** of the multiplexer **211**. The pass/no-pass switch or switch buffer **292** may have the input point at its node **N21** coupling to the output point of the pair of switch buffers **218** in the last stage, e.g., in the second stage or output stage in this case. For an element indicated by the same reference number shown in FIGS. **2B** and **4**, the specification of the element as seen in FIG. **4** may be referred to that of the element as illustrated in FIG. **2B**. Accordingly, referring to FIG. **4**, the multiplexer (MUXER) **211** may select a data input from its second input data set, e.g., **D0**, **D1**, **D2** and **D3**, at its second set of four input points as its data output **Dout** at its output point based on its first input data set, e.g., **A0** and **A1**, at its first set of two input points. The second type of pass/no-pass switch **292** may amplify its data input associated with the data output **Dout** of the pair of switch buffers **218** of the multiplexer **211** as its data output at its output point at its node **N22**.

Specification for Large I/O Circuits

[0159] FIG. **5A** is a circuit diagram of a large I/O circuit in accordance with an embodiment of the present application. Referring to FIG. **5A**, a semiconductor chip may include multiple I/O pads **272** each coupling to its large ESD protection circuit or device **273**, its large driver **274** and its large receiver **275**. The large driver **274**, large receiver **275** and large ESD protection circuit or device **273** may compose a large I/O circuit **341**. The large ESD protection circuit or device **273** may include a diode **282** having a cathode coupling to the voltage **Vcc** of power supply and an anode coupling to a node **281** and a diode **283** having a cathode coupling to the node **281** and an anode coupling to the voltage **Vss** of ground reference. The node **281** couples to one of the I/O pads **272**.

[0160] Referring to FIG. **5A**, the large driver **274** may have a first input point for a first data input **L_Enable** for enabling the large driver **274** and a second input point for a second data input **L_Data_out**, and may be configured to amplify or drive the second data input **L_Data_out** as its data output at its output point at the node **281** to be transmitted to circuits outside the semiconductor chip through said one of the I/O pads **272**. The large driver **274** may include a P-type MOS transistor **285** and N-type MOS transistor **286** both having respective drain terminals coupling to each other as its output point at the node **281** and respective source terminals coupling to the voltage **Vcc** of power supply and to the voltage **Vss** of ground reference. The large driver **274** may have a NAND gate **287** having a data output at an output point of the NAND gate **287** coupling to a gate terminal of the P-type MOS transistor **285** and a NOR gate **288** having a data output at an output point of the NOR gate **288** coupling to a gate terminal of the N-type MOS transistor **286**. The NAND gate **287** may have a first data input at its first input point associated with a data output of its inverter **289** at an output point of an inverter **289** of the large driver **274** and a second data input at its second input point associated with the second data input **L_Data_out** of the large driver **274** to perform a NAND operation on its first and second data inputs as its data output at its output point coupling to the gate terminal of its P-type MOS transistor **285**. The NOR gate **288** may have a first data input at its first input point associated with the second data input

L_Data_out of the large driver **274** and a second data input at its second input point associated with the first data input L_Enable of the large driver **274** to perform a NOR operation on its first and second data inputs as its data output at its output point coupling to the gate terminal of the N-type MOS transistor **286**. The inverter **289** may be configured to invert its data input at its input point associated with the first data input L_Enable of the large driver **274** as its data output at its output point coupling to the first input point of the NAND gate **287**.

[0161] Referring to FIG. 5A, when the large driver **274** has the first data input L_Enable at a logic level of “1”, the data output of the NAND gate **287** is always at a logic level of “1” to turn off the P-type MOS transistor **285** and the data output of the NOR gate **288** is always at a logic level of “0” to turn off the N-type MOS transistor **286**. Thereby, the large driver **274** may be disabled by its first data input L_Enable and the large driver **274** may not pass the second data input L_Data_out from its second input point to its output point at the node **281**.

[0162] Referring to FIG. 5A, the large driver **274** may be enabled when the large driver **274** has the first data input L_Enable at a logic level of “0”. Meanwhile, if the large driver **274** has the second data input L_Data_out at a logic level of “0”, the data outputs of the NAND and NOR gates **287** and **288** are at a logic level of “1” to turn off the P-type MOS transistor **285** and on the N-type MOS transistor **286**, and thereby the data output of the large driver **274** at the node **281** is at a logic level of “0” to be passed to said one of the I/O pads **272**. If the large driver **274** has the second data input L_Data_out is at a logic level of “1”, the data outputs of the NAND and NOR gates **287** and **288** are at a logic level of “0” to turn on the P-type MOS transistor **285** and off the N-type MOS transistor **286**, and thereby the data output of the large driver **274** at the node **281** is at a logic level of “1” to be passed to said one of the I/O pads **272**. Accordingly, the large driver **274** may be enabled by its first data input L_Enable to amplify or drive its second data input L_Data_out at its second input point as its data output at its output point at the node **281** to be transmitted to circuits outside the semiconductor chip through said one of the I/O pads **272**.

[0163] Referring to FIG. 5A, the large receiver **275** may have a first data input L_Inhibit at its first input point and a second data input at its second input point coupling to said one of the I/O pads **272** to be amplified or driven by the large receiver **275** as its data output L_Data_in. The large receiver **275** may be inhibited by its first data input L_Inhibit from generating its data output L_Data_in associated with its second data input. The large receiver **275** may include a NAND gate **290** and an inverter **291** having a data input at an input point of the inverter **291** associated with a data output of the NAND gate **290**. The NAND gate **290** has a first input point for its first data input associated with the second data input of the large receiver **275** and a second input point for its second data input associated with the first data input L_Inhibit of the large receiver **275** to perform a NAND operation on its first and second data inputs as its data output at its output point coupling to the input point of its inverter **291**. The inverter **291** may be configured to invert its data input associated with the data output of the NAND gate **290** as its data output at its output point acting as the data output L_Data_in of the large receiver **275** at an output point of the large receiver **275**.

[0164] Referring to FIG. 5A, when the large receiver **275** has the first data input L_Inhibit at a logic level of “0”, the data output of the NAND gate **290** is always at a logic level of “1” and the data output L_Data_in of the large receiver **275** is always at a logic level of “0”. Thereby, the large receiver **275** is inhibited from generating its data output L_Data_in associated with its second data input at the node **281**.

[0165] Referring to FIG. 5A, the large receiver **275** may be activated when the large receiver **275** has the first data input L_Inhibit at a logic level of “1”. Meanwhile, if the large receiver **275** has the second data input at a logic level of “1” from circuits outside the semiconductor chip through said one of the I/O pads **272**, the NAND gate **290** has its data output at a logic level of “0”, and thereby the large receiver **275** may have its data output L_Data_in at a logic level of “1”. If the large receiver **275** has the second data input at a logic level of “0” from circuits outside the semiconductor chip through said one of the I/O pads **272**, the NAND gate **290** has its data output at

a logic level of “1”, and thereby the large receiver **275** may have its data output L_Data_in at a logic level of “0”. Accordingly, the large receiver **275** may be activated by its first data input L_Inhibit signal to amplify or drive its second data input from circuits outside the semiconductor chip through said one of the I/O pads **272** as its data output L_Data_in.

[0166] Referring to FIG. 5A, the large I/O circuit **274** may have output capacitance or driving capability or loading, for example, between 2 pF and 100 pF, between 2 pF and 50 pF, between 2 pF and 30 pF, between 2 pF and 20 pF, between 2 pF and 15 pF, between 2 pF and 10 pF, or between 2 pF and 5 pF, or greater than 2 pF, 3 pF, 5 pF, 10 pF, 15 pF or 20 pF, provided by its large driver **274**. Further, the large I/O circuit **274** may have input capacitance, for example, between 2 pF and 100 pF, between 2 pF and 50 pF, between 2 pF and 30 pF, between 2 pF and 20 pF, between 2 pF and 15 pF, between 2 pF and 10 pF, or between 2 pF and 5 pF, or greater than 2 pF, 3 pF, 5 pF, 10 pF, 15 pF or 20 pF, provided by its large receiver **275** and/or its large ESD protection circuit **273**. The size of the large ESD protection circuit or device **273** may be between 0.5 pF and 20 pF, between 0.5 pF and 15 pF, between 0.5 pF and 10 pF, between 0.5 pF and 5 pF or between 0.5 pF and 2 pF, or larger than 0.5 pF, 1 pF, 2 pF, 3 pF, 5 pF or 10 pF.

Specification for Small I/O Circuits

[0167] FIG. 5B is a circuit diagram of a small I/O circuit in accordance with an embodiment of the present application. Referring to FIG. 5B, a semiconductor chip may include multiple I/O pads **372** each coupling to its small ESD protection circuit or device **373**, its small driver **374** and its small receiver **375**. The small driver **374**, small receiver **375** and small ESD protection circuit or device **373** may compose a small I/O circuit **203**. The small ESD protection circuit or device **373** may include a diode **382** having a cathode coupling to the voltage Vcc of power supply and an anode coupling to a node **381** and a diode **383** having a cathode coupling to the node **381** and an anode coupling to the voltage Vss of ground reference. The node **381** couples to one of the I/O pads **372**.

[0168] Referring to FIG. 5B, the small driver **374** may have a first input point for a first data input S_Enable for enabling the small driver **374** and a second input point for a second data input S_Data_out, and may be configured to amplify or drive the second data input S_Data_out as its data output at its output point at the node **381** to be transmitted to circuits outside the semiconductor chip through said one of the I/O pads **372**. The small driver **374** may include a P-type MOS transistor **385** and N-type MOS transistor **386** both having respective drain terminals coupling to each other as its output point at the node **381** and respective source terminals coupling to the voltage Vcc of power supply and to the voltage Vss of ground reference. The small driver **374** may have a NAND gate **387** having a data output at an output point of the NAND gate **387** coupling to a gate terminal of the P-type MOS transistor **385** and a NOR gate **388** having a data output at an output point of the NOR gate **388** coupling to a gate terminal of the N-type MOS transistor **386**. The NAND gate **387** may have a first data input at its first input point associated with a data output of its inverter **389** at an output point of an inverter **389** of the small driver **374** and a second data input at its second input point associated with the second data input S_Data_out of the small driver **374** to perform a NAND operation on its first and second data inputs as its data output at its output point coupling to the gate terminal of its P-type MOS transistor **385**. The NOR gate **388** may have a first data input at its first input point associated with the second data input S_Data_out of the small driver **374** and a second data input at its second input point associated with the first data input S_Enable of the small driver **374** to perform a NOR operation on its first and second data inputs as its data output at its output point coupling to the gate terminal of the N-type MOS transistor **386**. The inverter **389** may be configured to invert its data input at its input point associated with the first data input S_Enable of the small driver **374** as its data output at its output point coupling to the first input point of the NAND gate **387**.

[0169] Referring to FIG. 5B, when the small driver **374** has the first data input S_Enable at a logic level of “1”, the data output of the NAND gate **387** is always at a logic level of “1” to turn off the P-type MOS transistor **385** and the data output of the NOR gate **388** is always at a logic level of

“0” to turn off the N-type MOS transistor **386**. Thereby, the small driver **374** may be disabled by its first data input S_Enable and the small driver **374** may not pass the second data input S_Data_out from its second input point to its output point at the node **381**.

[0170] Referring to FIG. 5B, the small driver **374** may be enabled when the small driver **374** has the first data input S_Enable at a logic level of “0”. Meanwhile, if the small driver **374** has the second data input S_Data_out at a logic level of “0”, the data outputs of the NAND and NOR gates **387** and **388** are at a logic level of “1” to turn off the P-type MOS transistor **385** and on the N-type MOS transistor **386**, and thereby the data output of the small driver **374** at the node **381** is at a logic level of “0” to be passed to said one of the I/O pads **372**. If the small driver **374** has the second data input S_Data_out at a logic level of “1”, the data outputs of the NAND and NOR gates **387** and **388** are at a logic level of “0” to turn on the P-type MOS transistor **385** and off the N-type MOS transistor **386**, and thereby the data output of the small driver **374** at the node **381** is at a logic level of “1” to be passed to said one of the I/O pads **372**. Accordingly, the small driver **374** may be enabled by its first data input S_Enable to amplify or drive its second data input S_Data_out at its second input point as its data output at its output point at the node **381** to be transmitted to circuits outside the semiconductor chip through said one of the I/O pads **372**.

[0171] Referring to FIG. 5B, the small receiver **375** may have a first data input S_Inhibit at its first input point and a second data input at its second input point coupling to said one of the I/O pads **372** to be amplified or driven by the small receiver **375** as its data output S_Data_in. The small receiver **375** may be inhibited by its first data input S_Inhibit from generating its data output S_Data_in associated with its second data input. The small receiver **375** may include a NAND gate **390** and an inverter **391** having a data input at an input point of the inverter **391** associated with a data output of the NAND gate **390**. The NAND gate **390** has a first input point for its first data input associated with the second data input of the large receiver **275** and a second input point for its second data input associated with the first data input S_Inhibit of the small receiver **375** to perform a NAND operation on its first and second data inputs as its data output at its output point coupling to the input point of its inverter **391**. The inverter **391** may be configured to invert its data input associated with the data output of the NAND gate **390** as its data output at its output point acting as the data output S_Data_in of the small receiver **375** at an output point of the small receiver **375**.

[0172] Referring to FIG. 5B, when the small receiver **375** has the first data input S_Inhibit at a logic level of “0”, the data output of the NAND gate **390** is always at a logic level of “1” and the data output S_Data_in of the small receiver **375** is always at a logic level of “0”. Thereby, the small receiver **375** is inhibited from generating its data output S_Data_in associated with its second data input at the node **381**.

[0173] Referring to FIG. 5B, the small receiver **375** may be activated when the small receiver **375** has the first data input S_Inhibit at a logic level of “1”. Meanwhile, if the small receiver **375** has the second data input at a logic level of “1” from circuits outside the semiconductor chip through said one of the I/O pads **372**, the NAND gate **390** has its data output at a logic level of “0”, and thereby the small receiver **375** may have its data output S_Data_in at a logic level of “1”. If the small receiver **375** has the second data input at a logic level of “0” from circuits outside the semiconductor chip through said one of the I/O pads **372**, the NAND gate **390** has its data output at a logic level of “1”, and thereby the small receiver **375** may have its data output S_Data_in at a logic level of “0”. Accordingly, the small receiver **375** may be activated by its first data input S_Inhibit to amplify or drive its second data input from circuits outside the semiconductor chip through said one of the I/O pads **372** as its data output S_Data_in.

[0174] Referring to FIG. 5B, the small I/O circuit **203** may have output capacitance or driving capability or loading, for example, between 0.05 pF and 2 pF or between 0.1 pF and 1 pF, or smaller than 2 pF or 1 pF, provided by its small driver **374**. Further, the small I/O circuit **203** may have input capacitance, for example, between 0.05 pF and 2 pF or between 0.1 pF and 1 pF, or smaller than 2 pF or 1 pF, provided by its small receiver **375** and/or its small ESD protection circuit

Specification for Programmable Logic Blocks

[0175] FIG. 6A is a schematic view showing a block diagram of a programmable logic cell in accordance with an embodiment of the present application. Referring to FIG. 6A, a programmable logic block (LB) or element may include one or a plurality of programmable logic cells (LC) **1014** each configured to perform logic operation on its input data set at its input points. Each of the programmable logic cells (LC) **1014** may include multiple memory cells, i.e., configuration-programming-memory (CPM) cells, each configured to save or store one of resulting values or data of a look-up table (LUT) **210** and a multiplexer (MUXER) **211** having a first set of two input points arranged in parallel for a first input data set, e.g., A0 and A1 as illustrated in FIG. 4, and a second set of four input points arranged in parallel for a second input data set, e.g., D0, D1, D2 and D3 as illustrated in FIG. 4, each associated with one of the resulting values or data or programming codes for the look-up table (LUT) **210**. The multiplexer (MUXER) **211** is configured to select, in accordance with its first input data set associated with the input data set of said each of the programmable logic cells (LC) **1014**, a data input, e.g., D0, D1, D2 or D3 as illustrated in FIG. 4, from its second input data set as a data output Dout at its output point acting as a data output of said each of the programmable logic cells (LC) **1014** at an output point of said each of the programmable logic cells (LC) **1014**.

[0176] Referring to FIG. 6A, each of the memory cells **490**, i.e., configuration-programming-memory (CPM) cells, may be referred to the memory cell **446** as illustrated in FIG. 1A or 1B. The multiplexer (MUXER) **211** may have its second input data set, e.g., D0, D1, D2 and D3 as illustrated in FIG. 4, each associated with a data output, i.e., configuration-programming-memory (CPM) data, of one of the memory cells **490**, e.g., one of the first and second data outputs Out1 and Out2 of the memory cell **446** as illustrated in FIG. 1A or 1B via non-programmable interconnects **364** configured not to be programmable for interconnection. Alternatively, each of the programmable logic cells (LC) **2014** may further include the second type of pass/no-pass switch or switch buffer **292** as seen in FIGS. 2B and 4 having the input point coupling to the output point of its multiplexer (MUXER) **211** to amplify the data output Dout of its multiplexer **211** as a data output of said each of the programmable logic cells (LC) **1014** at an output point of said each of the programmable logic cells (LC) **1014**, wherein its second type of pass/no-pass switch or switch buffer **292** may have the data input SC-4 associated with a data output, i.e., configuration-programming-memory (CPM) data, of another of the memory cells **490**, e.g., one of the first and second data outputs Out1 and Out2 of the memory cell **446** as illustrated in FIG. 1A or 1B.

[0177] Referring to FIG. 6A, each of the programmable logic cells (LC) **2014** may have the memory cells **490**, i.e., configuration-programming-memory (CPM) cells, configured to be programed to store or save the resulting values or programming codes for the look-up table (LUT) **210** to perform the logic operation, such as AND operation, NAND operation, OR operation, NOR operation, EXOR operation or other Boolean operation, or an operation combining two or more of the above operations. For this case, each of the programmable logic cells (LC) **2014** may perform the logic operation on its input data set, e.g., A0 and A1, at its input points as a data output Dout at its output point. For more elaboration, each of the programmable logic cells (LC) **1014** may include the number $2^{\text{sup.}n}$ of memory cells **490**, i.e., configuration-programming-memory (CPM) cells, each configured to save or store one of resulting values of the look-up table (LUT) **210** and a multiplexer (MUXER) **211** having a first set of the number n of input points arranged in parallel for a first input data set, e.g., A0-A1, and a second set of the number $2^{\text{sup.}n}$ of input points arranged in parallel for a second input data set, e.g., D0-D3, each associated with one of the resulting values or programming codes for the look-up table (LUT) **210**, wherein the number n may range from 2 to 8, such as 2 for this case. The multiplexer (MUXER) **211** is configured to select, in accordance with its first input data set associated with the input data set of said each of the programmable logic cells (LC) **1014**, a data input, e.g., one of D0-D3, from its second input data set as a data output

Dout at its output point acting as a data output of said each of the programmable logic cells (LC) **1014** at an output point of said each of the programmable logic cells (LC) **1014**.

[0178] Alternatively, a plurality of programmable logic cells (LC) **2014** as illustrated in FIG. **6A** are configured to be programmed to be integrated into a programmable logic block (LB) or element **201** as seen in FIG. **6B** acting as a computation operator to perform computation operation, such as addition, subtraction, multiplication or division operation. The computation operator may be an adder, a multiplier, a multiplexer, a shift register, floating-point circuits and/or division circuits. FIG. **6B** is a block diagram illustrating a computation operator in accordance with an embodiment of the present application. For example, the computation operator as seen in FIG. **6B** may be configured to multiply two two-binary-digit data inputs, i.e., [A1, A0] and [A3, A2], into a four-binary-digit output data set, i.e., [C3, C2, C1, C0], as seen in FIG. **1C**. FIG. **6C** shows a truth table for a logic operator as seen in FIG. **6B**.

[0179] Referring to FIGS. **6B** and **6C**, four programmable logic cells (LC) **2014**, each of which may be referred to one as illustrated in FIG. **6A**, may be programmed to be integrated into the computation operator. Each of the four programmable logic cells (LC) **2014** may have its input data set at its four input points associated with an input data set [A1, A0, A3, A2] of the computation operator respectively. Each of the programmable logic cells (LC) **2014** of the computation operator may generate a data output, e.g., C0, C1, C2 or C3, of the four-binary-digit data output of the computation operator based on its input data set [A1, A0, A3, A2]. In the multiplication of the two-binary-digit number, i.e., [A1, A0], by the two-binary-digit number, i.e., [A3, A2], the programmable logic block (LB) **201** may generate its four-binary-digit output data set, i.e., [C3, C2, C1, C0], based on its input data set [A1, A0, A3, A2]. Each of the four programmable logic cells (LC) **2014** may have the memory cells **490**, each of which may be referred to the memory cell **446** as illustrated in FIG. **1A** or **1B**, to be programmed to save or store resulting values or programming codes of its look-up table **210**, e.g., Table-0, Table-1, Table-2 or Table-3.

[0180] For example, referring to FIGS. **6B** and **6C**, a first one of the four programmable logic cells (LC) **2014** may have its memory cells **490**, i.e., configuration-programming-memory (CPM) cells, configured to save or store the resulting values or programming codes of its look-up table (LUT) **210** of Table-0 and its multiplexer (MUXER) **211** configured to select, in accordance with the first input data set of its multiplexer (MUXER) **211** associated with the input data set [A1, A0, A3, A2] of the computation operator respectively, a data input from the second input data set D0-D15 of its multiplexer (MUXER) **211**, each associated with the data output of one of its memory cells **490**, e.g., one of the first and second data outputs Out1 and Out2 of the memory cell **446** as illustrated in FIG. **1A** or **1B**, associated with one of the resulting values or programming codes of its look-up table (LUT) **210** of Table-0, as its data output C0 acting as a binary-digit data output of the four-binary-digit output data set, i.e., [C3, C2, C1, C0], of the programmable logic block (LB) **201**. A second one of the four programmable logic cells (LC) **2014** may have its memory cells **490**, i.e., configuration-programming-memory (CPM) cells, configured to save or store the resulting values or programming codes of its look-up table (LUT) **210** of Table-1 and its multiplexer (MUXER) **211** configured to select, in accordance with the first input data set of its multiplexer (MUXER) **211** associated with the input data set [A1, A0, A3, A2] of the computation operator respectively, a data input from the second input data set D0-D15 of its multiplexer (MUXER) **211**, each associated with the data output of one of its memory cells **490**, e.g., one of the first and second data outputs Out1 and Out2 of the memory cell **446** as illustrated in FIG. **1A** or **1B**, associated with one of the resulting values or programming codes of its look-up table (LUT) **210** of Table-1, as its data output C1 acting as a binary-digit data output of the four-binary-digit output data set, i.e., [C3, C2, C1, C0], of the programmable logic block (LB) **201**. A third one of the four programmable logic cells (LC) **2014** may have its memory cells **490**, i.e., configuration-programming-memory (CPM) cells, configured to save or store the resulting values or programming codes of its look-up table (LUT) **210** of Table-2 and its multiplexer (MUXER) **211** configured to select, in accordance with the first

input data set of its multiplexer (MUXER) **211** associated with the input data set [A1, A0, A3, A2] of the computation operator respectively, a data input from the second input data set D0-D15 of its multiplexer (MUXER) **211**, each associated with the data output of one of its memory cells **490**, e.g., one of the first and second data outputs Out1 and Out2 of the memory cell **446** as illustrated in FIG. 1A or 1B, associated with one of the resulting values or programming codes of its look-up table (LUT) **210** of Table-2, as its data output C2 acting as a binary-digit data output of the four-binary-digit output data set, i.e., [C3, C2, C1, C0], of the programmable logic block (LB) **201**. A fourth one of the four programmable logic cells (LC) **2014** may have its memory cells **490**, i.e., configuration-programming-memory (CPM) cells, configured to save or store the resulting values or programming codes of its look-up table (LUT) **210** of Table-3 and its multiplexer (MUXER) **211** configured to select, in accordance with the first input data set of its multiplexer (MUXER) **211** associated with the input data set [A1, A0, A3, A2] of the computation operator respectively, a data input from the second input data set D0-D15 of its multiplexer (MUXER) **211**, each associated with the data output of one of its memory cells **490**, e.g., one of the first and second data outputs Out1 and Out2 of the memory cell **446** as illustrated in FIG. 1A or 1B, associated with one of the resulting values or programming codes of its look-up table (LUT) **210** of Table-3, as its data output C3 acting as a binary-digit data output of the four-binary-digit output data set, i.e., [C3, C2, C1, C0], of the programmable logic block (LB) **201**.

[0181] Thereby, referring to FIGS. 6B and 6C, the programmable logic block (LB) **201** acting as the computation operator may be composed of the four programmable logic cells (LC) **2014** to generate its four-binary-digit output data set, i.e., [C3, C2, C1, C0], based on its input data set [A1, A0, A3, A2].

[0182] Referring to FIGS. 6B and 6C, in a particular case for multiplication of 3 by 3, each of the four programmable logic cells (LC) **2014** may have its multiplexer (MUXER) **211** configured to select, in accordance with the first input data set of its multiplexer (MUXER) **211** associated with the input data set, i.e., [A1, A0, A3, A2]=[1, 1, 1, 1], of the computation operator respectively, a data input from the second input data set D0-D15 of its multiplexer (MUXER) **211**, each associated with one of the resulting values or programming codes of its look-up table (LUT) **210**, i.e., one of Table-0, Table-1, Table-2 and Table-3, as its data output, i.e., one of C0, C1, C2 and C3, acting as a binary-digit data output of the four-binary-digit output data set, i.e., [C3, C2, C1, C0]=[1, 0, 0, 1], of the programmable logic block (LB) **201**. The first one of the four programmable logic cells (LC) **2014** may generate its data output C0 at a logic level of "1" based on its input data set, i.e., [A1, A0, A3, A2]=[1, 1, 1, 1]; the second one of the four programmable logic cells (LC) **2014** may generate its data output C1 at a logic level of "0" based on its input data set, i.e., [A1, A0, A3, A2]=[1, 1, 1, 1]; the third one of the four programmable logic cells (LC) **2014** may generate its data output C2 at a logic level of "0" based on its input data set, i.e., [A1, A0, A3, A2]=[1, 1, 1, 1]; the fourth one of the four programmable logic cells (LC) **2014** may generate its data output C3 at a logic level of "1" based on its input data set, i.e., [A1, A0, A3, A2]=[1, 1, 1, 1].

[0183] Alternatively, FIG. 6D is a block diagram illustrating a programmable logic block for a standard commodity FPGA IC chip in accordance with an embodiment of the present application. Referring to FIG. 6D, the programmable logic block (LB) **201** may include (1) one or more cells (A) **2011** for fixed-wired adders, having the number ranging from 1 to 16 for example, (2) one or more cells (C/R) **2013** for caches and registers, each having capacity ranging from 256 to 2048 bits for example, and (3) the programmable logic cells (LC) **2014** as illustrated in FIGS. 6A-6C having the number ranging from 64 to 2048 for example. The programmable logic block (LB) **201** may further include multiple intra-block interconnects **2015** each extending over spaces between neighboring two of its cells **2011**, **2013** and **2014** arranged in an array therein. For the programmable logic block (LB) **201**, its intra-block interconnects **2015** may be divided into programmable interconnects **361** configured to be programmed for interconnection by its memory cells **362** as seen in FIGS. 3A, 3B and 7 and non-programmable interconnects **364** as seen in FIGS.

6A and 7 configured not to be programmable for interconnection.

[0184] Referring to FIG. 6D, each of the programmable logic cells (LC) **2014** may have the memory cells **490**, i.e., configuration-programming-memory (CPM) cells, having the number ranging from 4 to 256 for example, each configured to save or store one of the resulting values or programming codes of its look-up table **210** and the multiplexer (MUXER) **211** configured to select, in accordance with the first input data set of its multiplexer (MUXER) **211** having a bit-width ranging from 2 to 8 for example at its input points coupling to at least one of the programmable interconnects **361** and non-programmable interconnects **364** of the intra-block interconnects **2015**, a data input from the second input data set of its multiplexer (MUXER) **211** having a bit-width ranging from 4 to 256 for example as its data output at its output point coupling to at least one of the programmable interconnects **361** and non-programmable interconnects **364** of the intra-block interconnects **2015**.

Specification for Programmable Interconnect

[0185] FIG. 7 is a circuit diagram illustrating programmable interconnects programmed by a third type of cross-point switch in accordance with an embodiment of the present application. Besides the first and second types of cross-point switches **379** as illustrated in FIGS. 3A and 3B, a third type of cross-point switch **379** may presented as seen in FIG. 7 to include the four multiplexers (MUXERs) **211** as seen in FIG. 4. Each of the four multiplexers (MUXERs) **211** may be configured to select, in accordance with its first input data set, e.g., **A0** and **A1**, at its first set of input points, a data input from its second input data set, e.g., **D0-D2**, at its second set of input points as its data output. Each of the second set of three input points of one of the four multiplexers (MUXERs) **211** may couple to one of the second set of three input points of one of another two of the four multiplexers (MUXERs) **211** and to the output point of the other of the four multiplexers (MUXERs) **211**. Thereby, each of the four multiplexers (MUXERs) **211** may select, in accordance with its first input data set, e.g., **A0** and **A1**, a data input from its second input data set, e.g., **D0-D2**, at its second set of three input points coupling to three respective programmable interconnects **361** extending in three different directions and to the output points of the other respective three of the four multiplexers (MUXERs) **211** as its data output, e.g., **Dout**, at its output point at one of four nodes **N23-N26** of the third type of cross-point switch **379** coupling to the other programmable interconnect **361** extending in a direction other than the three different directions. For example, the top one of the four multiplexers (MUXERs) **211** may select, in accordance with its first input data set, e.g., **A0** and **A1**, a data input from its second input data set, e.g., **D0-D2**, at its second set of three input points at the nodes **N24**, **N25** and **N26** of the third type of cross-point switch **379** respectively, i.e., at the output points of the left, bottom and right ones of the four multiplexers **211** respectively, as its data output, e.g., **Dout**, at its output point at the node **N23** of the third type of cross-point switch **379**.

[0186] Referring to FIG. 7, the four programmable interconnects **361** may couple to the respective four nodes **N23-N26** of the third type of cross-point switch **379**. Thereby, data from one of the four programmable interconnects **361** may be switched by the third type of cross-point switch **379** to be passed to another one, two or three of the four programmable interconnects **361**. For the third type of cross-point switch **379**, each of its four multiplexers (MUXERs) **211**, which may be referred to that as seen in FIG. 4, may have the data inputs, e.g., **A0** and **A1**, of the first input data set each associated with a data output of one of its memory cells **362**, i.e., configuration-programming-memory (CPM) cell, e.g., one of the first and second data outputs **Out1** and **Out2** of the memory cell **446** as illustrated in FIG. 1A or 1B.

[0187] Alternatively, referring to FIG. 7, the third type of cross-point switch **379** may further include four pass/no-pass switches or switch buffers **258** of the second type each having the input point coupling to the output point of one of the four multiplexers (MUXERs) **211** as seen in FIG. 4. For the third type of cross-point switch **379**, each of its four pass/no-pass switch or switch buffer **258** is configured to be switched on or off in accordance with the data input **SC-4** of said each of its

four pass/no-pass switch or switch buffer **258** to pass or not to pass the data output, e.g., Dout, of one of its four multiplexers (MUXERs) **211** as its data output at its output point, i.e., at the node **23**, **24**, **25** or **26**, coupling to one of the four programmable interconnects **361**. For example, for the third type of cross-point switch **379**, the top one of its four multiplexers (MUXERs) **211** may couple to the top one of its four pass/no-pass switch or switch buffers **258** configured to be switched on or off in accordance with the data input SC-4 of the top one of its four pass/no-pass switch or switch buffers **258** to pass or not to pass the data output, e.g., Dout, of the top one of its four multiplexers (MUXERs) **211** as the data output of the top one of its four pass/no-pass switch or switch buffers **258** at the output point of the top one of its four pass/no-pass switch or switch buffers **258**, i.e., at the node **23**, coupling to the top one of the four programmable interconnects **361**. For the third type of cross-point switch **379**, each of its four pass/no-pass switch or switch buffer **258** may have the data input SC-4 associated with a data output of another of its memory cells **362**, i.e., configuration-programming-memory (CPM) cell, e.g., one of the first and second data outputs Out1 and Out2 of the memory cell **446** as illustrated in FIG. 1A or 1B.

[0188] Thereby, for the third type of cross-point switch **379**, each of its memory cells **362**, i.e., configuration-programming-memory (CPM) cell, is configured to be programmed to save or store a programming code to control data transmission between each of three of the four programmable interconnects **361** coupling respectively to the three input points of the second set of one of its four multiplexers (MUXERs) **211** and the other of the four programmable interconnects **361** coupling to the output point of said one of its four multiplexers (MUXERs) **211**, that is, to pass or not to pass one of the data inputs, e.g., D0, D1 and D2, of the second input data set of said one of its four multiplexers (MUXERs) **211** at the respective three input points of the second set of said one of its four multiplexers (MUXERs) **211** coupling respectively to said three of the four programmable interconnects **361** as the data output, e.g., Dout, of said one of its four multiplexers (MUXERs) **211** at the output point of said one of its four multiplexers (MUXERs) **211** coupling to the other of the four programmable interconnects **361**.

[0189] For example, referring to FIG. 7, for the third type of cross-point switch **379**, the top one of its four multiplexers (MUXERs) **211** as seen in FIG. 4 may have the data inputs, e.g., A0 and A1, of the first input data set associated respectively with the data outputs, i.e., configuration-programming-memory (CPM) data, of two of its three memory cells **362-1**, each of which may be referred to one of the data outputs Out1 and Out2 of the memory cell **446** as illustrated in FIG. 1A or 1B, and the top one of its four pass/no-pass switches or switch buffers **258** of the second type as seen in FIG. 4 may have the data input SC-4 associated with the data output, i.e., configuration-programming-memory (CPM) data, of the other of its three memory cells **362-1**, which may be referred to one of the data outputs Out1 and Out2 of the memory cell **446** as illustrated in FIG. 1A or 1B; the left one of its four multiplexers (MUXERs) **211** as seen in FIG. 4 may have the data inputs, e.g., A0 and A1, of the first input data set associated respectively with the data outputs, i.e., configuration-programming-memory (CPM) data, of two of its three memory cells **362-2**, each of which may be referred to one of the data outputs Out1 and Out2 of the memory cell **446** as illustrated in FIG. 1A or 1B, and the left one of its four pass/no-pass switches or switch buffers **258** of the second type as seen in FIG. 4 may have the data input SC-4 associated with the data output, i.e., configuration-programming-memory (CPM) data, of the other of its three memory cells **362-2**, which may be referred to one of the data outputs Out1 and Out2 of the memory cell **446** as illustrated in FIG. 1A or 1B; the bottom one of its four multiplexers (MUXERs) **211** as seen in FIG. 4 may have the data inputs, e.g., A0 and A1, of the first input data set associated respectively with the data outputs, i.e., configuration-programming-memory (CPM) data, of two of its three memory cells **362-3**, each of which may be referred to one of the data outputs Out1 and Out2 of the memory cell **446** as illustrated in FIG. 1A or 1B, and the bottom one of its four pass/no-pass switches or switch buffers **258** of the second type as seen in FIG. 4 may have the data input SC-4 associated with the data output, i.e., configuration-programming-memory (CPM) data, of the other of its three

memory cells **362-3**, which may be referred to one of the data outputs Out1 and Out2 of the memory cell **446** as illustrated in FIG. 1A or 1B; the right one of its four multiplexers (MUXERs) **211** as seen in FIG. 4 may have the data inputs, e.g., A0 and A1, of the first input data set associated respectively with the data outputs, i.e., configuration-programming-memory (CPM) data, of two of its three memory cells **362-4**, each of which may be referred to one of the data outputs Out1 and Out2 of the memory cell **446** as illustrated in FIG. 1A or 1B, and the right one of its four pass/no-pass switches or switch buffers **258** of the second type as seen in FIG. 4 may have the data input SC-4 associated with the data output, i.e., configuration-programming-memory (CPM) data, of the other of its three memory cells **362-4**, which may be referred to one of the data outputs Out1 and Out2 of the memory cell **446** as illustrated in FIG. 1A or 1B.

[0190] Referring to FIG. 7, for the third type of cross-point switch **379**, before its memory cells **362-1**, **362-2**, **362-3** and **362-4**, i.e., configuration-programming-memory (CPM) cells, are programmed or when its memory cells **362-1**, **362-2**, **362-3** and **362-4** are being programmed, the four programmable interconnects **361** may not be used for signal transmission. Its memory cells **362-1**, **362-2**, **362-3** and **362-4**, i.e., configuration-programming-memory (CPM) cells, may be programmed to save or store programming codes, i.e., configuration-programming-memory (CPM) data, to pass data from one of the four programmable interconnects **361** to another, another two or the other three of the four programmable interconnects **361**, that is, from one of the nodes N23-N26 to another, another two or the other three of the nodes N23-N26, for signal transmission in operation.

[0191] Alternatively, two programmable interconnects **361** may be controlled, by either of the first through third types of pass/no-pass switch **258** as seen in FIGS. 2A-2C, to pass or not to pass data therebetween. One of the programmable interconnects **361** may couple to the node N21 of the pass/no-pass switch **258**, and another of the programmable interconnects **361** may couple to the node N22 of the pass/no-pass switch **258**. Accordingly, either of the first through third types of pass/no-pass switch **258** may be switched on to pass data from said one of the programmable interconnects **361** to said another of the programmable interconnects **361**; either of the first through third types of pass/no-pass switch **258** may be switched off not to pass data from said one of the programmable interconnects **361** to said another of the programmable interconnects **361**.

[0192] Referring to FIG. 2A, the first type of pass/no-pass switch **258** may have the data input SC-3 associated via a non-programmable interconnect **364** with a data output, i.e., configuration-programming-memory (CPM) data, of a memory cell **362**, i.e., configuration-programming-memory (CPM) cell, which may be referred to one of the data outputs Out1 and Out2 of the memory cell **446** as illustrated in FIG. 1A or 1B. Thereby, the memory cell **362** may be programmed to save or store a programming code to switch on or off the first type of pass/no-pass switch **258** to control data transmission between said one of the programmable interconnects **361** and said another of the programmable interconnects **361**, that is, to pass or not to pass data from the node N21 of the first type of pass/no-pass switch **258** to the node N22 of the first type of pass/no-pass switch **258** or from the node N22 of the first type of pass/no-pass switch **258** to the node N21 of the first type of pass/no-pass switch **258**.

[0193] Referring to FIG. 2B, the second type of pass/no-pass switch **258** may have the data input SC-4 associated via a non-programmable interconnect **364** with a data output, i.e., configuration-programming-memory (CPM) data, of a memory cell **362**, i.e., configuration-programming-memory (CPM) cell, which may be referred to one of the data outputs Out1 and Out2 of the memory cell **446** as illustrated in FIG. 1A or 1B. Thereby, the memory cell **362** may be programmed to save or store a programming code to switch on or off the second type of pass/no-pass switch **258** to control data transmission between said one of the programmable interconnects **361** and said another of the programmable interconnects **361**, that is, to pass or not to pass data from the node N21 of the second type of pass/no-pass switch **258** to the node N22 of the second type of pass/no-pass switch **258**.

[0194] Referring to FIG. 2C, the third type of pass/no-pass switch 258 may have the data inputs SC-5 and SC-6 each associated via a non-programmable interconnect 364 with a data output, i.e., configuration-programming-memory (CPM) data, of a memory cell 362, i.e., configuration-programming-memory (CPM) cell, which may be referred to one of the data outputs Out1 and Out2 of the memory cell 446 as illustrated in FIG. 1A or 1B. Thereby, each of the memory cells 362 may be programmed to save or store a programming code to switch on or off the third type of pass/no-pass switch 258 to control data transmission between said one of the programmable interconnects 361 and said another of the programmable interconnects 361, that is, to pass or not to pass data from the node N21 of the third type of pass/no-pass switch 258 to the node N22 of the third type of pass/no-pass switch 258 or from the node N22 of the third type of pass/no-pass switch 258 to the node N21 of the third type of pass/no-pass switch 258.

[0195] Similarly, each of the first and second types of cross-point switches 379 as seen in FIGS. 3A and 3B may be composed of a plurality of pass/no-pass switches 258 of the first, second or third type, wherein each of the first, second or third type of pass/no-pass switches 258 may have the data input(s) SC-3, SC-4 or (SC-5 and SC-6) each associated with a data output, i.e., configuration-programming-memory (CPM) data, of a memory cell 362, i.e., configuration-programming-memory (CPM) cell, as mentioned above. Each of the memory cells 362 may be programmed to save or store a programming code to switch said each of the first and second types of cross-point switches 379 to pass data from one of the nodes N23-N26 of said each of the first and second types of cross-point switches 379 to another, another two or another three of the nodes N23-N26 of said each of the first and second types of cross-point switches 379 for signal transmission in operation. Four of the programmable interconnects 361 may couple respectively to the nodes N23-N26 of said each of the first and second types of cross-point switches 379 and thus may be controlled, by said each of the first and second types of cross-point switches 379, to pass data from one of said four of the programmable interconnects 361 to another one, two or three of said four of the programmable interconnects 361.

Specification for Standard Commodity Field-Programmable-Gate-Array (FPGA) Integrated-Circuit (IC) Chip

[0196] FIG. 8A is a schematically top view showing a block diagram of a standard commodity FPGA IC chip in accordance with an embodiment of the present application. Referring to FIG. 8A, the standard commodity FPGA IC chip 200 may include (1) a plurality of programmable logic blocks (LB) 201 as illustrated in FIGS. 6A-6D arranged in an array in a central region thereof, (2) a plurality of cross-point switches 379 as illustrated in FIGS. 3A, 3B and 7 arranged around each of the programmable logic blocks (LB) 201, (3) a plurality of memory cells 362 as illustrated in FIGS. 3A, 3B and 7 configured to be programmed to control its cross-point switches 379, (4) a plurality of intra-chip interconnects 502 each extending over spaces between neighboring two of the programmable logic blocks (LB) 201, wherein the intra-chip interconnects 502 may include the programmable interconnects 361 as seen in FIGS. 3A, 3B and 7 configured to be programmed for interconnection by its memory cells 362 and the non-programmable interconnects 364 for programming its memory cells 362 and 490, and (5) a plurality of small input/output (I/O) circuits 203 as illustrated in FIG. 5B each providing the small driver 374 with the second data input S_Data_out at the second input point of the small driver 374 configured to couple to its programmable interconnects 361 or non-programmable interconnects 364 and providing the small receiver 375 with the data output S_Data_in at the output point of the small receiver 375 configured to couple to its programmable interconnects 361 or non-programmable interconnects 364.

[0197] Referring to FIG. 8A, the programmable interconnects 361 of the intra-chip interconnects 502 may couple to the programmable interconnects 361 of the intra-block interconnects 2015 of each of the programmable logic blocks (LB) 201 as seen in FIG. 6D. The non-programmable interconnects 364 of the intra-chip interconnects 502 may couple to the non-programmable

interconnects **364** of the intra-block interconnects **2015** of each of the programmable logic blocks (LB) **201** as seen in FIG. **6D**.

[0198] Referring to FIG. **8A**, each of the programmable logic blocks (LB) **201** may include one or more programmable logic cells (LC) **2014** as illustrated in FIGS. **6A-6D**. Each of the one or more programmable logic cells (LC) **2014** may have the input data set at its input points each coupling to one of the programmable and non-programmable interconnects **361** and **364** of the intra-chip interconnects **502** and may be configured to perform logic operation or computation operation on its input data set into its data output coupling to another of the programmable and non-programmable interconnects **361** and **364** of the intra-chip interconnects **502**, wherein the computation operation may include an addition, subtraction, multiplication or division operation, and the logic operation may include a Boolean operation such as AND, NAND, OR or NOR operation.

[0199] Referring to FIG. **8A**, the standard commodity FPGA IC chip **200** may include multiple I/O pads **372** as seen in FIG. **5B** each vertically over one of its small input/output (I/O) circuits **203**. For example, in a first clock cycle, for one of the small input/output (I/O) circuits **203** of the standard commodity FPGA IC chip **200**, its small driver **374** may be enabled by the first data input S_Enable of its small driver **374** and its small receiver **375** may be inhibited by the first data input S_Inhibit of its small receiver **375**. Thereby, its small driver **374** may amplify the second data input S_Data_out of its small driver **374**, associated with the data output of one of the programmable logic cells (LC) **2014** of the standard commodity FPGA IC chip **200** as illustrated in FIGS. **6A-6D** through first one or more of the programmable interconnects **361** of the standard commodity FPGA IC chip **200** and/or one or more of the cross-point switches **379** of the standard commodity FPGA IC chip **200** each coupled between two of said first one or more of the programmable interconnects **361**, as the data output of its small driver **374** to be transmitted to one of the I/O pads **372** vertically over said one of the small input/output (I/O) circuits **203** for external connection to circuits outside the standard commodity FPGA IC chip **200**, such as non-volatile memory (NVM) integrated-circuit (IC) chip.

[0200] In a second clock cycle, for said one of the small input/output (I/O) circuits **203** of the standard commodity FPGA IC chip **200**, its small driver **374** may be disabled by the first data input S_Enable of its small driver **374** and its small receiver **375** may be activated by the first data input S_Inhibit of its small receiver **375**. Thereby, its small receiver **375** may amplify the second data input of its small receiver **375** transmitted from circuits outside the standard commodity FPGA IC chip **200** through said one of the I/O pads **372** as the data output S_Data_in of its small receiver **375** to be associated with a data input of the input data set of one of the programmable logic cells (LC) **2014** of the standard commodity FPGA IC chip **200** as illustrated in FIGS. **6A-6D** through second one or more of the programmable interconnects **361** of the standard commodity FPGA IC chip **200** and/or one or more of the cross-point switches **379** of the standard commodity FPGA IC chip **200** each coupled between two of said second one or more of the programmable interconnects **361**.

[0201] Referring to FIG. **8A**, the standard commodity FPGA IC chip **200** may include multiple I/O ports **377** having the number ranging from 2 to 64 for example, such as I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4** for this case. Each of the I/O ports **377** may include (1) the small I/O circuits **203** as seen in FIG. **5B** having the number ranging from 4 to 256, such as 64 for this case, arranged in parallel for data transmission with bit width ranging from 4 to 256, such as 64 for this case, and (2) the I/O pads **372** as seen in FIG. **5B** having the number ranging from 4 to 256, such as 64 for this case, arranged in parallel and vertically over the small I/O circuits **203** respectively.

[0202] Referring to FIG. **8A**, the standard commodity FPGA IC chip **200** may further include a chip-enable (CE) pad **209** configured for enabling or disabling the standard commodity FPGA IC chip **200**. For example, when the chip-enable (CE) pad **209** is at a logic level of "0", the standard commodity FPGA IC chip **200** may be enabled to process data and/or operate with circuits outside

of the standard commodity FPGA IC chip **200**; when the chip-enable (CE) pad **209** is at a logic level of “1”, the standard commodity FPGA IC chip **200** may be disabled not to process data and/or operate with circuits outside of the standard commodity FPGA IC chip **200**.

[0203] Referring to FIG. **8A**, the standard commodity FPGA IC chip **200** may include multiple input selection (IS) pads **231**, e.g., IS1, IS2, IS3 and IS4 pads, each configured to receive data to be associated with the first data input S_Inhibit of the small receiver **375** of each of the small I/O circuits **203** of one of its I/O ports **377**, e.g., I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4**. For more elaboration, the IS1 pad **231** may receive data to be associated with the first data input S_Inhibit of the small receiver **375** of each of the small I/O circuits **203** of its I/O Port **1** through a first one of its small I/O circuits **203**; the IS2 pad **231** may receive data to be associated with the first data input S_Inhibit of the small receiver **375** of each of the small I/O circuits **203** of I/O Port **2** through a second one of its small I/O circuits **203**; the IS3 pad **231** may receive data to be associated with the first data input S_Inhibit of the small receiver **375** of each of the small I/O circuits **203** of I/O Port **3** through a third one of its small I/O circuits **203**; and the IS4 pad **231** may receive data to be associated with the first data input S_Inhibit of the small receiver **375** of each of the small I/O circuits **203** of I/O Port **4** through a fourth one of its small I/O circuits **203**. The standard commodity FPGA IC chip **200** may select, in accordance with logic levels at the input selection (IS) pads **231**, e.g., IS1, IS2, IS3 and IS4 pads, one or more from its I/O ports **377**, e.g., I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4** to pass data for its input operation. For each of the small I/O circuits **203** of one of the I/O ports **377** selected in accordance with the logic level at one of the input selection (IS) pads **231** of the standard commodity FPGA IC chip **200**, its small receiver **375** may be activated by the first data input S_Inhibit of its small receiver **375** associated with the logic level at said one of the input selection (IS) pads **231** of the standard commodity FPGA IC chip **200** to amplify or pass the second data input of its small receiver **375**, transmitted from a data path of one of data buses **315** as illustrated in FIG. **12** outside the standard commodity FPGA IC chip **200** through one of the I/O pads **372** of said one of the I/O ports **377** selected in accordance with the logic level at said one of the input selection (IS) pads **231** of the standard commodity FPGA IC chip **200**, as the data output S_Data_in of its small receiver **375** to be associated with a data input of the input data set of one of the programmable logic cells (LC) **2014** as seen in FIGS. **6A-6D** of the standard commodity FPGA IC chip **200** through one or more of the programmable interconnects **361** as seen in FIGS. **3A**, **3B** and **7** of the standard commodity FPGA IC chip **200**, for example. For each of the small I/O circuits **203** of the other one or more of the I/O ports **377**, not selected in accordance with the logic level at the other(s) of the input selection (IS) pads **231**, of the standard commodity FPGA IC chip **200**, its small receiver **375** may be inhibited by the first data input S_Inhibit of its small receiver **375** associated with the logic level at one of the other(s) of the input selection (IS) pads **231**.

[0204] For example, referring to FIG. **8A**, provided that the standard commodity FPGA IC chip **200** may have (1) the chip-enable (CE) pad **209** at a logic level of “V”, (2) the IS1 pad **231** at a logic level of “1”, (3) the IS2 pad **231** at a logic level of “0”, (4) the IS3 pad **231** at a logic level of “0” and (5) the IS4 pad **231** at a logic level of “0”, the standard commodity FPGA IC chip **200** may be enabled in accordance with the logic level at its chip-enable (CE) pad **209** and may select, in accordance with the logic levels at its IS1, IS2, IS3 and IS4 pads **231**, one or more I/O port, i.e., I/O Port **1**, from its I/O ports **377**, i.e., I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4**, to pass data for the input operation. For each of the small I/O circuits **203** of the selected I/O port **377**, i.e., I/O Port **1**, of the standard commodity FPGA IC chip **200**, its small receiver **375** may be activated by the first data input S_Inhibit of its small receiver **375** associated with the logic level at the IS1 pad **231** of the standard commodity FPGA IC chip **200**. For each of the small I/O circuits **203** of the unselected I/O ports, i.e., I/O Port **2**, I/O Port **3** and I/O Port **4**, of the standard commodity FPGA IC chip **200**, its small receiver **375** may be inhibited by the first data input S_Inhibit of its small receiver **375** associated respectively with the logic levels at the IS2, IS3 and IS4 pads **231** of the

standard commodity FPGA IC chip **200**.

[0205] For example, referring to FIG. **8A**, provided that the standard commodity FPGA IC chip **200** may have (1) the chip-enable (CE) pad **209** at a logic level of “V”, (2) the IS1 pad **231** at a logic level of “1”, (3) the IS2 pad **231** at a logic level of “1”, (4) the IS3 pad **231** at a logic level of “1” and (5) the IS4 pad **231** at a logic level of “1”, the standard commodity FPGA IC chip **200** may be enabled in accordance with the logic level at its chip-enable (CE) pad **209** and may select, in accordance with the logic levels at its IS1, IS2, IS3 and IS4 pads **231**, all from its I/O ports **377**, i.e., I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4**, to pass data for the input operation at the same clock cycle. For each of the small I/O circuits **203** of the selected I/O ports **377**, i.e., I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4**, of the standard commodity FPGA IC chip **200**, its small receiver **375** may be activated by the first data input S_Inhibit of its small receiver **375** associated respectively with the logic levels at the IS1, IS2, IS3 and IS4 pads **231** of the standard commodity FPGA IC chip **200**.

[0206] Referring to FIG. **8A**, the standard commodity FPGA IC chip **200** may include multiple output selection (OS) pads **232**, e.g., OS1, OS2, OS3 and OS4 pads, each configured to receive data to be associated with the first data input S_Enable of the small driver **374** of each of the small I/O circuits **203** of one of its I/O ports **377**, e.g., I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4**. For more elaboration, the OS1 pad **232** may receive data to be associated with the first data input S_Enable of the small driver **374** of each of the small I/O circuits **203** of IO Port **1** through a fifth one of its small I/O circuits **203**; the OS2 pad **232** may receive data to be associated with the first data input S_Enable of the small driver **374** of each of the small I/O circuits **203** of IO Port **2** through a sixth one of its small I/O circuits **203**; the OS3 pad **232** may receive data to be associated with the first data input S_Enable of the small driver **374** of each of the small I/O circuits **203** of I/O Port **3** through a seventh one of its small I/O circuits **203**; the OS4 pad **232** may receive data to be associated with the first data input S_Enable of the small driver **374** of each of the small I/O circuits **203** of IO Port **4** through an eighth one of its small I/O circuits **203**. The standard commodity FPGA IC chip **200** may select, in accordance with logic levels at the output selection (OS) pads **232**, e.g., OS1, OS2, OS3 and OS4 pads, one or more from its I/O ports **377**, e.g., I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4** to pass data for its output operation. For each of the small I/O circuits **203** of each of the one or more I/O ports **377** selected in accordance with the logic levels at the output selection (OS) pads **232**, its small driver **374** may be enabled by the first data input S_Enable of its small driver **374** associated with the logic level at one of the output selection (OS) pads **232** to amplify or pass the second data input S_Data_out of its small driver **374**, associated with the data output of one of the programmable logic cells (LC) **2014** as seen in FIGS. **6A-6D** of the standard commodity FPGA IC chip **200** through one or more of the programmable interconnects **361** as seen in FIGS. **3A**, **3B** and **7** of the standard commodity FPGA IC chip **200**, as the data output of its small driver **374** to be transmitted to a data path of one of data buses **315** as illustrated in FIG. **12** outside the standard commodity FPGA IC chip **200** through one of the I/O pads **372** of said each of the one or more I/O ports **377**, for example. For each of the small I/O circuits **203** of each of the I/O ports **377**, not selected in accordance with in accordance with the logic levels at the output selection (OS) pads **232**, of the standard commodity FPGA IC chip **200**, its small driver **374** may be disabled by the first data input S_Enable of its small driver **374** associated with the logic level at one of the output selection (OS) pads **232**.

[0207] For example, referring to FIG. **8A**, provided that the standard commodity FPGA IC chip **200** may have (1) the chip-enable (CE) pad **209** at a logic level of “0”, (2) the OS1 pad **232** at a logic level of “0”, (3) the OS2 pad **232** at a logic level of “1”, (4) the OS3 pad **232** at a logic level of “1” and (5) the OS4 pad **232** at a logic level of “1”, the standard commodity FPGA IC chip **200** may be enabled in accordance with the logic level at its chip-enable (CE) pad **209** and may select, in accordance with the logic levels at its OS1, OS2, OS3 and OS4 pads **232**, one or more I/O port, i.e., I/O Port **1**, from its I/O ports **377**, i.e., I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4**, to pass

data for the output operation. For each of the small I/O circuits **203** of the selected I/O port **377**, i.e., I/O Port **1**, of the standard commodity FPGA IC chip **200**, its small driver **374** may be enabled by the first data input S_Enable of its small driver **374** associated with the logic level at the OS1 pad **232** of the standard commodity FPGA IC chip **200**. For each of the small I/O circuits **203** of the unselected I/O ports, i.e., I/O Port **2**, I/O Port **3** and I/O Port **4**, of the standard commodity FPGA IC chip **200**, its small driver **374** may be disabled by the first data input S_Enable of its small driver **374** associated respectively with the logic levels at the OS2, OS3 and OS4 pads **232** of the standard commodity FPGA IC chip **200**.

[0208] For example, referring to FIG. **8A**, provided that the standard commodity FPGA IC chip **200** may have (1) the chip-enable (CE) pad **209** at a logic level of "0", (2) the OS1 pad **232** at a logic level of "0", (3) the OS2 pad **232** at a logic level of "0", (4) the OS3 pad **232** at a logic level of "0" and (5) the OS4 pad **232** at a logic level of "0", the standard commodity FPGA IC chip **200** may be enabled in accordance with the logic level at its chip-enable (CE) pad **209** and may select, in accordance with the logic levels at its OS1, OS2, OS3 and OS4 pads **232**, all from its I/O ports **377**, i.e., I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4**, to pass data for the output operation. For each of the small I/O circuits **203** of the selected I/O port **377**, i.e., I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4**, of the standard commodity FPGA IC chip **200**, its small driver **374** may be enabled by the first data input S_Enable of its small driver **374** associated respectively with the logic levels at the OS1, OS2, OS3 and OS4 pads **232** of the standard commodity FPGA IC chip **200**.

[0209] Thereby, referring to FIG. **8A**, in a clock cycle, one or more of the I/O ports **377**, e.g., I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4**, may be selected, in accordance with the logic levels at the IS1, IS2, IS3 and IS4 pads **231**, to pass data for the input operation, while another one or more of the I/O ports **377**, e.g., I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4**, may be selected, in accordance with the logic levels at the OS1, OS2, OS3 and OS4 pads **232**, to pass data for the output operation. The input selection (IS) pads **231** and output selection (OS) pads **232** may be provided as I/O-port selection pads.

[0210] Referring to FIG. **8A**, the standard commodity FPGA IC chip **200** may further include (1) multiple power pads **205** configured for applying the voltage Vcc of power supply to its memory cells **490** for the look-up tables (LUT) **210** of its programmable logic cells (LC) **2014** as illustrated in FIGS. **6A-6D**, the multiplexers (MUXERs) **211** of its programmable logic cells (LC) **2014**, its memory cells **362** for its cross-point switches **379** as illustrated in FIGS. **3A**, **3B** and **7**, its cross-point switches **379** and/or the small drivers **374** and receivers **375** of its small I/O circuits **203** as seen in FIG. **5B** through one or more of its non-programmable interconnects **364**, wherein the voltage Vcc of power supply may be between 0.2V and 2.5V, between 0.2V and 2V, between 0.2V and 1.5V, between 0.1V and 1V, or between 0.2V and 1V, or, smaller or lower than or equal to 2.5V, 2V, 1.8V, 1.5V or 1V, and (2) multiple ground pads **206** configured for providing the voltage Vss of ground reference to its memory cells **490** for the look-up tables (LUT) **210** of its programmable logic cells (LC) **2014** as illustrated in FIGS. **6A-6D**, the multiplexers (MUXERs) **211** of its programmable logic cells (LC) **2014**, its memory cells **362** for its cross-point switches **379** as illustrated in FIGS. **3A**, **3B** and **7**, its cross-point switches **379** and/or the small drivers **374** and receivers **375** of its small I/O circuits **203** as seen in FIG. **5B** through one or more of its non-programmable interconnects **364**.

[0211] Referring to FIG. **8A**, the standard commodity FPGA IC chip **200** may further include a clock pad (CLK) **229** configured to receive a clock signal from circuits outside of the standard commodity FPGA IC chip **200** and multiple control pads (CP) **378** configured to receive control commands to control the standard commodity FPGA IC chip **200**.

[0212] Referring to FIG. **8A**, for the standard commodity FPGA IC chip **200**, its programmable logic cells (LC) **2014** as seen in FIGS. **6A-6D** may be reconfigurable for artificial-intelligence (AI) application. For example, in a clock cycle, one of the programmable logic cells (LC) **2014** of the standard commodity FPGA IC chip **200** may have its memory cells **490** to be programmed to

operation; however, after one or more events happen, in another clock cycle said one of its programmable logic cells (LC) **2014** of the standard commodity FPGA IC chip **200** may have its memory cells **490** to be programmed to perform NAND operation for better A1 performance.

[0213] Referring to FIG. **8A**, the standard commodity FPGA IC chip **200** may be designed, implemented and fabricated using an advanced semiconductor technology node or generation, for example more advanced than or equal to, or below or equal to 30 nm, 20 nm or 10 nm. The standard commodity FPGA IC chip **200** may have an area between 400 mm.^{sup.2} and 9 mm.^{sup.2}, 225 mm.^{sup.2} and 9 mm.^{sup.2}, 144 mm.^{sup.2} and 16 mm.^{sup.2}, 100 mm.^{sup.2} and 16 mm.^{sup.2}, 75 mm.^{sup.2} and 16 mm.^{sup.2}, or 50 mm.^{sup.2} and 16 mm.^{sup.2}. Transistors or semiconductor devices of the standard commodity FPGA IC chip **200** used in the advanced semiconductor technology node or generation may be a FIN Field-Effect-Transistor (FINFET), a FINFET on Silicon-On-Insulator (FINFET SOI), a Fully Depleted Silicon-On-Insulator (FDSOI) MOSFET, a Partially Depleted Silicon-On-Insulator (PDSOI) MOSFET or a conventional MOSFET.

[0214] FIG. **8B** is a top view showing a layout of a standard commodity FPGA IC chip in accordance with an embodiment of the present application. Referring to FIG. **8B**, the standard commodity FPGA IC chip **200** may include multiple repetitive circuit arrays **2021** arranged in an array therein, and each of the repetitive circuit arrays **2021** may include multiple repetitive circuit units **2020** arranged in an array therein. Each of the repetitive circuit units **2020** may include a programmable logic cell (LC) **2014** as illustrated in FIG. **6A**, and/or the memory cells **362** for the programmable interconnection as illustrated in FIGS. **2A-2C**, **3A**, **3B** and **7**. The programmable logic cells (LC) **2014** may be programmed or configured as functions of, for example, digital-signal processor (DSP), microcontroller, adders, and/or multipliers. For the standard commodity FPGA IC chip **200**, its programmable interconnects **361** may couple neighboring two of its repetitive circuit units **2020** and the repetitive circuit units **2020** in neighboring two of its repetitive circuit units **2020**. The standard commodity FPGA IC chip **200** may include a seal ring **2022** at its four edges, enclosing its repetitive circuit arrays **2021**, its I/O ports **277** and its various circuits as illustrated in FIG. **8A**, and a scribe line, kerf or die-saw area **2023** at its border and outside and around the seal ring **2022**. For example, for the standard commodity FPGA IC chip **200**, greater than 85%, 90%, 95% or 99% area (not counting its seal ring **2022** and scribe line **2023**, that is, only including an area within an inner boundary **2022a** of its seal ring **2022**) is used for its repetitive circuit arrays **2021**; alternatively, all or most of its transistors are used for its repetitive circuit arrays **2021**. Alternatively, for the standard commodity FPGA IC chip **200**, none or minimal area may be provided for its control circuits, I/O circuits or hard macros, for example, less than 15%, 10%, 5%, 2% or 1% of its area (not counting its seal ring **2022** and scribe line **2023**, that is, only including an area within an inner boundary **2022a** of its seal ring **2022**) is used for its control circuits, I/O circuits or hard macros; alternatively, none or minimal transistors may be provided for its control circuits, I/O circuits or hard macros, for example, less than 15%, 10/a, 5%, 2% or 1% of the total number of its transistors are used for its control circuits, I/O circuits or hard macros.

[0215] The standard commodity plural FPGA IC chip **200** may have standard common features, counts or specifications: (1) its regular repetitive logic array may have the number of programmable logic arrays or sections equal to or greater than 2, 4, 8, 10 or 16, wherein its regular repetitive logic array may include programmable logic blocks or elements **201** as illustrated in FIGS. **6A-6D** with the count equal to or greater than 128K, 512K, 1M, 4M, 8M, 16M, 32M or 80M; (2) its regular memory array may have the number of memory banks equal to or greater than 2, 4, 8, 10 or 16, wherein its regular memory array may include memory cells with the bit count equal to or greater than 1M, 10M, 50M, 100M, 200M or 500M bits; (3) the number of data inputs to each of its programmable logic blocks or elements **201** may be greater than or equal to 4, 8, 16, 32, 64, 128 or 256; (4) its applied voltage may be between 0.1V and 1.5V, between 0.1V and 1.0V, between 0.1V and 0.7V, or between 0.1V and 0.5V; and (4) its I/O pads **372** as seen in FIG. **8A** may be arranged in terms of layout, location, number and function.

Specification for Dedicated Programmable Interconnection (DPI) Integrated-Circuit (IC) Chip [0216] FIG. 9 is a schematically top view showing a block diagram of a dedicated programmable interconnection (DPI) integrated-circuit (IC) chip in accordance with an embodiment of the present application.

[0217] Referring to FIG. 9, the DPIIC chip 410 may include (1) a plurality of memory-array blocks 423 arranged in an array in a central region thereof, wherein each of the memory-array blocks 423 may include a plurality of memory cells 362 as illustrated in FIGS. 3A, 3B and 7 arranged in an array, (2) a plurality of groups of cross-point switches 379 as illustrated in FIGS. 3A, 3B and 7, each group of which is arranged in one or more rings around one of the memory-array blocks 423, wherein each of its memory cells 362 in one of its memory-array blocks 423 is configured to be programmed to control its cross-point switches 379 around said one of its memory-array blocks 423, (4) a plurality of intra-chip interconnects including the programmable interconnects 361 as seen in FIGS. 3A, 3B and 7 configured to be programmed for interconnection by its memory cells 362 and multiple non-programmable interconnects for programming its memory cells 362, and (6) a plurality of small input/output (I/O) circuits 203 as illustrated in FIG. 5B each providing the small receiver 375 with the data output S_Data_in associated with a data input at one of the nodes N23-N26 of one of its cross-point switches 379 as illustrated in FIGS. 3A, 3B and 8 through one or more of its programmable interconnects 361 and providing the small driver 374 with the data input S_Data_out associated with a data output at one of the nodes N23-N26 of another of its cross-point switches 379 as illustrated in FIGS. 3A, 3B and 8 through another one or more of its programmable interconnects 361.

[0218] Referring to FIG. 9, each of the memory cells 362 may be referred to a memory cell 446 as illustrated in FIGS. 1A and 1B. The DPIIC chip 410 may provide the first type of pass/no-pass switches 258 for its first or second type of cross-point switches 379 as illustrated in FIGS. 3A and 3B close to one of its memory-array blocks 423, each of which may have the data input SC-3 as seen in FIG. 2A associated with a data output, i.e., configuration-programming-memory (CPM) data, of one of its memory cells 362, i.e., configuration-programming-memory (CPM) cells, in said one of its memory-array blocks 423, which may be referred to one of the data outputs Out1 and Out2 of the memory cell 446 as illustrated in FIGS. 1A and 1B. Alternatively, the DPIIC chip 410 may provide the third type of pass/no-pass switches 258 for its first or second type of cross-point switches 379 as illustrated in FIGS. 3A and 3B close to one of the memory-array blocks 423, each of which may have the data inputs SC-5 and SC-6 as seen in FIG. 2C each associated with a data output, i.e., configuration-programming-memory (CPM) data, of one of its memory cells 362, i.e., configuration-programming-memory (CPM) cells, in said one of its memory-array blocks 423, which may be referred to one of the data outputs Out1 and Out2 of the memory cell 446 as illustrated in FIGS. 1A and 1B. Alternatively, the DPIIC chip 410 may provide the multiplexers 211 for its third type of cross-point switches 379 as illustrated in FIG. 7 close to one of the memory-array blocks 423, each of which may have the first set of input points for multiple data inputs of the first input data set of said each of its multiplexers 211 each associated with a data output, i.e., configuration-programming-memory (CPM) data, of one of its memory cells 362, i.e., configuration-programming-memory (CPM) cells, in said one of its memory-array blocks 423, which may be referred to one of the data outputs Out1 and Out2 of the memory cell 446 as illustrated in FIGS. 1A and 1B.

[0219] Referring to FIG. 9, the DPIIC chip 410 may include multiple intra-chip interconnects (not shown) each extending over spaces between neighboring two of the memory-array blocks 423, wherein said each of the intra-chip interconnects may be the programmable interconnect 361, coupling to one of the nodes N23-N26 of one of its cross-point switches 379 as illustrated in FIGS. 3A, 3B and 7. For the DPIIC chip 410, each of its small input/output (I/O) circuits 203, as illustrated in FIGS. 5B, may provide the small receiver 375 with the data output S_Data_in to be passed through one or more of its programmable interconnects 361 and the first data input

S_Inhibit passed through another one or more of its programmable interconnects **361** and provide the small driver **374** with the first data input S_Enable passed through another one or more of its programmable interconnects **361** and the second data input S_Data_out passed through another one or more of its programmable interconnects.

[0220] Referring to FIG. 9, the DPIIC chip **410** may include multiple of the I/O pads **372** as seen in FIG. 5B, each vertically over one of its small input/output (I/O) circuits **203**, coupling to the node **381** of said one of its small input/output (I/O) circuits **203**. For the DPIIC chip **410**, in a first clock cycle, data from one of the nodes N23-N26 of one of its cross-point switches **379** as illustrated in FIGS. 3A, 3B and 7 may be associated with the second data input S_Data_out of the small driver **374** of one of its small input/output (I/O) circuits **203** through one or more of the programmable interconnects **361** programmed by a first group of its memory cells **362**, and then the small driver **374** of said one of its small input/output (I/O) circuits **203** may amplify or pass the second data input S_Data_out of the small driver **374** of said one of its small input/output (I/O) circuits **203** into the data output of the small driver **374** of said one of its small input/output (I/O) circuits **203** to be transmitted to one of its I/O pads **372** vertically over said one of its small input/output (I/O) circuits **203** for external connection to circuits outside the DPIIC chip **410**. In a second clock cycle, data from circuits outside the DPIIC chip **410** may be associated with the second data input of the small receiver **375** of said one of its small input/output (I/O) circuits **203** through said one of its I/O pads **372**, and then the small receiver **375** of said one of the small input/output (I/O) circuits **203** may amplify or pass the second data input of the small receiver **375** of said one of its small input/output (I/O) circuits **203** into the data output S_Data_in of the small receiver **375** of said one of its small input/output (I/O) circuits **203** to be associated with one of the nodes N23-N26 of another of its cross-point switches **379** as illustrated in FIGS. 3A, 3B and 7 through another one or more of the programmable interconnects **361** programmed by a second group of its memory cells **362**.

[0221] Referring to FIG. 9, the DPIIC chip **410** may further include (1) multiple power pads **205** for applying the voltage Vcc of power supply to its memory cells **362** for its cross-point switches **379** as illustrated in FIGS. 3A, 3B and 7 and/or its cross-point switches **379**, wherein the voltage Vcc of power supply may be between 0.2V and 2.5V, between 0.2V and 2V, between 0.2V and 1.5V, between 0.1V and 1V, or between 0.2V and 1V, or, smaller or lower than or equal to 2.5V, 2V, 1.8V, 1.5V or 1V, and (2) multiple ground pads **206** for providing the voltage Vss of ground reference to its memory cells **362** for its cross-point switches **379** as illustrated in FIGS. 3A, 3B and 7 and/or its cross-point switches **379**.

[0222] Referring to FIG. 9, the DPIIC chip **410** may further include multiple volatile storage units **398** of the first type as illustrated in FIG. 1A used as cache memory for data latch or storage. Each of the volatile storage units **398** may include two switches **449**, such as N-type or P-type MOS transistors, for bit and bit-bar data transfer, and two pairs of P-type and N-type MOS transistors **447** and **448** for data latch or storage nodes. For each of the volatile storage units **398** acting as the cache memory of the DPIIC chip **410**, its two switches **449** may perform control of writing data into each of its memory cells **446** and reading data stored in each of its memory cells **446**. The DPIIC chip **410** may further include a sense amplifier for reading, amplifying or detecting data from the memory cells **446** of its volatile storage units **398** acting as the cache memory.

[0223] Referring to FIG. 9, the dedicated programmable interconnection (DPI) integrated-circuit (IC) chip **410** may be designed, implemented and fabricated using an advanced semiconductor technology node or generation, for example more advanced than or equal to, or below or equal to 30 nm, 20 nm or 10 nm. The DPIIC chip **410** may have an area between 400 mm.sup.2 and 9 mm.sup.2, 225 mm.sup.2 and 9 mm.sup.2, 144 mm.sup.2 and 16 mm.sup.2, 100 mm.sup.2 and 16 mm.sup.2, 75 mm.sup.2 and 16 mm.sup.2, or 50 mm.sup.2 and 16 mm.sup.2. Transistors or semiconductor devices of the DPIIC chip **410** used in the advanced semiconductor technology node or generation may be a FIN Field-Effect-Transistor (FINFET), a FINFET on Silicon-On-Insulator (FINFET SOI), a Fully Depleted Silicon-On-Insulator (FDSOI) MOSFET, a Partially Depleted

Silicon-On-Insulator (PDSOI) MOSFET or a conventional MOSFET.

Specification for Standard Commodity Logic Drive

1. First Type of Standard Commodity Logic Drive

[0224] FIG. **10A** is a schematically top view showing arrangement for various chips packaged in a first type of standard commodity logic drive in accordance with an embodiment of the present application. Referring to FIG. **10A**, a first type of standard commodity logic drive **300** may be packaged with multiple processing and/or computing (PC) integrated circuit (IC) chips **269**, a non-volatile memory (NVM) IC chip **250**, multiple first high speed, high bandwidth memory (HBM) IC chips **251-1**, an innovated application-specific integrated circuit (ASIC) chip or customer-owned tooling (COT) chip **402**, abbreviated as IAC chip below, a first memory module **159-1** as seen in FIG. **15A** or **15B** and multiple operation modules **190** each as seen in FIG. **17E**, **17G**, **19E** or **19G**, which are arranged in an array. For each of the operation modules **190** of the first type of standard commodity logic drive **300**, a standard commodity FPGA IC chip **200** as illustrated in FIGS. **8A** and **8B** is provided at a bottom thereof, and a second high bandwidth memory (HBM) IC chip **251-2** or a second memory module **159-2** as seen in FIG. **15A** or **15B** may be provided over its standard commodity FPGA IC chip **200**, and thereby its standard commodity FPGA IC chip **200** may operate with its second HBM IC chip **251-2** or multiple third HBM IC chips **251-3** of its second memory module **159-2** for high speed, high bandwidth, wide bitwidth parallel processing and/or parallel computing. A data bus between its standard commodity FPGA IC chip **200** and its second HBM IC chip **251-2**, or each of the third HBM IC chips **251-3** of its second memory module **159-2**, may have a data bit width of equal to or greater than 64, 128, 256, 512, 1024, 2048, 4096, 8K, or 16K.

[0225] Referring to FIG. **10A**, for the first type of standard commodity logic drive **300**, its NVM IC chip **250** is configured to store the resulting values and programming codes in a non-volatile manner for programming the programmable logic cells (LC) **2014** and cross-point switches **379** of the standard commodity FPGA IC chip **200** of each of its operation modules **190**, as illustrated in FIGS. **6A-6D**, **7**, **8A** and **8B**. The resulting values and programming codes stored in its NVM IC chip **250** may be passed to and stored in the memory cells **490** and **362** of the standard commodity FPGA IC chip **200** of each of its operation modules **190**. For the first type of standard commodity logic drive **300**, each of its PCIC chips **269** may be a graphic-processing-unit (GPU) chip, central-processing-unit (CPU) chip, digital-signal-processing (DSP) chip, tensor-processing-unit (TPU) chip or neural-processing-unit (NPU) chip. Each of its first, second and third HBM IC chips **251-1**, **251-2** and **251-3** may be a high speed, high bandwidth, wide bitwidth dynamic-random-access-memory (DRAM) IC chip, high speed, high bandwidth, wide bitwidth cache static-random-access-memory (SRAM) chip, high speed, high bandwidth, wide bitwidth NVM chip, high speed, high bandwidth, wide bitwidth magnetoresistive random-access-memory (MRAM) chip or high speed, high bandwidth, wide bitwidth resistive random-access-memory (RRAM) chip. One of its PCIC chips **269** may operate with one of its first HBM IC chips **251-1** next to said one of its PCIC chips **269** for high speed, high bandwidth, wide bitwidth parallel processing and/or parallel computing. One of its PCIC chips **269** may operate with the third HBM IC chips **251-3** of one of its first memory modules **159-1** next to said one of its PCIC chips **269** for high speed, high bandwidth, wide bitwidth parallel processing and/or parallel computing.

[0226] Referring to FIG. **10A**, the first type of standard commodity logic drive **300** may include multiple inter-chip interconnects **371** each extending under spaces between neighboring two of its NVM IC chip **250**, PCIC chips **269**, first HBM IC chips **251-1**, operation modules **190** and first memory module **159-1**. The first type of standard commodity logic drive **300** may include a plurality of dedicated-programmable-interconnection (DPI) integrated-circuit (IC) chips **410** as illustrated in FIG. **9** each aligned with a cross of a vertical bundle of its inter-chip interconnects **371** and a horizontal bundle of its inter-chip interconnects **371**.

[0227] Referring to FIG. **10A**, for the first type of standard commodity logic drive **300**, each of its

inter-chip interconnects **371** may be a non-programmable interconnect **364** for programming one or more of the memory cells **362** and **490** of the standard commodity FPGA IC chip **200** of one of its operation modules **190** or one or more of the memory cells **362** of one of its DPIIC chips **410**, or a programmable interconnect **361** configured to be programmed by one or more of the memory cells **362** of the standard commodity FPGA IC chip **200** of one of its operation modules **190** or one or more of the memory cells **362** of one of its DPIIC chips **410**. Signal transmission may be built (1) between one of the programmable interconnects **361** of its inter-chip interconnects **371** and one of the programmable interconnects **361** of the intra-chip interconnects **502** of the standard commodity FPGA IC chip **200** of one of its operation modules **190** via one of the small input/output (I/O) circuits **203** of the standard commodity FPGA IC chip **200** of said one of its operation modules **190**, or (2) between one of the programmable interconnects **361** of its inter-chip interconnects **371** and one of the programmable interconnects of the intra-chip interconnects of one of its DPIIC chips **410** via one of the small input/output (I/O) circuits **203** of said one of its DPIIC chips **410**. Signal transmission may be built (1) between one of the non-programmable interconnects **364** of its inter-chip interconnects **371** and one of the non-programmable interconnects **364** of the intra-chip interconnects **502** of the standard commodity FPGA IC chip **200** of said one of its operation modules **190** via one of the small input/output (I/O) circuits **203** of the standard commodity FPGA IC chip **200** of said one of its operation modules **190** or (2) between one of the non-programmable interconnects **364** of its inter-chip interconnects **371** and one of the non-programmable interconnects of the intra-chip interconnects of one of its DPIIC chips **410** via one of the small input/output (I/O) circuits **203** of said one of its DPIIC chips **410**. For the first type of standard commodity logic drive **300**, its NVM IC chip **250** is configured to store the programming codes in a non-volatile manner for programming the cross-point switches **379** of its DPIIC chips **410**, as illustrated in FIGS. **7** and **9**. The programming codes stored in its NVM IC chip **250** may be passed to and stored in the memory cells **362** of its DPIIC chips **410**.

[0228] Referring to FIG. **10A**, for the first type of standard commodity logic drive **300**, one or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from the standard commodity FPGA IC chip **200** of each of its operation modules **190** to all of its DPIIC chips **410**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from the standard commodity FPGA IC chip **200** of each of its operation modules **190** to its IAC chip **402**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from the standard commodity FPGA IC chip **200** of each of its operation modules **190** to its NVM IC chip **250**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from the standard commodity FPGA IC chip **200** of each of its operation modules **190** to both of its PCIC chips **269**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from the standard commodity FPGA IC chip **200** of one of its operation modules **190** to one of its first HBM IC chips **251-1** next to said one of its operation modules **190** and compose a data bus between the standard commodity FPGA IC chip **200** of said one of its operation modules **190** and said one of its first HBM IC chips **251-1** having a data bit width of equal to or greater than 64, 128, 256, 512, 1024, 2048, 4096, 8K, or 16K. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from the standard commodity FPGA IC chip **200** of one of its operation modules **190** to each of the third HBM IC chips **251-3** of its first memory module **159-1** next to said one of its operation modules **190** and compose a data bus between the standard commodity FPGA IC chip **200** of said one of its operation modules **190** and said each of the third HBM IC chips **251-3** of its first memory module **159-1** having a data bit width of equal to or greater than 64, 128, 256, 512, 1024, 2048, 4096, 8K, or 16K. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its DPIIC

chips **410** to its IAC chip **402**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its DPIIC chips **410** to its NVM IC chip **250**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its DPIIC chips **410** to both of its PCIC chips **269**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its DPIIC chips **410** to both of its first HBM IC chips **251-1**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its DPIIC chips **410** to all of the third HBM IC chips **251-3** of its first memory module **159-1**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its DPIIC chips **410** to the second HBM IC chip **251-2** of each of its operation modules **190**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its DPIIC chips **410** to each of the third HBM IC chips **251-3** of the second memory module **159-2** of each of its operation modules **190**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its DPIIC chips **410** to the others of its DPIIC chips **410**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its PCIC chips **269** to all of its first, second and third HBM IC chips **251-1**, **251-2** and **251-3**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from one of its PCIC chips **269** to one of its first HBM IC chips **251-1** next to said one of its PCIC chips **269** and compose a data bus between said one of its PCIC chips **269** and said one of its first HBM IC chips **251-1** having a data bit width of equal to or greater than 64, 128, 256, 512, 1024, 2048, 4096, 8K, or 16K. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from one of its PCIC chips **269** to each of the third HBM IC chips **251-3** of its first memory module **159-1** next to said one of its PCIC chips **269** and compose a data bus between said one of its PCIC chips **269** and said each of the third HBM IC chips **251-3** of its first memory module **159-1** having a data bit width of equal to or greater than 64, 128, 256, 512, 1024, 2048, 4096, 8K, or 16K. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its PCIC chips **269** to its IAC chip **402**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its PCIC chips **269** to its NVM IC chip **250**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from its NVM IC chip **250** to its IAC chip **402**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from its NVM IC chip **250** to all of its first, second and third HBM IC chips **251-1**, **251-2** and **251-3**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from its IAC chip **402** to all of its first, second and third HBM IC chips **251-1**, **251-2** and **251-3**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from its IAC chip **402** to its first and/or second memory modules **159-1** and/or **159-2**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its first, second and third HBM IC chips **251-1**, **251-2** and **251-3** to the others of its first, second and third HBM IC chips **251-1**, **251-2** and **251-3**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from one of its PCIC chips **269** to the other of its PCIC chips **269**.

[0229] Accordingly, referring to FIG. **10A**, for the first type of standard commodity logic drive **300**, the standard commodity FPGA IC chip **200** of a first one of its operation modules **190** may have a first one of the programmable logic cells (LC) **2014**, as illustrated in FIG. **6A**, to transmit

the output Dout of the first one of the programmable logic cells (LC) **2014** to one of the inputs A0-A1 of a second one of the programmable logic cells (LC) **2014**, as illustrated in FIG. 6A, of the standard commodity FPGA IC chip **200** of a second one of its operation modules **190** through one of the cross-point switches **379** of one of its DPIIC chips **410**. The output Dout of the first one of the programmable logic cells (LC) **2014** may be passed to said one of the inputs A0-A1 of the second one of the programmable logic cells (LC) **2014** through, in sequence, (1) the programmable interconnects **361** of the intra-chip interconnects **502** of the standard commodity FPGA IC chip **200** of the first one of its operation modules **190**, (2) a first group of programmable interconnects **361** of its inter-chip interconnects **371**, (3) a first group of programmable interconnects **361** of the intra-chip interconnects of said one of its DPIIC chips **410**, (4) said one of the cross-point switches **379** of said one of its DPIIC chips **410**, (5) a second group of programmable interconnects **361** of the intra-chip interconnects of said one of its DPIIC chips **410**, (6) a second group of programmable interconnects **361** of its inter-chip interconnects **371** and (7) the programmable interconnects **361** of the intra-chip interconnects **502** of the standard commodity FPGA IC chip **200** of the second one of its operation modules **190**.

[0230] Alternatively, referring to FIGS. 10A, for the first type of standard commodity logic drive **300**, the standard commodity FPGA IC chip **200** of one of its operation modules **190** may have a first one of the programmable logic cells (LC) **2014**, as illustrated in FIG. 6A, to transmit the output Dout of the first one of the programmable logic cells (LC) **2014** to one of the inputs A0-A1 of a second one of the programmable logic cells (LC) **2014**, as illustrated in FIG. 6A, of the standard commodity FPGA IC chip **200** of said one of its operation modules **190** through one of the cross-point switches **379** of one of its DPIIC chips **410**. The output Dout of the first one of the programmable logic cells (LC) **2014** may be passed to one of the inputs A0-A1 of the second one of the programmable logic cells (LC) **2014** through, in sequence, (1) a first group of programmable interconnects **361** of the intra-chip interconnects **502** of the standard commodity FPGA IC chip **200** of said one of its operation modules **190**, (2) a first group of programmable interconnects **361** of its inter-chip interconnects **371**, (3) a first group of programmable interconnects **361** of the intra-chip interconnects of said one of its DPIIC chips **410**, (4) said one of the cross-point switches **379** of said one of its DPIIC chips **410**, (5) a second group of programmable interconnects **361** of the intra-chip interconnects of said one of its DPIIC chips **410**, (6) a second group of programmable interconnects **361** of its inter-chip interconnects **371** and (7) a second group of programmable interconnects **361** of the intra-chip interconnects **502** of the standard commodity FPGA IC chip **200** of said one of its operation modules **190**.

[0231] Referring to FIG. 10A, the first type of standard commodity logic drive **300** may include multiple dedicated control and input/output (I/O) chips **265** in a peripheral region thereof surrounding a central region thereof having its NVM IC chip **250**, IAC chip **402**, PCIC chips **269**, first HBM IC chips **251-1**, DPIIC chips **410**, first memory module **159-1** and operation modules **190** located therein. For the first type of standard commodity logic drive **300**, one or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from the standard commodity FPGA IC chip **200** of each of its operation modules **190** to all of its dedicated control and input/output (I/O) chips **265**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its DPIIC chips **410** to all of its dedicated control and input/output (I/O) chips **265**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from its NVM IC chip **250** to all of its dedicated control and input/output (I/O) chips **265**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from its IAC chip **402** to all of its dedicated control and input/output (I/O) chips **265**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its PCIC chips **269** to all of its dedicated control and input/output (I/O) chips **265**. One or more

of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its first, second and third HBM IC chips **251-1**, **251-2** and **251-3** to all of its dedicated control and input/output (I/O) chips **265**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its dedicated control and input/output (I/O) chips **265** to the others of its dedicated control and input/output (I/O) chips **265**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its first and/or second memory modules **159-1** and/or **159-2** to all of its dedicated control and input/output (I/O) chips **265**.

[0232] Referring to FIG. **10A**, for the first type of standard commodity logic drive **300**, the standard commodity FPGA IC chip **200** of each of its operation modules **190** may be referred to one as illustrated in FIGS. **8A** and **8B** and each of its DPIIC chips **410** may be referred to one as illustrated in FIG. **9**. Its IAC chip **402** may include intellectual property (IP) circuits, application specific (AS) circuits, analog circuits, mixed-mode signal circuits, radio-frequency (RF) circuits and/or transmitter, receiver, transceiver circuits. Its NVM IC chip **250** may be a NAND flash chip. Data stored in its NVM IC chip **250** may be kept even if the first type of standard commodity logic drive **300** is powered off. Alternatively, its NVM IC chip **250** may be a Non-Volatile Radom-Access-Memory (NVRAM) IC chip. The NVRAM may be a Ferroelectric RAM (FRAM), Magnetoresistive RAM (MRAM), or Phase-change RAM (PRAM). Its NVM IC chip **250** may have a standard memory density, capacity or size of greater than or equal to 64 Mb, 512 Mb, 1 Gb, 4 Gb, 16 Gb, 64 Gb, 128 Gb, 256 Gb, or 512 Gb, wherein “b” is bits.

[0233] Referring to FIG. **10A**, for the first type of standard commodity logic drive **300**, the voltage V_{cc} of power supply for each of its dedicated control and input/output (I/O) chips **265** may be greater than or equal to 1.5V, 2.0V, 2.5V, 3V, 3.5V, 4V, or 5V, while the voltage V_{cc} of power supply for the standard commodity FPGA IC chip **200** of each of its operation modules **190** and for its DPIIC chips **410** may be between 0.2V and 2.5V, between 0.2V and 2V, between 0.2V and 1.5V, between 0.1V and 1V, or between 0.2V and 1V, or smaller or lower than or equal to 2.5V, 2V, 1.8V, 1.5V or 1V. The gate oxide (physical) thickness of the Field-Effect-Transistors (FETs) of each of its control and input/output (I/O) chips **265** may be thicker than or equal to 5 nm, 6 nm, 7.5 nm, 10 nm, 12.5 nm, or 15 nm, while the gate oxide (physical) thickness of FETs of the standard commodity FPGA IC chip **200** of each of its operation modules **190** and of its DPIIC chips **410** may be thinner than 4.5 nm, 4 nm, 3 nm or 2 nm.

[0234] Referring to FIG. **10A**, for the first type of standard commodity logic drive **300**, each of its dedicated control and input/output (I/O) chips **265** may be designed, implemented and fabricated using varieties of semiconductor technology nodes or generations, including old or matured technology nodes or generations, for example, a semiconductor node or generation less advanced than or equal to, or more mature than 20 nm or 30 nm, and for example using the technology node of 22 nm, 28 nm, 40 nm, 90 nm, 130 nm, 180 nm, 250 nm, 350 nm or 500 nm. The semiconductor technology node or generation used in each of its dedicated control and input/output (I/O) chips **265** is 1, 2, 3, 4, 5 or greater than 5 nodes or generations older, more matured or less advanced than that used in the standard commodity FPGA IC chip **200** of each of its operation modules **190** and each of its DPIIC chips **410**. Transistors or semiconductor devices used in each of its dedicated control and input/output (I/O) chips **265** may be a Fully Depleted Silicon-on-insulator (FDSOI) MOSFET, a Partially Depleted Silicon-on-insulator (PDSOI) MOSFET or a conventional MOSFET.

[0235] Referring to FIG. **10A**, for the first type of standard commodity logic drive **300**, each of its PCIC chips **269** may be designed, implemented and fabricated using an advanced semiconductor technology node or generation, for example more advanced than or equal to, or below or equal to 30 nm, 20 nm or 10 nm, and for example using the technology node of 28 nm, 22 nm, 16 nm, 14 nm, 12 nm, 10 nm, 7 nm, 5 nm or 3 nm, which may be the same as, one generation or node less

advanced than or one generation or node more advanced than that used for the standard commodity FPGA IC chip **200** of each of its operation modules **190** and each of its DPIIC chips **410**. Transistors or semiconductor devices used in its PCIC chip **269** may be a FIN Field-Effect-Transistor (FINFET), a FINFET on Silicon-On-Insulator (FINFET SOI), a Fully Depleted Silicon-On-Insulator (FDSOI) MOSFET, a Partially Depleted Silicon-On-Insulator (PDSOI) MOSFET or a conventional MOSFET.

[0236] Referring to FIG. **10A**, for the first type of standard commodity logic drive **300**, each of its dedicated control and input/output (I/O) chip(s) **165** may arrange a plurality of large I/O circuits **341** and I/O pads **272** as seen in FIG. **5A** to employ one or multiple (2, 3, 4, or more than 4) Universal Serial Bus (USB) ports, one or more IEEE 1394 ports, one or more Ethernet ports, one or more HDMI ports, one or more VGA ports, one or more audio ports or serial ports, for example, RS-232 or COM (communication) ports, wireless transceiver I/Os, and/or Bluetooth transceiver I/Os, and etc. Further, each of its dedicated control and input/output (I/O) chips **165** may have a plurality of large I/O circuits **341** and I/O pads **272** as seen in FIG. **5A** to employ Serial Advanced Technology Attachment (SATA) ports, or Peripheral Components Interconnect express (PCIe) ports to communicate, connect or couple with a memory device.

II. Second Type of Standard Commodity Logic Drive

[0237] FIG. **10B** is a schematically top view showing arrangement for various chips packaged in a second type of standard commodity logic drive in accordance with an embodiment of the present application. For an element indicated by the same reference number shown in FIGS. **10A** and **10B**, the specification of the element as seen in FIG. **10B** and the process for forming the same may be referred to that of the element as illustrated in FIG. **10A** and the process for forming the same.

[0238] Referring to FIG. **10B**, a second type of standard commodity logic drive **300** may be packaged with multiple GPU chips **269a** and a CPU chip **269b** for the PCIC chips **269** as above mentioned. Further, the second type of standard commodity logic drive **300** may be packaged with multiple first high-bitwidth-memory (HBM) integrated-circuit (IC) chips **251-1** each arranged next to one of the GPU chips **269a** for communication with said one of the GPU chips **269a** in a high speed, high bandwidth and wide bitwidth. The second type of standard commodity logic drive **300** may be further packaged with an operation module **190** as seen in FIG. **18H** therein. For the operation module **190** of the second type of standard commodity logic drive **300**, a standard commodity FPGA IC chip **200** as illustrated in FIGS. **8A** and **8B** is provided at a bottom thereof, and a second high bandwidth memory (HBM) IC chip **251-2** or a second memory module **159-2** as seen in FIG. **15A** or **15B** may be provided over its standard commodity FPGA IC chip **200**, and thereby its standard commodity FPGA IC chip **200** may operate with its second HBM IC chip **251-2** or multiple third HBM IC chips **251-3** of its second memory module **159-2** for high speed, high bandwidth, wide bitwidth parallel processing and/or parallel computing. A data bus between its standard commodity FPGA IC chip **200** and its second HBM IC chip **251-2**, or each of the third HBM IC chips **251-3** of its second memory module **159-2**, may have a data bit width of equal to or greater than 64, 128, 256, 512, 1024, 2048, 4096, 8K, or 16K.

[0239] Referring to FIG. **10B**, the second type of standard commodity logic drive **300** may be further packaged with a plurality of NVM IC chips **250** configured to store the resulting values or programming codes in a non-volatile manner for programming the programmable logic cells (LC) **2014** or cross-point switches **379** of the standard commodity FPGA IC chip **200** of each of its operation modules **190**, as illustrated in FIGS. **6A-6D**, **7**, **8A** and **8B**. The resulting values and programming codes stored in its NVM IC chips **250** may be passed to and stored in the memory cells **490** and **362** of the standard commodity FPGA IC chip **200** of each of its operation modules **190**. The second type of standard commodity logic drive **300** may be further packaged with a first memory module **159-1** as illustrated in FIG. **15A** or **15B**, configured to be access by one of its GPU chips **269a**, its CPU chip **269b** and the standard commodity FPGA IC chip **200** of one of its operation modules **190** next to its first memory module **159-1** for signal transmission in a high

bandwidth or bitwidth.

[0240] Referring to FIG. 10B, the second type of standard commodity logic drive **300** may include multiple inter-chip interconnects **371** each extending under spaces between neighboring two of its NVM IC chips **250**, IAC chip **402**, GPU chips **269a**, CPU chip **269b**, first HBM IC chips **251**, first memory module **159-1** and operation modules **190**. The second type of standard commodity logic drive **300** may include a plurality of DPIIC chip **410** as illustrated in FIG. 9 each aligned with a cross of a vertical bundle of its inter-chip interconnects **371** and a horizontal bundle of its inter-chip interconnects **371**.

[0241] Referring to FIG. 10B, for the second type of standard commodity logic drive **300**, each of its inter-chip interconnects **371** may be a non-programmable interconnect **364** for programming one or more of the memory cells **362** and **490** of the standard commodity FPGA IC chip **200** of one of its operation modules **190** or one or more of the memory cells **362** of one of its DPIIC chip **410**, or a programmable interconnect **361** configured to be programmed by one or more of the memory cells **362** of the standard commodity FPGA IC chip **200** of one of its operation modules **190** or one or more of the memory cells **362** of one of its DPIIC chip **410**. Signal transmission may be built (1) between one of the programmable interconnects **361** of its inter-chip interconnects **371** and one of the programmable interconnects **361** of the intra-chip interconnects **371** of the standard commodity FPGA IC chip **200** of one of its operation modules **190** via one of the small input/output (I/O) circuits **203** of the standard commodity FPGA IC chip **200** of said one of its operation modules **190**, and (2) between one of the programmable interconnects **361** of its inter-chip interconnects **371** and one of the programmable interconnects **361** of the intra-chip interconnects of one of its DPIIC chips **410** via one of the small input/output (I/O) circuits **203** of said one of its DPIIC chips **410**. Signal transmission may be built (1) between one of the non-programmable interconnects **364** of its inter-chip interconnects **371** and one of the non-programmable interconnects **364** of the intra-chip interconnects **502** of the standard commodity FPGA IC chip **200** of one of its operation modules **190** via one of the small input/output (I/O) circuits **203** of the standard commodity FPGA IC chip **200** of said one of its operation modules **190**, and (2) between one of the non-programmable interconnects **364** of its inter-chip interconnects **371** and one of the non-programmable interconnects **364** of the intra-chip interconnects of one of its DPIIC chips **410** via one of the small input/output (I/O) circuits **203** of said one of its DPIIC chips **410**. For the second type of standard commodity logic drive **300**, its NVM IC chips **250** are configured to store the programming codes in a non-volatile manner for programming the cross-point switches **379** of its DPIIC chips **410**, as illustrated in FIGS. 7 and 9. The programming codes stored in its NVM IC chips **250** may be passed to and stored in the memory cells **362** of its DPIIC chips **410**.

[0242] Referring to FIG. 10B, for the second type of standard commodity logic drive **300**, one or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from the standard commodity FPGA IC chip **200** of each of its operation modules **190** to all of its DPIIC chips **410**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from the standard commodity FPGA IC chip **200** of each of its operation modules **190** to its IAC chip **402**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from the standard commodity FPGA IC chip **200** of each of its operation modules **190** to all of its NVM IC chips **250**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from the standard commodity FPGA IC chip **200** of each of its operation modules **190** to all of its GPU chips **269a**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from the standard commodity FPGA IC chip **200** of each of its operation modules **190** to its CPU chip **269b**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from the standard commodity FPGA IC chip **200** of one of its operation modules **190** to one of its first HBM

IC chips **251-1** next to the standard commodity FPGA IC chip **200** of said one of its operation modules **190** and compose a data bus between the standard commodity FPGA IC chip **200** of said one of its operation modules **190** and said one of its first HBM IC chips **251-1** having a data bit width of equal to or greater than 64, 128, 256, 512, 1024, 2048, 4096, 8K, or 16K. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from the standard commodity FPGA IC chip **200** of one of its operation modules **190** to each of the third HBM IC chips **251-3** of its first memory module **159-1** next to said one of its operation modules **190** and compose a data bus between the standard commodity FPGA IC chip **200** of said one of its operation modules **190** and said each of the third HBM IC chips **251-3** of its first memory module **159-1** having a data bit width of equal to or greater than 64, 128, 256, 512, 1024, 2048, 4096, 8K, or 16K. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from the standard commodity FPGA IC chip **200** of one of its operation modules **190** to the standard commodity FPGA IC chip **200** of each of the others of its operation modules **190**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its DPIIC chips **410** to its IAC chip **402**. One or more the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its DPIIC chips **410** to all of its NVM IC chips **250**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its DPIIC chips **410** to all of its GPU chips **269a**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its DPIIC chips **410** to its CPU chip **269b**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its DPIIC chips **410** to both of its first HBM IC chips **251-1**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its DPIIC chips **410** to each of the third HBM IC chips **251-3** of its first memory module **159-1**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its DPIIC chips **410** to the second HBM IC chip **251-2** of each of its operation modules **190**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its DPIIC chips **410** to all of the third HBM IC chips **251-3** of the second memory module **159-2** of each of its operation modules **190**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its DPIIC chips **410** to the others of its DPIIC chips **410**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from its CPU chip **269b** to all of its GPU chips **269a**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from its CPU chip **269b** to all of its NVM IC chips **250**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from its CPU chip **269b** to all of its first, second and third HBM IC chips **251-1**, **251-2** and **251-3**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from its CPU chip **269b** to one of its first HBM IC chips **251-1** next to its CPU chip **269b** and composes a data bus between its CPU chip **269b** and said one of its first HBM IC chips **251-1** having a data bit width of equal to or greater than 64, 128, 256, 512, 1024, 2048, 4096, 8K, or 16K. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from its CPU chip **269b** to each of the third HBM IC chips **251-3** of its first memory module **159-1** next to its CPU chip **269b** and compose a data bus between its CPU chip **269b** and said each of the third HBM IC chips **251-3** of its first memory module **159-1** having a data bit width of equal to or greater than 64, 128, 256, 512, 1024, 2048, 4096, 8K, or 16K. One or more of the programmable or non-programmable

interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its GPU chips **269a** to all of its first, second and third HBM IC chips **251-1**, **251-2** and **251-3**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from one of its GPU chips **269a** to one of its first HBM IC chips **251-1** next to said one of its GPU chips **269a** and composes a data bus between said one of its GPU chips **269a** and said one of its first HBM IC chips **251-1** having a data bit width of equal to or greater than 64, 128, 256, 512, 1024, 2048, 4096, 8K, or 16K. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from one of its GPU chips **269a** to each of the third HBM IC chips **251-3** of its first memory module **159-1** next to said one of its GPU chips **269a** and compose a data bus between said one of its GPU chips **269a** and said each of the third HBM IC chips **251-3** of its first memory module **159-1** having a data bit width of equal to or greater than 64, 128, 256, 512, 1024, 2048, 4096, 8K, or 16K. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its GPU chips **269a** to all of its NVM IC chips **250**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its GPU chips **269a** to the others of its GPU chips **269a**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its NVM IC chips **250** to its IAC chip **402**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from its IAC chip **402** to all of its first, second and third HBM IC chips **251-1**, **251-2** and **251-3**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its first and/or second memory modules **159-1** and/or **159-2** to its IAC chip **402**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its GPU chips **269a** to its IAC chip **402**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from its CPU chip **269b** to its IAC chip **402**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its NVM IC chips **250** to all of its first, second and third HBM IC chips **251-1**, **251-2** and **251-3**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its NVM IC chips **250** to all of its first and/or second memory modules **159-1** and/or **159-2**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its NVM IC chips **250** to the others of its NVM IC chips **250**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its first, second and third HBM IC chips **251-1**, **251-2** and **251-3** to the others of its first, second and third HBM IC chips **251-1**, **251-2** and **251-3**.

[0243] Referring to FIG. **10B**, the second type of standard commodity logic drive **300** may include multiple dedicated control and input/output (I/O) chips **265** in a peripheral region thereof surrounding a central region thereof having its NVM IC chips **250**, IAC chip **402**, GPU chips **269a**, CPU chip **269b**, first HBM IC chips **251-1**, DPIIC chips **410**, first memory module **159-1** and operation modules **190** located therein. For the second type of standard commodity logic drive **300**, one or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from the standard commodity FPGA IC chip **200** of each of its operation modules **190** to all of the dedicated control and input/output (I/O) chips **265**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its DPIIC chips **410** to all of its dedicated control and input/output (I/O) chips **265**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its NVM IC chips **250** to all of its dedicated control and input/output (I/O) chips **265**. One or more of the programmable or non-

programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from its IAC chip **402** to all of its dedicated control and input/output (I/O) chips **265**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its GPU chips **269a** to all of its dedicated control and input/output (I/O) chips **265**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from its CPU chip **269b** to all of its dedicated control and input/output (I/O) chips **265**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its first, second and third HBM IC chips **251-1**, **251-2** and **251-3** to all of its dedicated control and input/output (I/O) chips **265**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its first and/or second memory modules **159-1** and/or **159-2** to all of its dedicated control and input/output (I/O) chips **265**.

[0244] Referring to FIG. **10B**, for the second type of standard commodity logic drive **300**, the standard commodity FPGA IC chip **200** of each of its operation modules **190** may be referred to one as illustrated in FIGS. **8A** and **8B**, and each of its DPIIC chips **410** may be referred to one as illustrated in FIG. **9**. Its IAC chip **402** may include intellectual property (IP) circuits, application specific (AS) circuits, analog circuits, mixed-mode signal circuits, radio-frequency (RF) circuits and/or transmitter, receiver, transceiver circuits. Each of its NVM IC chip **250** may be a NAND flash chip. Data stored in its NVM IC chips **250** may be kept even if the second type of standard commodity logic drive **300** is powered off. Alternatively, each of its NVM IC chips **250** may be a Non-Volatile Random-Access-Memory (NVRAM) IC chip. The NVRAM may be a Ferroelectric RAM (FRAM), Magnetoresistive RAM (MRAM), or Phase-change RAM (PRAM). Each of its NVM IC chips **250** may have a standard memory density, capacity or size of greater than or equal to 64 Mb, 512 Mb, 1 Gb, 4 Gb, 16 Gb, 64 Gb, 128 Gb, 256 Gb, or 512 Gb, wherein “b” is bits. III. Third Type of Standard Commodity Logic Drive

III. Third Type of Standard Commodity Logic Drive

[0245] FIG. **10C** is a schematically top view showing arrangement for various chips packaged in a third type of standard commodity logic drive in accordance with an embodiment of the present application. For an element indicated by the same reference number shown in FIGS. **10A-10C**, the specification of the element as seen in FIG. **10C** and the process for forming the same may be referred to that of the element as illustrated in FIG. **10A** or **10B** and the process for forming the same.

[0246] Referring to FIG. **10C**, a third type of standard commodity logic drive **300** may be packaged with an NVM IC chip **250** and multiple operation modules **190** each as seen in FIG. **18H** arranged in an array, wherein its NVM IC chip **250** is surrounded by its operation modules **190**. For the operation module **190** of the third type of standard commodity logic drive **300**, a standard commodity FPGA IC chip **200** as illustrated in FIGS. **8A** and **8B** is provided at a bottom thereof, and a second high bandwidth memory (HBM) IC chip **251-2** or a second memory module **159-2** as seen in FIG. **15A** or **15B** may be provided over its standard commodity FPGA IC chip **200**, and thereby its standard commodity FPGA IC chip **200** may operate with its second HBM IC chip **251-2** or multiple third HBM IC chips **251-3** of its second memory module **159-2** for high speed, high bandwidth, wide bitwidth parallel processing and/or parallel computing. A data bus between its standard commodity FPGA IC chip **200** and its second HBM IC chip **251-2**, or each of the third HBM IC chips **251-3** of its second memory module **159-2**, may have a data bit width of equal to or greater than 64, 128, 256, 512, 1024, 2048, 4096, 8K, or 16K.

[0247] Referring to FIG. **10C**, for the third type of standard commodity logic drive **300**, its NVM IC chip **250** is configured to store the resulting values and programming codes in a non-volatile manner for programming the programmable logic cells (LC) **2014** and cross-point switches **379** of the standard commodity FPGA IC chip **200** of each of its operation modules **190**, as illustrated in

FIGS. 6A-6D, 7, 8A and 8B. The resulting values and programming codes stored in its NVM IC chip **250** may be passed to and stored in the memory cells **490** and **362** of the standard commodity FPGA IC chip **200** of each of its operation modules **190**.

[0248] Referring to FIG. **10C**, the third type of standard commodity logic drive **300** may include multiple inter-chip interconnects **371** each extending under spaces between neighboring two of its operation modules **190**. For the third type of standard commodity logic drive **300**, each of its inter-chip interconnects **371** may be a non-programmable interconnect **364** for programing one or more of the memory cells **362** and **490** of the standard commodity FPGA IC chip **200** of one of its operation modules **190**, or a programmable interconnect **361** configured to be programmed by one or more of the memory cells **362** of the standard commodity FPGA IC chip **200** of one of its operation modules **190**. Signal transmission may be built (1) between one of the programmable interconnects **361** of its inter-chip interconnects **371** and one of the programmable interconnects **361** of the intra-chip interconnects **371** of the standard commodity FPGA IC chip **200** of one of its operation modules **190** via one of the small input/output (I/O) circuits **203** of the standard commodity FPGA IC chip **200** of said one of its operation modules **190**. Signal transmission may be built (1) between one of the non-programmable interconnects **364** of its inter-chip interconnects **371** and one of the non-programmable interconnects **364** of the intra-chip interconnects **502** of the standard commodity FPGA IC chip **200** of one of its operation modules **190** via one of the small input/output (I/O) circuits **203** of the standard commodity FPGA IC chip **200** of said one of its operation modules **190**.

[0249] Referring to FIG. **10C**, for the third type of standard commodity logic drive **300**, one or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from the standard commodity FPGA IC chip **200** of one of its operation modules **190** to the standard commodity FPGA IC chip **200** of each of the others of its operation modules **190**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from the standard commodity FPGA IC chip **200** of one of its operation modules **190** to all of the third HBM IC chips **251-3** of the second memory module **159-2**, or the second HBM IC chip **251-2**, of each of the others of its operation modules **190**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of the third HBM IC chips **251-3** of the second memory module **159-2**, or the second HBM IC chip **251-2**, of one of its operation modules **190** to all of the third HBM IC chips **251-3** of the second memory module **159-2**, or the second HBM IC chip **251-2**, of each of the others of its operation modules **190**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from the standard commodity FPGA IC chip **200** of each of its operation modules **190** to its NVM IC chip **250**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of the third HBM IC chips **251-3** of the second memory module **159-2**, or the second HBM IC chip **251-2**, of each of its operation modules **190** to its NVM IC chip **250**.

[0250] Referring to FIG. **10C**, the third type of standard commodity logic drive **300** may include multiple dedicated control and input/output (I/O) chips **265** in a peripheral region thereof surrounding a central region thereof having its operation modules **190** and NVM IC chip **250** located therein. For the third type of standard commodity logic drive **300**, one or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from the standard commodity FPGA IC chip **200** of each of its operation modules **190** to all of the dedicated control and input/output (I/O) chips **265**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of the third HBM IC chips **251-3** of the second memory module **159-2**, or the second HBM IC chip **251-2**, of each of its operation modules **190** to all of the dedicated control and input/output (I/O) chips **265**.

[0251] Referring to FIG. 10C, for the third type of standard commodity logic drive **300**, the standard commodity FPGA IC chip **200** of each of its operation modules **190** may be referred to one as illustrated in FIGS. 8A and 8B. Its NVM IC chip **250** may be a NAND flash chip. Data stored in its NVM IC chip **250** may be kept even if the third type of standard commodity logic drive **300** is powered off. Alternatively, its NVM IC chip **250** may be a Non-Volatile Random-Access-Memory (NVRAM) IC chip. The NVRAM may be a Ferroelectric RAM (FRAM), Magnetoresistive RAM (MRAM), or Phase-change RAM (PRAM).

[0252] Referring to FIG. 10C, one or more of the programmable interconnects **361** of its inter-chip interconnects **371** may couple one or more of the small I/O circuits **203** of each of its dedicated control and input/output (I/O) chips **265** to one or more of the small I/O circuits **203** of the standard commodity FPGA IC chip **200** of each of its operation modules **190**. One or more of the non-programmable interconnects **364** of the inter-chip interconnects **371** may couple one or more of the small I/O circuits **203** of each of its dedicated control and input/output (I/O) chips **265** to one or more of the small I/O circuits **203** of the standard commodity FPGA IC chip **200** of each of its operation modules **190**. One or more of the programmable interconnects **361** of its inter-chip interconnects **371** may couple one or more of the small I/O circuits **203** of the standard commodity FPGA IC chip **200** of each of its operation modules **190** to one or more of the small I/O circuits **203** of the standard commodity FPGA IC chip **200** of another of its operation modules **190**. One or more of the non-programmable interconnects **364** of its inter-chip interconnects **371** may couple one or more of the small I/O circuits **203** of the standard commodity FPGA IC chip **200** of each of its operation modules **190** to one or more of the small I/O circuits **203** of the standard commodity FPGA IC chip **200** of another of the others of its operation modules **190**. One or more of the non-programmable interconnects **364** of its inter-chip interconnects **371** may couple one or more of the large I/O circuits **341** of each of its dedicated control and input/output (I/O) chips **265** to one or more of the large I/O circuits **341** of another of its dedicated control and input/output (I/O) chips **265**. One or more of the large I/O circuits **341** of each of its dedicated control and input/output (I/O) chips **265** may couple to the external circuitry outside the third type of standard commodity logic drive **300**.

IV. Fourth Type of Standard Commodity Logic Drive

[0253] FIG. 10D is a schematically top view showing arrangement for various chips packaged in a fourth type of standard commodity logic drive in accordance with an embodiment of the present application. For an element indicated by the same reference number shown in FIGS. 10A-10D, the specification of the element as seen in FIG. 10D and the process for forming the same may be referred to that of the element as illustrated in FIG. 10A, 10B or 10C and the process for forming the same. The third and fourth types of standard commodity logic drive **300** as seen in FIGS. 10C and 10D respectively are similar to each other, and the specification for the fourth type of standard commodity logic drive **300** may be referred to that for the third type of standard commodity logic drive **300**. The difference between the third and fourth types of standard commodity logic drive **300** as seen in FIGS. 10C and 10D respectively is that the fourth type of standard commodity logic drive **300** may further include a plurality of dedicated-programmable-interconnection (DPI) integrated-circuit (IC) chips **410** as illustrated in FIG. 9 each aligned with a cross of a vertical bundle of its inter-chip interconnects **371** and a horizontal bundle of its inter-chip interconnects **371**.

[0254] Referring to FIG. 10A, for the fourth type of standard commodity logic drive **300**, each of its inter-chip interconnects **371** may be a non-programmable interconnect **364** for programming one or more of the memory cells **362** and **490** of the standard commodity FPGA IC chip **200** of one of its operation modules **190** or one or more of the memory cells **362** of one of its DPIIC chips **410**, or a programmable interconnect **361** configured to be programmed by one or more of the memory cells **362** of the standard commodity FPGA IC chip **200** of one of its operation modules **190** or one or more of the memory cells **362** of one of its DPIIC chips **410**. Signal transmission may be further

built between one of the programmable interconnects **361** of its inter-chip interconnects **371** and one of the programmable interconnects of the intra-chip interconnects of one of its DPIIC chips **410** via one of the small input/output (I/O) circuits **203** of said one of its DPIIC chips **410**. Signal transmission may be further built between one of the non-programmable interconnects **364** of its inter-chip interconnects **371** and one of the non-programmable interconnects of the intra-chip interconnects of one of its DPIIC chips **410** via one of the small input/output (I/O) circuits **203** of said one of its DPIIC chips **410**. For the fourth type of standard commodity logic drive **300**, its NVM IC chip **250** is configured to store the programming codes in a non-volatile manner for programming the cross-point switches **379** of its DPIIC chips **410**, as illustrated in FIGS. **7** and **9**. The programming codes stored in its NVM IC chip **250** may be passed to and stored in the memory cells **362** of its DPIIC chips **410**.

[0255] Referring to FIG. **10D**, for the fourth type of standard commodity logic drive **300**, one or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from the standard commodity FPGA IC chip **200** of each of its operation modules **190** to all of its DPIIC chips **410**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its DPIIC chips **410** to its NVM IC chip **250**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its DPIIC chips **410** to the others of its DPIIC chips **410**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its DPIIC chips **410** to all of the third HBM IC chips **251-3** of the second memory module **159-2**, or the second HBM IC chip **251-2**, of each of its operation modules **190**. One or more of the programmable or non-programmable interconnects **361** or **364** of its inter-chip interconnects **371** may couple from each of its DPIIC chips **410** to all of its dedicated control and input/output (I/O) chips **265**.

[0256] Referring to FIG. **10D**, for the fourth type of standard commodity logic drive **300**, the standard commodity FPGA IC chip **200** of each of its operation modules **190** may be referred to one as illustrated in FIGS. **8A** and **8B** and each of its DPIIC chips **410** may be referred to one as illustrated in FIG. **9**. Its NVM IC chip **250** may be a NAND flash chip. Data stored in its NVM IC chip **250** may be kept even if the first type of standard commodity logic drive **300** is powered off. Alternatively, its NVM IC chip **250** may be a Non-Volatile Random-Access-Memory (NVRAM) IC chip. The NVRAM may be a Ferroelectric RAM (FRAM), Magnetoresistive RAM (MRAM), or Phase-change RAM (PRAM).

Interconnection for Standard Commodity Logic Drive

[0257] FIG. **11** is a block diagram showing interconnection between chips in a standard commodity logic drive in accordance with an embodiment of the present application. Referring to FIG. **11**, each of two blocks **200** may be a combination of the standard commodity FPGA IC chip(s) **200** of one or more of the operation modules **190** of the first, second or fourth type of standard commodity logic drive **300** illustrated in FIG. **10A**, **10B** or **10D**; a block **410** may be a combination of the DPIIC chips **410** in the first, second or fourth type of standard commodity logic drive **300** illustrated in FIG. **10A**, **10B** or **10D**; a block **360** may be a combination of the dedicated control and input/output (I/O) chips **265** in the first, second or fourth type of standard commodity logic drive **300** illustrated in FIG. **10A**, **10B** or **10D**.

[0258] Referring to FIG. **11**, for each of the first, second and fourth types of standard commodity logic drives **300** as illustrated in FIGS. **10A**, **10B** and **10D** respectively, one or more of the programmable interconnects **361** of its inter-chip interconnects **371** may couple one or more of the small I/O circuits **203** of each of its dedicated control and input/output (I/O) chips **265** in the block **360** to one or more of the small I/O circuits **203** of the standard commodity FPGA IC chip **200** of one of its operation modules **190**. One or more of the programmable interconnects **361** of its inter-chip interconnects **371** may couple one or more of the small I/O circuits **203** of each of its

dedicated control and input/output (I/O) chips **265** in the block **360** to one or more of the small I/O circuits **203** of one of its DPIIC chips **410**. One or more of the non-programmable interconnects **364** of the inter-chip interconnects **371** may couple one or more of the small I/O circuits **203** of each of its dedicated control and input/output (I/O) chips **265** in the block **360** to one or more of the small I/O circuits **203** of the standard commodity FPGA IC chip **200** of one of its operation modules **190**. One or more of the non-programmable interconnects **364** of the inter-chip interconnects **371** may couple one or more of the small I/O circuits **203** of each of its dedicated control and input/output (I/O) chips **265** in the block **360** to one or more of the small I/O circuits **203** of one of its DPIIC chips **410**.

[0259] Referring to FIG. **11**, for each of the first, second and fourth types of standard commodity logic drives **300** as illustrated in FIGS. **10A**, **10B** and **10D** respectively, one or more of the programmable interconnects **361** of its inter-chip interconnects **371** may couple one or more of the small I/O circuits **203** of each of its DPIIC chips **410** to one or more of the small I/O circuits **203** of the standard commodity FPGA IC chip **200** of one of its operation modules **190**. One or more of the programmable interconnects **361** of its inter-chip interconnects **371** may couple one or more of the small I/O circuits **203** of each of its DPIIC chips **410** to one or more of the small I/O circuits **203** of another of its DPIIC chips **410**. One or more of the non-programmable interconnects **364** of the inter-chip interconnects **371** may couple one or more of the small I/O circuits **203** of each of its DPIIC chips **410** to one or more of the small I/O circuits **203** of the standard commodity FPGA IC chip **200** of one of its operation modules **190**. One or more of the non-programmable interconnects **364** of the inter-chip interconnects **371** may couple one or more of the small I/O circuits **203** of each of its DPIIC chips **410** to one or more of the small I/O circuits **203** of another of its DPIIC chips **410**.

[0260] Referring to FIG. **11**, for each of the first, second and fourth types of standard commodity logic drives **300** as illustrated in FIGS. **10A**, **10B** and **10D** respectively, one or more of the programmable interconnects **361** of its inter-chip interconnects **371** may couple one or more of the small I/O circuits **203** of the standard commodity FPGA IC chip **200** of each of its operation modules **190** to one or more of the small I/O circuits **203** of the standard commodity FPGA IC chip **200** of another of its operation modules **190**. One or more of the non-programmable interconnects **364** of its inter-chip interconnects **371** may couple one or more of the small I/O circuits **203** of the standard commodity FPGA IC chip **200** of each of its operation modules **190** to one or more of the small I/O circuits **203** of the standard commodity FPGA IC chip **200** of another of its operation modules **190**.

[0261] Referring to FIG. **11**, for each of the first, second and fourth types of standard commodity logic drives **300** as illustrated in FIGS. **10A**, **10B** and **10D** respectively, one or more of the non-programmable interconnects **364** of its inter-chip interconnects **371** may couple one or more of the large I/O circuits **341** of each of its dedicated control and input/output (I/O) chips **265** in the block **360** to one or more of the large I/O circuits **341** of another of its dedicated control and input/output (I/O) chips **265**. One or more of the large I/O circuits **341** of each of its dedicated control and input/output (I/O) chips **265** in the block **360** may couple to the external circuitry **271** outside the first, second or fourth type of standard commodity logic drive **300**.

(1) Interconnection for Operation

[0262] Referring to FIG. **11**, for each of the first, second and fourth types of standard commodity logic drives **300** as illustrated in FIGS. **10A**, **10B** and **10D** respectively, the standard commodity FPGA IC chip **200** of each of its operation modules **190** may reload resulting values or first programming codes from its non-volatile memory (NVM) IC chip(s) **250** to the memory cells **490** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190** via one or more of the non-programmable interconnects **364** of its intra-chip interconnects **502**, and thereby the resulting values or first programming codes may be stored or latched in the memory cells **490** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190** to program

the programmable logic cells (LC) **2014** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190** as illustrated in FIGS. **6A-6D**, **8A** and **8B**. The standard commodity FPGA IC chip **200** of said each of its operation modules **190** may reload second programming codes from its non-volatile memory (NVM) IC chip(s) **250** to the memory cells **362** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190** via one or more of the non-programmable interconnects **364** of its intra-chip interconnects **502**, and thereby the second programming codes may be stored or latched in the memory cells **362** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190** to program the pass/no-pass switches **258** or cross-point switches **379** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190** as illustrated in FIGS. **2A-2C**, **3A**, **3B**, **7**, **8A** and **8B**. Each of its DPIIC chips **410** may reload third programming codes from its non-volatile memory (NVM) IC chip(s) **250** to the memory cells **362** of said each of its DPIIC chips **410**, and thereby the third programming codes may be stored or latched in the memory cells **362** of said each of its DPIIC chips **410** to program the pass/no-pass switches **258** or cross-point switches **379** of said each of its DPIIC chips **410** as illustrated in FIGS. **2A-2C**, **3A**, **3B**, **7** and **9**.

[0263] Thereby, referring to FIG. **11**, one of the dedicated control and input/output (I/O) chips **265** of the first, second or fourth type of standard commodity logic drive **300** illustrated in FIG. **10A**, **10B** or **10D** may have one of its large I/O circuits **341** to drive data from the external circuitry **271** outside the first, second or fourth type of standard commodity logic drive **300** to one of its small I/O circuits **203**. For said one of the dedicated control and input/output (I/O) chips **265**, said one of its small I/O circuits **203** may drive the data to a first one of the small I/O circuits **203** of one of the DPIIC chips **410** of the first, second or fourth type of standard commodity logic drive **300** via one or more of the programmable interconnects **361** of the inter-chip interconnects **371** of the first, second or fourth type of standard commodity logic drive **300**. For said one of the dedicated DPIIC chips **410**, the first one of its small I/O circuits **203** may drive the data to one of its cross-point switches **379** via a first group of programmable interconnects **361** of its intra-chip interconnects; said one of its cross-point switches **379** may pass the data from the first group of programmable interconnects **361** of its intra-chip interconnects to a second group of programmable interconnects **361** of its intra-chip interconnects to be passed to a second one of its small I/O circuits **203**; the second one of its small I/O circuits **203** may drive the data to one of the small I/O circuits **203** of the standard commodity FPGA IC chip **200** of one of the operation modules **190** of the first, second or fourth type of standard commodity logic drive **300** via one or more of the programmable interconnects **361** of the inter-chip interconnects **371** of the first, second or fourth type of standard commodity logic drive **300**. For the standard commodity FPGA IC chip **200** of said one of its operation modules **190**, said one of its small I/O circuits **203** may drive the data to one of its cross-point switches **379** through a first group of programmable interconnects **361** of its intra-chip interconnects **502** as seen in FIGS. **2A-2C**, **3A**, **3B**, **7**, **8A** and **8B**; said one of its cross-point switches **379** may pass the data from the first group of programmable interconnects **361** of its intra-chip interconnects **502** to a second group of programmable interconnects **361** of its intra-chip interconnects **502** to be associated with a data input of the input data set, e.g., **A0** and **A1**, of one of its programmable logic cells (LC) **2014** as seen in FIGS. **6A-6D**, **8A** and **8B**.

[0264] Referring to FIG. **11**, in another aspect, for the standard commodity FPGA IC chip **200** of a first one of the operation modules **190** of the first, second or fourth type of standard commodity logic drive **300**, one of its programmable logic cells (LC) **2014** as seen in FIGS. **6A-6D**, **8A** and **8B** may have the data output, e.g., **Dout** as seen in FIG. **6A**, to be passed to one of its cross-point switches **379** via a first group of programmable interconnects **361** of its intra-chip interconnects **502**; said one of its cross-point switches **379** may pass data associated with the data output, e.g., **Dout**, of said one of its programmable logic cells (LC) **2014** from the first group of programmable interconnects **361** of its intra-chip interconnects **502** to a second group of programmable interconnects **361** of its intra-chip interconnects **502** to be passed to one of its small I/O circuits

203; said one of its small I/O circuits **203** may drive the data to a first one of the small I/O circuits **203** of one of the DPIIC chips **410** of the first, second or fourth type of standard commodity logic drive **300** via one or more of programmable interconnects **361** of the inter-chip interconnects **371** of the first, second or fourth type of standard commodity logic drive **300**. For said one of the DPIIC chips **410**, the first one of its small I/O circuits **203** may drive the data to one of its cross-point switches **379** via a first group of programmable interconnects **361** of its intra-chip interconnects; said one of its cross-point switches **379** may pass the data from the first group of programmable interconnects **361** of its intra-chip interconnects to a second group of programmable interconnects **361** of its intra-chip interconnects to be passed to a second one of its small I/O circuits **203**; the second one of its small I/O circuits **203** may drive the data to one of the small I/O circuits **203** of the standard commodity FPGA IC chip **200** of a second one of the operation modules **190** of the first, second or fourth type of standard commodity logic drive **300** via one or more of the programmable interconnects **361** of the inter-chip interconnects **371** of the first, second or fourth type of standard commodity logic drive **300**. For the standard commodity FPGA IC chip **200** of the second one of its operation modules **190**, said one of its small I/O circuits **203** may drive the data to one of its cross-point switches **379** through a first group of programmable interconnects **361** of its intra-chip interconnects **502**; said one of its cross-point switches **379** may pass the data from the first group of programmable interconnects **361** of its intra-chip interconnects **502** to a second group of programmable interconnects **361** of its intra-chip interconnects **502** to be associated with a data input of the input data set, e.g., **A0** and **A1** as seen in FIG. **6A**, of one of its programmable logic cells (LC) **2014** as seen in FIGS. **6A-6D**, **8A** and **8B**.

[0265] Referring to FIG. **11**, in another aspect, for the standard commodity FPGA IC chip **200** of one of the operation modules **190** of the first, second or fourth type of standard commodity logic drive **300**, one of its programmable logic cells (LC) **2014** as seen in FIGS. **6A-6D**, **8A** and **8B** may have the data output, e.g., **Dout** as seen in FIG. **6A**, to be passed to one of its cross-point switches **379** via a first group of programmable interconnects **361** of its intra-chip interconnects **502**; said one of its cross-point switches **379** may pass data associated with the data output, e.g., **Dout**, of said one of its programmable logic cells (LC) **2014** from the first group of programmable interconnects **361** of its intra-chip interconnects **502** to a second group of programmable interconnects **361** of its intra-chip interconnects **502** to be passed to one of its small I/O circuits **203**; said one of its small I/O circuits **203** may drive the data to a first one of the small I/O circuits **203** of one of the DPIIC chips **410** of the first, second or fourth type of standard commodity logic drive **300** via one or more of the programmable interconnects **361** of the inter-chip interconnects **371** of the first, second or fourth type of standard commodity logic drive **300**. For said one of the DPIIC chips **410**, the first one of its small I/O circuits **203** may drive the data to one of its cross-point switches **379** via a first group of programmable interconnects **361** of its intra-chip interconnects; said one of its cross-point switches **379** may pass the data from the first group of programmable interconnects **361** of its intra-chip interconnects to a second group of programmable interconnects **361** of its intra-chip interconnects to be passed to a second one of its small I/O circuits **203**; the second one of its small I/O circuits **203** may drive the data to one of the small I/O circuits **203** of one of the dedicated control and input/output (I/O) chips **265** of the first, second or fourth type of standard commodity logic drive **300** via one or more of programmable interconnects **361** of the inter-chip interconnects **371** of the first, second or fourth type of standard commodity logic drive **300**. For said one of the dedicated control and input/output (I/O) chips **265**, said one of its small I/O circuits **203** may drive the data to one of its large I/O circuits **341** to be passed to the external circuitry **271** outside the first, second or fourth type of standard commodity logic drive **300**.

(3) Accessibility

[0266] Referring to FIG. **11**, the external circuitry **271** outside the first, second or fourth type of standard commodity logic drive **300** may not be allowed to reload the resulting values and first,

second and third programming codes from any of the NVM IC chip(s) **250** of the first, second or fourth type of standard commodity logic drive **300**. Alternatively, the external circuitry **271** outside the first, second or fourth type of standard commodity logic drive **300** may be allowed to reload the resulting values and first, second and third programming codes from the NVM IC chip(s) **250** of the first, second or fourth type of standard commodity logic drive **300**.

Data and Control Buses for Expandable Logic Scheme Based on Standard Commodity FPGA IC Chips and/or High Bandwidth Memory (HBM) IC Chips

[0267] FIG. **12** is a block diagram illustrating multiple control buses for one or more standard commodity FPGA IC chips and multiple data buses for an expandable logic scheme based on one or more standard commodity FPGA IC chips and high bandwidth memory (HBM) IC chips in accordance with an embodiment of the present application. Referring to FIG. **12**, each of the first through third types of standard commodity logic drive **300** as seen in FIGS. **10A-10C** may be provided with multiple control buses **416** each constructed from multiple of the programmable interconnects **361** of its inter-chip interconnects **371** or multiple of the non-programmable interconnects **364** of its inter-chip interconnects **371**.

[0268] For example, in the arrangement as illustrated in FIGS. **8A** and **8B**, for each of the first through fourth types of standard commodity logic drives **300** as seen in FIGS. **10A-10D**, one of its control buses **416** may couple the IS1 pads **231** of the standard commodity FPGA IC chips **200** of all of its operation modules **190** to each other or one another and to one of the small I/O circuits **203** of one of its dedicated control and input/output (I/O) circuits **265**. Another of its control buses **416** may couple the IS2 pads **231** of the standard commodity FPGA IC chips **200** of all of its operation modules **190** to each other or one another and to another of the small I/O circuits **203** of said one of its dedicated control and input/output (I/O) circuits **265**. Another of its control buses **416** may couple the IS3 pads **231** of the standard commodity FPGA IC chips **200** of all of its operation modules **190** to each other or one another and to another of the small I/O circuits **203** of said one of its dedicated control and input/output (I/O) circuits **265**. Another of its control buses **416** may couple the IS4 pads **231** of the standard commodity FPGA IC chips **200** of all of its operation modules **190** to each other or one another and to another of the small I/O circuits **203** of said one of its dedicated control and input/output (I/O) circuits **265**. Another of its control buses **416** may couple the OS1 pads **232** of the standard commodity FPGA IC chips **200** of all of its operation modules **190** to each other or one another and to another of the small I/O circuits **203** of said one of its dedicated control and input/output (I/O) circuits **265**. Another of its control buses **416** may couple the OS2 pads **232** of the standard commodity FPGA IC chips **200** of all of its operation modules **190** to each other or one another and to another of the small I/O circuits **203** of said one of its dedicated control and input/output (I/O) circuits **265**. Another of its control buses **416** may couple the OS3 pads **232** of the standard commodity FPGA IC chips **200** of all of its operation modules **190** to each other or one another and to another of the small I/O circuits **203** of said one of its dedicated control and input/output (I/O) circuits **265**. Another of its control buses **416** may couple the OS4 pads **232** of the standard commodity FPGA IC chips **200** of all of its operation modules **190** to each other or one another and to another of the small I/O circuits **203** of said one of its dedicated control and input/output (I/O) circuits **265**. Each of its control buses **416** may couple to the I/O pad **272** of one of the large I/O circuits **341** of said one of its dedicated control and input/output (I/O) circuits **265** as seen in FIG. **5A**, for the connection to an external circuitry outside said each of the first through fourth types of standard commodity logic drives **300**, through one of the small I/O circuits **203** of said one of its dedicated control and input/output (I/O) circuits **265**.

[0269] Referring to FIG. **12**, each of the first through fourth types of standard commodity logic drives **300** as seen in FIGS. **10A-OD** may be provided with multiple chip-enable (CE) lines **417** each constructed from one or more of the programmable interconnects **361** of its inter-chip interconnects **371** or one or more of the non-programmable interconnects **364** of its inter-chip

interconnects **371** to couple to the chip-enable (CE) pad **209** of the standard commodity FPGA IC chip **200** of one of its operation modules **190** as seen in FIGS. **8A** and **8B** and to another of the small I/O circuits **203** of said one of its dedicated control and input/output (I/O) circuits **265**. Each of its chip-enable (CE) lines **417** may couple to the I/O pad **272** of one of the large I/O circuits **341** of said one of its dedicated control and input/output (I/O) circuits **265** as seen in FIG. **5A**, for the connection to an external circuitry outside said each of the first through fourth types of standard commodity logic drives **300**, through one of the small **1/1** circuits **203** of said one of its dedicated control and input/output (I/O) circuits **265**.

[0270] Furthermore, referring to FIG. **12**, each of the first through fourth types of standard commodity logic drives **300** as illustrated in FIGS. **10A-10D** may be provided with a set of data buses **315** for use in an expandable interconnection scheme. In this case, for each of the first through fourth types of standard commodity logic drives **300** as illustrated in FIGS. **10A-10D**, its set of data buses **315** may include four data bus subsets or data buses, e.g., **315A**, **315B**, **315C** and **315D**, each coupling to the small I/O circuits **203** of one of the I/O ports **377**, e.g., I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4**, of the standard commodity FPGA IC chip **200** of each of its operation modules **190** as seen in FIGS. **8A** and **8B** and, alternatively, the small I/O circuits **203** of one of multiple I/O ports of each of its first high bandwidth memory (HBM) IC chips **251-1**, and to a set of small I/O circuits **203** of said one of its dedicated control and input/output (I/O) circuits **265**; that is, its data bus **315A** couples to and is associated with the small I/O circuits **203** of one of the I/O ports **377**, e.g., I/O Port **1**, of the standard commodity FPGA IC chip **200** of each of its operation modules **190** and, alternatively, the small I/O circuits **203** of a first one of the I/O ports of each of its first high bandwidth memory (HBM) IC chips **251-1** or each of the third high bandwidth memory (HBM) IC chips **251-3** of its first memory module **159-1**, and to a first set of small I/O circuits **203** of said one of its dedicated control and input/output (I/O) circuits **265**; its data bus **315B** couples to and is associated with the small I/O circuits **203** of one of the I/O ports **377**, e.g., I/O Port **2**, of the standard commodity FPGA IC chip **200** of each of its operation modules **190** and, alternatively, the small I/O circuits **203** of a second one of the I/O ports of each of its first high bandwidth memory (HBM) IC chips **251-1** or each of the third high bandwidth memory (HBM) IC chips **251-3** of its first memory module **159-1**, and to a second set of small I/O circuits **203** of said one of its dedicated control and input/output (I/O) circuits **265**; its data bus **315C** couples to and is associated with the small I/O circuits **203** of one of the I/O ports **377**, e.g., I/O Port **3**, of the standard commodity FPGA IC chip **200** of each of its operation modules **190** and, alternatively, the small I/O circuits **203** of a third one of the I/O ports of each of its first high bandwidth memory (HBM) IC chips **251-1** or each of the third high bandwidth memory (HBM) IC chips **251-3** of its first memory module **159-1**, and to a fourth set of small I/O circuits **203** of said one of its dedicated control and input/output (I/O) circuits **265**; and its data bus **315D** couples to and is associated with the small I/O circuits **203** of one of the I/O ports **377**, e.g., I/O Port **4**, of the standard commodity FPGA IC chip **200** of each of its operation modules **190** and, alternatively, the small I/O circuits **203** of a fourth one of the I/O ports of each of its first high bandwidth memory (HBM) IC chips **251-1** or each of the third high bandwidth memory (HBM) IC chips **251-3** of its first memory module **159-1**, and to a fourth set of small I/O circuits **203** of said one of its dedicated control and input/output (I/O) circuits **265**. Its data buses **315A** may couple to the I/O pads **272** of a first set of large I/O circuits **341** of said one of its dedicated control and input/output (I/O) circuits **265** as seen in FIG. **5A**, for the connection to an external circuitry outside said each of the first through fourth types of standard commodity logic drives **300**, through the first set of small I/O circuits **203** of said one of its dedicated control and input/output (I/O) circuits **265** respectively. Its data buses **315B** may couple to the I/O pads **272** of a second set of large I/O circuits **341** of said one of its dedicated control and input/output (I/O) circuits **265** as seen in FIG. **5A**, for the connection to an external circuitry outside said each of the first through fourth types of standard commodity logic drives **300**, through the second set of small I/O circuits **203** of said one of its dedicated control and input/output

(I/O) circuits **265** respectively. Its data buses **315C** may couple to the I/O pads **272** of a third set of large I/O circuits **341** of said one of its dedicated control and input/output (I/O) circuits **265** as seen in FIG. 5A, for the connection to an external circuitry outside said each of the first through fourth types of standard commodity logic drives **300**, through the third set of small I/O circuits **203** of said one of its dedicated control and input/output (I/O) circuits **265** respectively. Its data buses **315D** may couple to the I/O pads **272** of a fourth set of large I/O circuits **341** of said one of its dedicated control and input/output (I/O) circuits **265** as seen in FIG. 5A, for the connection to an external circuitry outside said each of the first through fourth types of standard commodity logic drives **300**, through the fourth set of small I/O circuits **203** of said one of its dedicated control and input/output (I/O) circuits **265** respectively.

[0271] Each of its four data buses, e.g., **315A**, **315B**, **315C** and **315D**, may provide data transmission with bit width ranging from 4 to 256, such as 64 for a case. In this case, for each of the first through fourth types of standard commodity logic drives **300**, each of its four data buses, e.g., **315A**, **315B**, **315C** and **315D**, may be composed of multiple data paths, having the number of 64 arranged in parallel, coupling respectively to the I/O pads **372**, having the number of 64 arranged in parallel, of one of the I/O ports **377**, e.g., I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4**, of the standard commodity FPGA IC chip **200** of each of its operation modules **190**, wherein each of the data paths of said each of its four data buses, e.g., **315A**, **315B**, **315C** and **315D**, may be constructed from multiple of the programmable interconnects **361** of its inter-chip interconnects **371** or multiple of the non-programmable interconnects **364** of its inter-chip interconnects **371**.

[0272] Furthermore, referring to FIG. 12, for each of the first through fourth types of standard commodity logic drives **300** as illustrated in FIGS. 10A-10D, each of its data buses **315** may pass data for the standard commodity FPGA IC chip **200** of each of its operation modules **190** and, alternatively, each of its first high bandwidth memory (HBM) IC chips **251-1** (only one is shown in FIG. 12). For example, in a third clock cycle, for each of the first through fourth types of standard commodity logic drives **300**, the standard commodity FPGA IC chip **200** of a first one of its operation modules **190** may be selected in accordance with a logic level at the chip-enable pad **209** of the standard commodity FPGA IC chip **200** of the first one of its operation modules **190** to be enabled to pass data for the input operation of the standard commodity FPGA IC chip **200** of the first one of its operation modules **190**, and the standard commodity FPGA IC chip **200** of a second one of its operation modules **190** may be selected in accordance with a logic level at the chip-enable pad **209** of the standard commodity FPGA IC chip **200** of the second one of its operation modules **190** to be enabled to pass data for the output operation of the standard commodity FPGA IC chip **200** of the second one of its operation modules **190**. In the arrangement as illustrated in FIGS. 8A and 8B, for the standard commodity FPGA IC chip **200** of the first one of the operation modules **190** of each of the first through fourth types of standard commodity logic drives **300**, an I/O port, e.g. I/O Port **1**, may be selected from its I/O ports **377**, e.g., I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4**, to activate the small receivers **375** of the small I/O circuits **203** of its selected I/O port **377**, e.g. I/O Port **1**, in accordance with logic levels at its input-selection (IS) pads **231**, e.g., IS1, IS2, IS3 and IS4 pads, and to disable the small drivers **374** of the small I/O circuits **203** of its selected I/O port **377**, e.g. I/O Port **1**, in accordance with logic levels at its output-selection (OS) pads **232**, e.g., OS1, OS2, OS3 and OS4 pads; for the standard commodity FPGA IC chip **200** of the second one of the operation modules **190** of each of the first through fourth types of standard commodity logic drives **300**, the same I/O port, e.g. I/O Port **1**, may be selected from its I/O ports **377**, e.g., I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4**, to enable the small drivers **374** of the small I/O circuits **203** of its selected I/O port **377**, e.g. I/O Port **1**, in accordance with logic levels at its output-selection (OS) pads **232**, e.g., OS1, OS2, OS3 and OS4 pads, and to inhibit the small receivers **375** of the small I/O circuits **203** of its selected I/O port **377**, e.g. I/O Port **1**, in accordance with logic levels at its input-selection (IS) pads **231**, e.g., IS1, IS2, IS3 and IS4 pads.

[0273] Thereby, in the arrangement as illustrated in FIGS. 8A and 8B, in the third clock cycle, for

each of the first through fourth types of standard commodity logic drives **300**, the selected I/O port, e.g., I/O Port **1**, of the standard commodity FPGA IC chip **200** of the second one of its operation modules **190** may have the small drivers **374** to drive or pass first data associated with the data output, e.g., Dout as seen in FIG. **6A**, of one of the programmable logic cells (LC) **2014** of the standard commodity FPGA IC chip **200** of the second one of its operation modules **190**, for example, to a first one, e.g., **315A**, of its data buses **315** and the small receivers **375** of the selected I/O port, e.g., I/O Port **1**, of the standard commodity FPGA IC chip **200** of the first one of its operation modules **190** may receive the first data to be associated with a data input of the input data set, e.g., **A0** and **A1** as seen in FIG. **6A**, of one of the programmable logic cells (LC) **2014** of the standard commodity FPGA IC chip **200** of the first one of its operation modules **190**, for example, from the first one, e.g., **315A**, of its data buses **315**. The first one, e.g., **315A**, of its data buses **315** may have the data paths each coupling the small driver **374** of one of the small I/O circuits **203** of the selected I/O port, e.g., I/O Port **1**, of the standard commodity FPGA IC chip **200** of the second one of its operation modules **190** to the small receiver **375** of one of the small I/O circuits **203** of the selected I/O port, e.g., I/O Port **1**, of the standard commodity FPGA IC chip **200** of the first one of its operation modules **190**.

[0274] Furthermore, referring to FIG. **12**, in the third clock cycle, for the second, third or fourth type of standard commodity logic drive **300** as seen in FIG. **10B**, **10C** or **10D**, the standard commodity FPGA IC chip **200** of a third one of its operation modules **190** may be selected in accordance with a logic level at the chip-enable pad **209** of the standard commodity FPGA IC chip **200** of the third one of its operation modules **190** to be enabled to pass data for the input operation of the standard commodity FPGA IC chip **200** of the third one of its operation modules **190**. In the arrangement as illustrated in FIGS. **8A** and **8B**, for the standard commodity FPGA IC chip **200** of the third one of the operation modules **190** of the second, third or fourth type of standard commodity logic drive **300**, an I/O port, e.g. I/O Port **1**, may be selected from its I/O ports **377**, e.g., I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4**, to activate the small receivers **375** of the small I/O circuits **203** of its selected I/O port **377**, e.g. I/O Port **1**, in accordance with logic levels at its input-selection (IS) pads **231**, e.g., IS1, IS2, IS3 and IS4 pads, and to disable the small drivers **374** of the small I/O circuits **203** of its selected I/O port **377**, e.g. I/O Port **1**, in accordance with logic levels at its output-selection (OS) pads **232**, e.g., OS1, OS2, OS3 and OS4 pads. Thereby, in the arrangement as illustrated in FIGS. **8A** and **8B**, in the third clock cycle, for the second, third or fourth type of standard commodity logic drive **300**, the small receivers **375** of the selected I/O port, e.g., I/O Port **1**, of the standard commodity FPGA IC chip **200** of the third one of its operation modules **190** may receive the first data to be associated with a data input of the input data set, e.g., **A0** and **A1** as seen in FIG. **6A**, of one of the programmable logic cells (LC) **2014** of the standard commodity FPGA IC chip **200** of the third one of its operation modules **190**, for example, from the first one, e.g., **315A**, of its data buses **315**. The first one, e.g., **315A**, of its data buses **315** may have the data paths each coupling to the small receiver **375** of one of the small I/O circuits **203** of the selected I/O port, e.g., I/O Port **1**, of the standard commodity FPGA IC chip **200** of the third one of its operation modules **190**. For the standard commodity FPGA IC chip **200** of the other(s) of its operation modules **190** of the second, third or fourth type of standard commodity logic drive **300**, the small driver and receiver **374** and **375** of each of the small I/O circuits **203** of one of its I/O ports **377**, e.g. I/O Port **1**, coupling to the first one, e.g., **315A**, of the data buses **315** of the second, third or fourth type of standard commodity logic drive **300** may be disabled and inhibited.

[0275] Referring to FIG. **12**, in the third clock cycle, for each of the first high bandwidth memory (HBM) IC chips **251-1** of the first or second type of standard commodity logic drive **300**, the small driver and receiver **374** and **375** of each of the small I/O circuits **203** of one of its I/O ports, e.g. first I/O port, coupling to the first one, e.g., **315A**, of the data buses **315** of the first or second type of standard commodity logic drive **300** may be disabled and inhibited.

[0276] Furthermore, referring to FIG. **12**, in the third clock cycle, in the arrangement as illustrated

in FIGS. 8A and 8B, for the standard commodity FPGA IC chip **200** of the first one of the operation modules **190** of each of the first through fourth types of standard commodity logic drives **300** as illustrated in FIGS. 10A-10C, an I/O port, e.g. I/O Port **2**, may be selected from its I/O ports **377**, e.g., I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4**, to enable the small drivers **374** of the small I/O circuits **203** of its selected I/O port **377**, e.g. I/O Port **2**, in accordance with logic levels at its output-selection (OS) pads **232**, e.g., OS1, OS2, OS3 and OS4 pads, and to inhibit the small receivers **375** of the small I/O circuits **203** of its selected I/O port **377**, e.g. I/O Port **2**, in accordance with logic levels at its input-selection (IS) pads **231**, e.g., IS1, IS2, IS3 and IS4 pads; for the standard commodity FPGA IC chip **200** of the second one of its operation modules **190**, the same I/O port, e.g. I/O Port **2**, may be selected from its I/O ports **377**, e.g., I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4**, to activate the small receivers **375** of the small I/O circuits **203** of its selected I/O port **377**, e.g. I/O Port **2**, in accordance with logic levels at its input-selection (IS) pads **231**, e.g., IS1, IS2, IS3 and IS4 pads, and to disable the small drivers **374** of the small I/O circuits **203** of its selected I/O port **377**, e.g. I/O Port **2**, in accordance with logic levels at its output-selection (OS) pads **232**, e.g., OS1, OS2, OS3 and OS4 pads. Thereby, in the arrangement as illustrated in FIGS. 8A and 8B, in the third clock cycle, for each of the first through fourth types of standard commodity logic drives **300** as illustrated in FIGS. 10A-10C, the selected I/O port, e.g., I/O Port **2**, of the standard commodity FPGA IC chip **200** of the first one of its operation modules **190** may have the small drivers **374** to drive or pass second data associated with the data output, e.g., Dout as seen in FIG. 6A, of said one of the programmable logic cells (LC) **2014** of the standard commodity FPGA IC chip **200** of the first one of its operation modules **190**, for example, to a second one, e.g., **315B**, of its data buses **315** and the small receivers **375** of the selected I/O port, e.g., I/O Port **2**, of the standard commodity FPGA IC chip **200** of the second one of its operation modules **190** may receive the second data to be associated with a data input of the input data set, e.g., A0 and A1 as seen in FIG. 6A, of said one of the programmable logic cells (LC) **2014** of the standard commodity FPGA IC chip **200** of the second one of its operation modules **190**, for example, from the second one, e.g., **315B**, of its data buses **315**. The second one, e.g., **315B**, of its data buses **315** may have the data paths each coupling the small driver **374** of one of the small I/O circuits **203** of the selected I/O port, e.g., I/O Port **2**, of the standard commodity FPGA IC chip **200** of the first one of its operation modules **190** to the small receiver **375** of one of the small I/O circuits **203** of the selected I/O port, e.g., I/O Port **2**, of the standard commodity FPGA IC chip **200** of the second one of its operation modules **190**. For example, said one of the programmable logic cells (LC) **2014** of the standard commodity FPGA IC chip **200** of the first one of its operation modules **190** may be programmed to perform logic operation for multiplication.

[0277] Further, referring to FIG. 12, in a fourth clock cycle, for the first or second type of standard commodity logic drive **300** as seen in FIG. 10A or 10B, the standard commodity FPGA IC chip **200** of the first one of its operation modules **190** may be selected in accordance with the logic level at the chip-enable pad **209** of the standard commodity FPGA IC chip **200** of the first one of its operation modules **190** to be enabled to pass data for the input operation of the standard commodity FPGA IC chip **200** of the first one of its operation modules **190**. In the arrangement as illustrated in FIGS. 8A and 8B, for the standard commodity FPGA IC chip **200** of the first one of the operation modules **190** of the first or second type of standard commodity logic drive **300**, an I/O port, e.g. I/O Port **1**, may be selected from its I/O ports **377**, e.g., I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4**, to activate the small receivers **375** of the small I/O circuits **203** of its selected I/O port **377**, e.g. I/O Port **1**, in accordance with logic levels at its input-selection (IS) pads **231**, e.g., IS1, IS2, IS3 and IS4 pads, and to disable the small drivers **374** of the small I/O circuits **203** of its selected I/O port **377**, e.g. I/O Port **1**, in accordance with logic levels at its output-selection (OS) pads **232**, e.g., OS1, OS2, OS3 and OS4 pads. Further, in the fourth clock cycle, for the first or second type of standard commodity logic drive **300**, a first one of its first high bandwidth memory (HBM) IC chips **251-1** may be selected to be enabled to pass data for an output operation of the first one of its

first high bandwidth memory (HBM) IC chips **251-1**. For the first one of the first high bandwidth memory (HBM) IC chips **251-1** of the first or second type of standard commodity logic drive **300**, its first I/O port may be selected from its I/O ports, e.g., first, second, third and fourth I/O ports, to enable the small drivers **374** of the small I/O circuits **203** of its selected I/O port, e.g. first I/O port, in accordance with logic levels at its output-selection pads, and to inhibit the small receivers **375** of the small I/O circuits **203** of its selected I/O port, e.g. first I/O port, in accordance with logic levels at its input-selection pads. Thereby, in the arrangement as illustrated in FIGS. **8A** and **8B**, in the fourth clock cycle, for the first or second type of standard commodity logic drive **300**, the selected I/O port, e.g., first I/O port, of the first one of its first high bandwidth memory (HBM) IC chips **251-1** may have the small drivers **374** to drive or pass third data to the first one, e.g., **315A**, of its data buses **315** and the small receivers **375** of the selected I/O port, e.g., I/O Port **1**, of the standard commodity FPGA IC chip **200** of the first one of its operation modules **190** may receive the third data to be associated with a data input of the input data set, e.g., **A0** and **A1** as seen in FIG. **6A**, of said one of the programmable logic cells (LC) **2014** of the standard commodity FPGA IC chip **200** of the first one of its operation modules **190**, for example, from the first one, e.g., **315A**, of its data buses **315**. The first one, e.g., **315A**, of its data buses **315** may have the data paths each coupling the small driver **374** of one of the small I/O circuits **203** of the selected I/O port, e.g., first I/O port, of the first one of its first high bandwidth memory (HBM) IC chips **251-1** to the small receiver **375** of one of the small I/O circuits **203** of the selected I/O port, e.g., I/O Port **1**, of the standard commodity FPGA IC chip **200** of the first one of its operation modules **190**.

[0278] Furthermore, referring to FIG. **12**, in the fourth clock cycle, for the first or second type of standard commodity logic drive **300**, the standard commodity FPGA IC chip **200** of the second one of its operation modules **190** may be selected in accordance with a logic level at the chip-enable pad **209** of the standard commodity FPGA IC chip **200** of the second one of its operation modules **190** to be enabled to pass data for the input operation of the standard commodity FPGA IC chip **200** of the second one of its operation modules **190**. In the arrangement as illustrated in FIGS. **8A** and **8B**, for the standard commodity FPGA IC chip **200** of the second one of the operation modules **190** of the first or second type of standard commodity logic drive **300**, the same I/O port, e.g. I/O Port **1**, may be selected from its I/O ports **377**, e.g., I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4**, to activate the small receivers **375** of the small I/O circuits **203** of its selected I/O port **377**, e.g. I/O Port **1**, in accordance with logic levels at its input-selection (IS) pads **231**, e.g., IS1, IS2, IS3 and IS4 pads, and to disable the small drivers **374** of the small I/O circuits **203** of its selected I/O port **377**, e.g. I/O Port **1**, in accordance with logic levels at its output-selection (OS) pads **232**, e.g., OS1, OS2, OS3 and OS4 pads. Thereby, in the arrangement as illustrated in FIGS. **8A** and **8B**, in the fourth clock cycle, for the first or second type of standard commodity logic drive **300**, the small receivers **375** of the selected I/O port, e.g., I/O Port **1**, of the standard commodity FPGA IC chip **200** of the second one of its operation modules **190** may receive the third data to be associated with a data input of the input data set, e.g., **A0** and **A1** as seen in FIG. **6A**, of said one of the programmable logic cells (LC) **2014** of the standard commodity FPGA IC chip **200** of the second one of its operation modules **190**, for example, from the first one, e.g., **315A**, of its data buses **315**. The first one, e.g., **315A**, of its data buses **315** may have the data paths each coupling to the small receiver **375** of one of the small I/O circuits **203** of the selected I/O port, e.g., I/O Port **1**, of the standard commodity FPGA IC chip **200** of the second one of its operation modules **190**.

[0279] Referring to FIG. **12**, for the standard commodity FPGA IC chip **200** of each of the others of its operation modules **190** of the second type of standard commodity logic drive **300**, the small driver and receiver **374** and **375** of each of the small I/O circuits **203** of one of its I/O ports **377**, e.g. I/O Port **1**, coupling to the first one, e.g., **315A**, of the data buses **315** of the second type of standard commodity logic drive **300** may be disabled and inhibited.

[0280] Referring to FIG. **12**, for the other of the first high bandwidth memory (HBM) IC chips **251-1** of the first or second type of standard commodity logic drive **300**, the small driver and

receiver **374** and **375** of each of the small I/O circuits **203** of one of its I/O ports, e.g. first I/O port, coupling to the first one, e.g., **315A**, of the data buses **315** of the first or second type of standard commodity logic drive **300** may be disabled and inhibited.

[0281] Further, referring to FIG. **12**, in a fifth clock cycle, for the first or second type of standard commodity logic drive **300** as seen in FIG. **10A** or **10B**, the standard commodity FPGA IC chip **200** of the first one of its operation modules **190** may be selected in accordance with a logic level at the chip-enable pad **209** of the standard commodity FPGA IC chip **200** of the first one of its operation modules **190** to be enabled to pass data for the output operation of the standard commodity FPGA IC chip **200** of the first one of its operation modules **190**. In the arrangement as illustrated in FIGS. **8A** and **8B**, for the standard commodity FPGA IC chip **200** of the first one of the operation modules **190** of the first or second type of standard commodity logic drive **300**, an I/O port, e.g. I/O Port **1**, may be selected from its I/O ports **377**, e.g., I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4**, to enable the small drivers **374** of the small I/O circuits **203** of its selected I/O port **377**, e.g. I/O Port **1**, in accordance with logic levels at its output-selection (OS) pads **232**, e.g., OS1, OS2, OS3 and OS4 pads, and to inhibit the small receivers **375** of the small I/O circuits **203** of its selected I/O port **377**, e.g. I/O Port **1**, in accordance with logic levels at its input-selection (IS) pads **231**, e.g., IS1, IS2, IS3 and IS4 pads. Further, in the fifth clock cycle, for the first or second type of standard commodity logic drive **300**, the first one of its first high bandwidth memory (HBM) IC chips **251-1** may be selected to be enabled to pass data for an input operation of the first one of its first high bandwidth memory (HBM) IC chips **251-1**. For the first one of the first high bandwidth memory (HBM) IC chips **251-1** of the first or second type of standard commodity logic drive **300**, its first I/O port may be selected from its I/O ports, e.g., first, second, third and fourth I/O ports, to activate the small receivers **375** of the small I/O circuits **203** of its selected I/O port, e.g. first I/O port, in accordance with logic levels at its input-selection pads, and to disable the small drivers **374** of the small I/O circuits **203** of its selected I/O port, e.g. first I/O port, in accordance with logic levels at its output-selection pads. Thereby, in the arrangement as illustrated in FIGS. **8A** and **8B**, in the fifth clock cycle, for the first or second type of standard commodity logic drive **300**, the selected I/O port, e.g., first I/O port, of the first one of its first high bandwidth memory (HBM) IC chips **251-1** may have the small receivers **375** to receive fourth data from the first one, e.g., **315A**, of its data buses **315** and the small drivers **374** of the selected I/O port, e.g., I/O Port **1**, of the standard commodity FPGA IC chip **200** of the first one of its operation modules **190** may drive or pass the fourth data associated with the data output, e.g., Dout as seen in FIG. **6A**, of said one of the programmable logic cells (LC) **2014** of the standard commodity FPGA IC chip **200** of the first one of its operation modules **190**, for example, to the first one, e.g., **315A**, of its data buses **315**. The first one, e.g., **315A**, of its data buses **315** may have the data paths each coupling the small driver **374** of one of the small I/O circuits **203** of the selected I/O port, e.g., I/O Port **1**, of the standard commodity FPGA IC chip **200** of the first one of its operation modules **190** to the small receiver **375** of one of the small I/O circuits **203** of the selected I/O port, e.g., first I/O port, of the first one of its first high bandwidth memory (HBM) IC chips **251-1**.

[0282] Furthermore, referring to FIG. **12**, in the fifth clock cycle, for the first or second type of standard commodity logic drive **300** as seen in FIG. **10A** or **10B**, the standard commodity FPGA IC chip **200** of the second one of its operation modules **190** may be selected in accordance with a logic level at the chip-enable pad **209** of the standard commodity FPGA IC chip **200** of the second one of its operation modules **190** to be enabled to pass data for the input operation of the standard commodity FPGA IC chip **200** of the second one of its operation modules **190**. In the arrangement as illustrated in FIGS. **8A** and **8B**, for the standard commodity FPGA IC chip **200** of the second one of the operation modules **190** of the first or second type of standard commodity logic drive **300**, the same I/O port, e.g. I/O Port **1**, may be selected from its I/O ports **377**, e.g., I/O Port **1**, I/O Port **2**, I/O Port **3** and I/O Port **4**, to activate the small receivers **375** of the small I/O circuits **203** of its selected I/O port **377**, e.g. I/O Port **1**, in accordance with logic levels at its input-selection (IS) pads

231, e.g., IS1, IS2, IS3 and IS4 pads, and to disable the small drivers 374 of the small I/O circuits 203 of its selected I/O port 377, e.g. I/O Port 1, in accordance with logic levels at its output-selection (OS) pads 232, e.g., OS1, OS2, OS3 and OS4 pads. Thereby, in the arrangement as illustrated in FIGS. 8A and 8B, in the fifth clock cycle, for the first or second type of standard commodity logic drive 300, the small receivers 375 of the selected I/O port, e.g., I/O Port 1, of the standard commodity FPGA IC chip 200 of the second one of its operation modules 190 may receive the fourth data to be associated with a data input of the input data set, e.g., A0 and A1 as seen in FIG. 6A, of said one of the programmable logic cells (LC) 2014 of the standard commodity FPGA IC chip 200 of the second one of its operation modules 190, for example, from the first one, e.g., 315A, of its data buses 315. The first one, e.g., 315A, of its data buses 315 may have the data paths each coupling to the small receiver 375 of one of the small I/O circuits 203 of the selected I/O port, e.g., I/O Port 1, of the standard commodity FPGA IC chip 200 of the second one of its operation modules 190.

[0283] For the standard commodity FPGA IC chip 200 of each of the others of the operation modules 190 of the second type of standard commodity logic drive 300, the small driver and receiver 374 and 375 of each of the small I/O circuits 203 of one of its I/O ports 377, e.g. I/O Port 1, coupling to the first one, e.g., 315A, of the data buses 315 of the second type of standard commodity logic drive 300 may be disabled and inhibited.

[0284] For the other of the first high bandwidth memory (HBM) IC chips 251-1 of the first or second type of standard commodity logic drive 300, the small driver and receiver 374 and 375 of each of the small I/O circuits 203 of one of its I/O ports, e.g. first I/O port, coupling to the first one, e.g., 315A, of the data buses 315 of the first or second type of standard commodity logic drive 300 may be disabled and inhibited.

[0285] Further, referring to FIG. 12, in a sixth clock cycle, for the first or second type of standard commodity logic drive 300 as seen in FIG. 10A or 10B, the first one of its first high bandwidth memory (HBM) IC chips 251-1 may be selected to be enabled to pass data for an input operation of the first one of its first high bandwidth memory (HBM) IC chips 251-1. For the first one of the first high bandwidth memory (HBM) IC chips 251-1 of the first or second type of standard commodity logic drive 300, its first I/O port may be selected from its I/O ports, e.g., first, second, third and fourth I/O ports, to activate the small receivers 375 of the small I/O circuits 203 of its selected I/O port, e.g. first I/O port, in accordance with logic levels at its input-selection pads, and to disable the small drivers 374 of the small I/O circuits 203 of its selected I/O port, e.g. first I/O port, in accordance with logic levels at its output-selection pads. Further, in the sixth clock cycle, for the first or second type of standard commodity logic drive 300, a second one of its first high bandwidth memory (HBM) IC chips 251-1 may be selected to be enabled to pass data for an output operation of the second one of its first high bandwidth memory (HBM) IC chips 251-1. For the second one of the first high bandwidth memory (HBM) IC chips 251-1 of the first or second type of standard commodity logic drive 300, its first I/O port may be selected from its I/O ports, e.g., first, second, third and fourth I/O ports, to enable the small drivers 374 of the small IO circuits 203 of its selected I/O port, e.g. first I/O port, in accordance with logic levels at its output-selection pads, and to inhibit the small receivers 375 of the small I/O circuits 203 of its selected I/O port, e.g. first I/O port, in accordance with logic levels at its input-selection pads. Thereby, in the sixth clock cycle, for the first or second type of standard commodity logic drive 300, the selected I/O port, e.g., first I/O port, of the first one of its first high bandwidth memory (HBM) IC chips 251-1 may have the small receivers 375 to receive fifth data from the first one, e.g., 315A, of its data buses 315 and the selected I/O port, e.g., first I/O port, of the second one of its first high bandwidth memory (HBM) IC chips 251-1 may have the small drivers 374 to drive or pass the fifth data to the first one, e.g., 315A, of its data buses 315. The first one, e.g., 315A, of its data buses 315 may have the data paths each coupling the small driver 374 of one of the small IO circuits 203 of the selected I/O port, e.g., first I/O port, of the second one of its first high bandwidth memory (HBM) IC chips 251-1 to the

small receiver **375** of one of the small I/O circuits **203** of the selected I/O port, e.g., first I/O port, of the first one of its first high bandwidth memory (HBM) IC chips **251-1**. For the standard commodity FPGA IC chip **200** of each of the operation modules **190** of the first or second type of standard commodity logic drive **300**, the small driver and receiver **374** and **375** of each of the small I/O circuits **203** of one of its I/O ports **377**, e.g. I/O Port **1**, coupling to the first one, e.g., **315A**, of its data buses **315** may be disabled and inhibited.

Architecture of Programming and Operation in Standard Commodity FPGA IC Chip

[0286] FIG. **13** is a block diagrams showing architecture of programming and operation in a standard commodity FPGA IC chip in accordance with an embodiment of the present application. Referring to FIG. **13**, for each of the first through fourth types of standard commodity logic drives **300** as illustrated in FIGS. **10A-10D**, each of its non-volatile memory (NVM) IC chip(s) **250** may include three non-volatile memory blocks each composed of multiple non-volatile memory cells arranged in an array. The non-volatile memory cells, i.e., configuration programming memory (CPM) cells, of a first one of the three non-volatile memory blocks of said each of its non-volatile memory (NVM) IC chip(s) **250** are configured to save or store configuration programming memory (CPM) data including original resulting values or programming codes of the look-up tables (LUT) **210** of the standard commodity FPGA IC chip **200** of each of its operation modules **190** as illustrated in FIGS. **6A-6D** and original programming codes for the cross-point switches **379** of the standard commodity FPGA IC chip **200** of each of its operation modules **190** and each of its DPIIC chips **410** as illustrated in FIGS. **3A**, **3B** and **7**; the non-volatile memory cells, i.e., configuration programming memory (CPM) cells, of a second one of the three non-volatile memory blocks of said each of its non-volatile memory (NVM) IC chip(s) **250** are configured to save or store configuration programming memory (CPM) data including immediately-previously self-configured resulting values or programming codes of the look-up tables (LUT) **210** of the standard commodity FPGA IC chip **200** of each of its operation modules **190** as illustrated in FIGS. **6A-6D** and immediately-previously self-configured programming codes for the cross-point switches **379** the standard commodity FPGA IC chip **200** of each of its operation modules **190** and each of its DPIIC chips **410** as illustrated in FIGS. **3A**, **3B** and **7**; the non-volatile memory cells, i.e., configuration programming memory (CPM) cells, of a third one of the three non-volatile memory blocks of said each of its non-volatile memory (NVM) IC chips **250** are configured to save or store configuration programming memory (CPM) data including currently self-configured resulting values or programming codes of the look-up tables (LUT) **210** the standard commodity FPGA IC chip **200** of each of its operation modules **190** as illustrated in FIGS. **6A-6D** and currently self-configured programming codes for the cross-point switches **379** of the standard commodity FPGA IC chip **200** of each of its operation modules **190** and each of its DPIIC chips **410** as illustrated in FIGS. **3A**, **3B** and **7**.

[0287] Referring to FIG. **13**, for each of the first through fourth types of standard commodity logic drives **300** as illustrated in FIGS. **10A-10D**, the original, immediately-previously self-configured or currently self-configured resulting values or programming codes of the look-up tables (LUT) **210** and the original, immediately-previously self-configured or currently self-configured programming codes for the cross-point switches **379** stored in one of the three non-volatile memory blocks of said each of its non-volatile memory (NVM) IC chip(s) **250** may be passed to and stored in the memory cells **490**, i.e., configuration programming memory (CPM) cells, of the programmable logic cells (LC) **2014** of the standard commodity FPGA IC chip **200** of each of its operation modules **190** as illustrated in FIGS. **6A-6D** and the memory cells **362**, i.e., configuration programming memory (CPM) cells, for the cross-point switches **379** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190** as illustrated in FIGS. **3A**, **3B** and **7** through multiple of the small I/O circuits **203** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190** as seen in FIG. **5B**, which are defined in an I/O buffering block **469** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190**.

Thereby, the programmable logic cells (LC) **2014** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190** may be programmed by the original, immediately-previously self-configured or currently self-configured resulting values or programming codes of the look-up tables (LUT) **210** and the cross-point switches **379** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190** may be programmed by the original, immediately-previously self-configured or currently self-configured programming codes for the cross-point switches **379**.

[0288] BJ Referring to FIG. **13**, for each of the first through fourth types of standard commodity logic drives **300** as illustrated in FIGS. **10A-10D**, a first data information memory (DIM) cell of circuits **475** external of the standard commodity FPGA IC chip **200** of said each of its operation modules **190**, such as SRAM or DRAM cells of one of its first, second and third HBM IC chips **251-1**, **251-2** and **251-3**, may pass a first data information memory (DIM) dataset to be associated with a data input of the first input data set, e.g., **A0** and **A1** as seen in FIGS. **4** and **6A**, of the multiplexer **211** of one of the programmable logic cells (LC) **2014** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190** through a first one of the small I/O circuits **203** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190** as seen in FIG. **5B**, which are defined in an I/O buffering block **471** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190**. A first one of the cross-point switches **379** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190** may pass the first data information memory (DIM) dataset from the first one of the small I/O circuits **203** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190** to be associated with the data input of the first input data set of the multiplexer **211** of said one of the programmable logic cells (LC) **2014** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190**. A second data information memory (DIM) cell of circuits **475** external of the standard commodity FPGA IC chip **200** of said each of its operation modules **190**, such as SRAM or DRAM cell of said one of its first, second and third HBM IC chips **251-1**, **251-2** and **251-3**, may receive a second data information memory (DIM) dataset associated with a data output, e.g., **Dout** as seen in FIGS. **4** and **6A**, of the multiplexer **211** of said one of the programmable logic cells (LC) **2014** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190** through a second one of the small I/O circuits **203** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190** as seen in FIG. **5B**. A second one of the cross-point switches **379** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190** may pass the second data information memory (DIM) dataset associated with the data output of the multiplexer **211** of said one of the programmable logic cells (LC) **2014** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190** to the second one of the small I/O circuits **203** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190**.

[0289] Referring to FIG. **13**, for each of the first through fourth types of standard commodity logic drives **300** as illustrated in FIGS. **10A-10D**, the data information memory (DIM) datasets saved or stored in the SRAM or DRAM cells, i.e., data information memory (DIM) cells, of one of its first, second and third HBM IC chips **251-1**, **251-2** and **251-3** may be backed up or stored in one of its NVM IC chip(s) **250** or circuits outside said each of the first through fourth types of standard commodity logic drives **300**. Thereby, when said each of the first through fourth types of standard commodity logic drives **300** is powered off, the data information memory (DIM) datasets stored in said one of its NVM IC chip(s) **250** may be kept.

[0290] For reconfiguration for artificial intelligence (AI), machine learning or deep learning, for the standard commodity FPGA IC chip **200** of each of the operation modules **190** of each of the first through fourth types of standard commodity logic drives **300** as illustrated in FIGS. **10A-10D**, the current logic operation, such as AND logic operation, of one of its programmable logic cells (LC) **2014** may be self-reconfigured to another logic operation, such as NAND logic operation, by

reconfiguring the resulting values or programming codes, i.e., configuration programming memory (CPM) data, in the memory cells **490** of said one of its programmable logic cells (LC) **2014**. The current switching state of one of its cross-point switches **379** may be self-reconfigured to another switching state by reconfiguring the programming codes, i.e., configuration programming memory (CPM) data, in the memory cells **362** for said one of its cross-point switches **379**. The currently self-reconfigured resulting values or programming codes, i.e., configuration programming memory (CPM) data, in the memory cells **490** of said one of its programmable logic cells (LC) **2014** and in the memory cells **362** for said one of its cross-point switches **379** may be passed to and stored in the non-volatile memory cells, i.e., configuration programming memory (CPM) cells, of the third one of the three non-volatile memory blocks of said each of the non-volatile memory (NVM) IC chip(s) **250** of said each of the first through fourth types of standard commodity logic drives **300** through multiple of its small I/O circuits **203** as seen in FIG. 5B, which are defined in its I/O buffering block **469**.

[0291] Accordingly, referring to FIG. 13, for said each of the first through fourth types of standard commodity logic drives **300**, when it is powered on, the currently self-configured configuration programming memory (CPM) data stored or saved in the non-volatile memory cells in the third one of the three non-volatile memory blocks of said each of its non-volatile memory (NVM) IC chip(s) **250** may be reloaded to the memory cells **490** and **362** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190**. During operation, the standard commodity FPGA IC chip **200** of said each of its operation modules **190** may be reset to pass the original or immediately-previously self-configured configuration programming memory (CPM) data from the non-volatile memory cells in the first or second one of the three non-volatile memory blocks of said each of its non-volatile memory (NVM) IC chips **250** to the memory cells **490** and **362** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190** to be stored in the memory cells **490** and **362** of the standard commodity FPGA IC chip **200** of said each of its operation modules **190**.

Specification for Processes for Fabricating Semiconductor Chip

1. First Type of Semiconductor Chip

[0292] FIG. 14A is a schematically cross-sectional view showing a first type of semiconductor chip in accordance with an embodiment of the present application. A first type of semiconductor chip **100** may include (1) a semiconductor substrate **2**, such as silicon substrate, GaAs substrate, SiGe substrate or Silicon-On-Insulator (SOI) substrate; (2) multiple semiconductor devices **4** on its semiconductor substrate **2**; (3) a first interconnection scheme for a chip (FISC) **20** over its semiconductor substrate **2**, provided with one or more interconnection metal layers **6** coupling to its semiconductor devices **4** and one or more insulating dielectric layers **12** each between neighboring two of its interconnection metal layers **6**, wherein each of its one or more interconnection metal layers **6** may have a thickness between 0.1 and 2 micrometers; (4) a passivation layer **14** over its first interconnection scheme for a chip (FISC) **20**, wherein multiple openings **14a** in its passivation layer **14** may be aligned with and over multiple metal pads of the topmost one of the interconnection metal layers **6** of its first interconnection scheme for a chip (FISC) **20**; (5) a second interconnection scheme for a chip (SISC) **29** optionally provided over its passivation layer **14**, provided with one or more interconnection metal layers **27** coupling to the topmost one of the interconnection metal layers **6** of its first interconnection scheme for a chip (FISC) **20** through the openings **14a** in its passivation layer **14** and one or more polymer layers **42** each between neighboring two of its interconnection metal layers **27**, under a bottommost one of its interconnection metal layers **27** or over a topmost one of its interconnection metal layers **27**, wherein multiple openings **42a** in the topmost one of its polymer layers **42** may be aligned with and over multiple metal pads of the topmost one of the interconnection metal layers **27** of its second interconnection scheme for a chip (SISC) **29**, wherein each of the interconnection metal layers **27** of its second interconnection scheme for a chip (SISC) **29** may have a thicknesses between 3 and 5

micrometers; and (6) multiple micro-bumps or micro-pillars **34** on the topmost one of the interconnection metal layers **27** of its second interconnection scheme for a chip (SISC) **29** or, if the second interconnection scheme for a chip (SISC) **29** is not provided, on the topmost one of the interconnection metal layers **6** of its first interconnection scheme for a chip (FISC) **20**.

[0293] Referring to FIG. **14A**, for the first type of semiconductor chip **100**, its semiconductor devices **4** may include a memory cell, a logic circuit, a passive device, such as resistor, capacitor, inductor or filter, or an active device, such as p-channel and/or n-channel MOS devices. Its semiconductor devices **4** may compose the memory cells **362** and multiplexer **211** for the cross-point switches **379** and small I/O circuits **203**, as illustrated in FIGS. **1A-5B**, **7** and **9**, for each of the DPIIC chips **410** of the first, second or fourth type of standard commodity logic drive **300** as seen in FIG. **10A**, **10B** or **10D**. Its semiconductor devices **4** may compose the large and small I/O circuits **341** and **203**, as illustrated in FIGS. **5A** and **5B**, for each of the dedicated control and input/output (I/O) chips **265** of each of the first through fourth types of standard commodity logic drives **300** as illustrated in FIGS. **10A-10D**.

[0294] Referring to FIG. **14A**, for the first type of semiconductor chip **100**, each of the interconnection metal layers **6** of its first interconnection scheme for a chip (FISC) **20** may include (1) a copper layer **24** having lower portions in openings in a lower one of the insulating dielectric layers **12**, such as SiOC layers having a thickness of between 3 nm and 500 nm, and upper portions having a thickness of between 3 nm and 500 nm over the lower one of the insulating dielectric layers **12** and in openings in an upper one of the insulating dielectric layers **12**, (2) an adhesion layer **18**, such as titanium or titanium nitride having a thickness of between 1 nm and 50 nm, at a bottom and sidewall of each of the lower portions of the copper layer **24** and at a bottom and sidewall of each of the upper portions of the copper layer **24**, and (3) a seed layer **22**, such as copper, between the copper layer **24** and the adhesion layer **18**, wherein the copper layer **24** has a top surface substantially coplanar with a top surface of the upper one of the insulating dielectric layers **12**. Each of the interconnection metal layers **6** of its first interconnection scheme for a chip (FISC) **20** may be patterned with a metal line or trace having a thickness between 0.1 and 2 micrometers, between 3 nm and 1,000 nm or between 10 nm and 500 nm, or thinner than or equal to 5 nm, 10 nm, 30 nm, 50 nm, 100 nm, 200 nm, 300 nm, 500 nm or 1,000 nm and a width between 3 nm and 1,000 nm or between 10 nm and 500 nm, or narrower than 5 nm, 10 nm, 20 nm, 30 nm, 70 nm, 100 nm, 300 nm, 500 nm or 1,000 nm, for example. Each of the insulating dielectric layers **12** of its first interconnection scheme for a chip (FISC) **20** may have a thickness between 0.1 and 2 micrometers, between 3 nm and 1,000 nm or between 10 nm and 500 nm, or thinner than 5 nm, 10 nm, 30 nm, 50 nm, 100 nm, 200 nm, 300 nm, 500 nm or 1,000 nm.

[0295] Referring to FIG. **14A**, for the first type of semiconductor chip **100**, its passivation layer **14** containing a silicon-nitride, SiON or SiCN layer having a thickness greater than 0.3 μm for example and, alternatively, a polymer layer having a thickness between 1 and 10 μm may protect the semiconductor devices **4** and the interconnection metal layers **6** from being damaged by moisture foreign ion contamination, or from water moisture or contamination from external environment, for example sodium mobile ions. Each of the openings **14a** in its passivation layer **14** may have a transverse dimension, from a top view, of between 0.5 and 20 μm .

[0296] Referring to FIG. **14A**, for the first type of semiconductor chip **100**, each of the interconnection metal layers **27** of its second interconnection scheme for a chip (SISC) **29** may include (1) a copper layer **40** having lower portions in openings in one of the polymer layers **42** having a thickness of between 0.3 μm and 20 μm , and upper portions having a thickness 0.3 μm and 20 μm over said one of the polymer layers **42**, (2) an adhesion layer **28a**, such as titanium or titanium nitride having a thickness of between 1 nm and 50 nm, at a bottom and sidewall of each of the lower portions of the copper layer **40** and at a bottom of each of the upper portions of the copper layer **40**, and (3) a seed layer **28b**, such as copper, between the copper layer **40** and the adhesion layer **28a**, wherein said each of the upper portions of the copper layer **40** may have a

sidewall not covered by the adhesion layer **28a**. Each of the interconnection metal layers **27** of its second interconnection scheme for a chip (SISC) **29** may be patterned with a metal line or trace having a thickness between, for example, 0.3 μm and 20 μm , 0.5 μm and 10 μm , 1 μm and 5 μm , 1 μm and 10 μm , or 2 μm and 10 μm , or thicker than or equal to 0.3 μm , 0.5 μm , 0.7 μm , 1 μm , 1.5 μm , 2 μm or 3 μm and a width between, for example, 0.3 μm and 20 μm , 0.5 μm and 10 μm , 1 μm and 5 μm , 1 μm and 10 μm , or 2 μm and 10 μm , or wider than or equal to 0.3 μm , 0.5 μm , 0.7 μm , 1 μm , 1.5 μm , 2 μm or 3 μm . Each of the polymer layers **42** of its second interconnection scheme for a chip (SISC) **29** may have a thickness between, for example, 0.3 μm and 20 μm , 0.5 μm and 10 μm , 1 μm and 5 μm , or 1 μm and 10 μm , or thicker than or equal to 0.3 μm , 0.5 μm , 0.7 μm , 1 μm , 1.5 μm , 2 μm or 3 μm .

[0297] Referring to FIG. **14A**, for the first type of semiconductor chip **100**, each of its micro-bumps or micro-pillars **34** may be of various types. A first type of micro-bumps or micro-pillars **34** may include, as seen in FIG. **14A**, (1) an adhesion layer **26a**, such as titanium (Ti) or titanium nitride (TiN) layer having a thickness of between 1 nm and 50 nm, on the topmost one of the interconnection metal layers **27** of its second interconnection scheme for a chip (SISC) **29** or, if the second interconnection scheme for a chip (SISC) **29** is not provided, on the topmost one of the interconnection metal layers **6** of its first interconnection scheme for a chip (FISC) **20**, (2) a seed layer **26b**, such as copper, on its adhesion layer **26a** and (3) a copper layer **32** having a thickness of between 1 μm and 60 μm on its seed layer **26b**.

[0298] Alternatively, a second type of micro-bumps or micro-pillars **34** may include the adhesion layer **26a**, seed layer **26b** and copper layer **32** as mentioned above, and may further include a tin-containing solder cap made of tin or a tin-silver alloy, which has a thickness of between 1 μm and 50 μm on its copper layer **32**.

[0299] Alternatively, a third type of micro-bumps or micro-pillars **34** may be thermal compression bumps, including the adhesion layer **26a** and seed layer **26b** as mentioned above, and may further include, as seen in FIGS. **16A**, **16B**, **18A**, **18B**, **22A** and **22B**, a copper layer **37** having a thickness t_3 of between 2 μm and 20 μm , such as 3 μm , and a largest transverse dimension w_3 , such as diameter in a circular shape, between 1 μm and 15 μm , such as 3 μm , on its seed layer **26b** and a solder cap **38** made of a tin-silver alloy, a tin-gold alloy, a tin-copper alloy, a tin-indium alloy, indium or tin, which has a thickness of between 1 μm and 15 μm , such as 2 μm , and a largest transverse dimension, such as diameter in a circular shape, between 1 μm and 15 μm , such as 3 μm , on its copper layer **37**. The third type of micro-bumps or micro-pillars **34** are formed respectively on multiple metal pads **6b** provided as seen in FIGS. **16A**, **16B**, **18A**, **18B**, **22A** and **22B** by a frontmost one of the interconnection metal layers **27** of its second interconnection scheme for a chip (SISC) **29** or by, if the second interconnection scheme for a chip (SISC) **29** is not provided, a frontmost one of the interconnection metal layers **6** of its first interconnection scheme for a chip (FISC) **20**, wherein each of the metal pads **6b** may have a thickness t_1 between 1 and 10 micrometers or between 2 and 10 micrometers and a largest transverse dimension w_1 , such as diameter in a circular shape, between 1 μm and 15 μm , such as 5 μm . A pitch between neighboring two of its third type of micro-bumps or micro-pillars **34** may be between 3 μm and 20 μm .

[0300] Alternatively, a fourth type of micro-bumps or micro-pillars **34** may be thermal compression pads, including the adhesion layer **26a** and seed layer **26b** as mentioned above, and further including, as seen in FIGS. **18A**, **18B** and **22A-22D**, a copper layer **48** having a thickness t_2 of between 1 μm and 10 μm or between 2 and 10 micrometers and a largest transverse dimension w_2 , such as diameter in a circular shape, between 1 μm and 15 μm , such as 5 μm , on its seed layer **26b** and a metal cap **49** made of a tin-silver alloy, a tin-gold alloy, a tin-copper alloy, a tin-indium alloy, indium, tin or gold, which has a thickness of between 0.1 μm and 5 μm , such as 1 μm , on its copper layer **48**. Neighboring two of its fourth type of micro-bumps or micro-pillars **34** may have a pitch between 3 μm and 20 μm .

2. Second Type of Semiconductor Chip

[0301] FIG. **14B** is a schematically cross-sectional view showing a second type of semiconductor chip in accordance with an embodiment of the present application. Referring to FIG. **14B**, a second type of semiconductor chip **100** may have similar structure as illustrated in FIG. **14A**. For an element indicated by the same reference number shown in FIGS. **14A** and **14B**, the specification of the element as seen in FIG. **14B** may be referred to that of the element as illustrated in FIG. **14A**. The difference between the first and second types of semiconductor chips **100** is that the second type of semiconductor chip **100** may further include multiple through silicon vias (TSV) **157** in its semiconductor substrate **2**, wherein each of its through silicon vias (TSV) **157** may couple to one or more of its semiconductor devices **4** through one or more the interconnection metal layers **6** of its first interconnection scheme for a chip (FISC) **20**.

[0302] Referring to FIG. **14B**, each of the through silicon vias (TSV) **157** may include (1) an electroplated copper layer **156** having a depth, for example, between 10 nm and 3,000 nm, between 10 nm and 1,000 nm or between 10 nm and 500 nm in the semiconductor substrate **2** of the second type of semiconductor chip **100**, (2) an insulating lining layer **153**, such as thermally grown silicon oxide (SiO.sub.2) and/or CVD silicon nitride (Si.sub.3N.sub.4) at a bottom and sidewall of its electroplated copper layer **156**, (3) an adhesion layer **154**, such as titanium (Ti) or titanium nitride (TiN) layer having a thickness between 1 nm to 50 nm, at the bottom and sidewall of its electroplated copper layer **156** and between its electroplated copper layer **156** and its insulating lining layer **153**, and (4) an electroplating seed layer **155**, such as copper seed layer **155** having a thickness between 3 nm and 200 nm, at the bottom and sidewall of its electroplated copper layer **156** and between its electroplated copper layer **156** and its adhesion layer **154**.

3. Third Type of Semiconductor Chip

[0303] FIG. **14C** is a schematically cross-sectional view showing a third type of semiconductor chip in accordance with an embodiment of the present application. Referring to FIG. **14C**, a third type of semiconductor chip **100** may have similar structure as illustrated in FIG. **14A**. For an element indicated by the same reference number shown in FIGS. **14A** and **14C**, the specification of the element as seen in FIG. **14C** may be referred to that of the element as illustrated in FIG. **14A**. The difference between the first and third types of semiconductor chips **100** is that the third type of semiconductor chip **100** may further include multiple through silicon vias (TSV) **157** in its semiconductor substrate **2**, wherein each of its through silicon vias (TSV) **157** may couple to one or more of its semiconductor devices **4** through one or more the interconnection metal layers **6** of its first interconnection scheme for a chip (FISC) **20**.

[0304] Referring to FIG. **14C**, each of the through silicon vias (TSV) **157** may include (1) an electroplated copper layer **156** having a depth, for example, between 10 nm and 3,000 nm, between 10 nm and 1,000 nm or between 10 nm and 500 nm in the semiconductor substrate **2** of the third type of semiconductor chip **100**, (2) an insulating lining layer **153**, such as thermally grown silicon oxide (SiO.sub.2) and/or CVD silicon nitride (Si.sub.3N.sub.4) at the sidewall of its electroplated copper layer **156**, (3) an adhesion layer **154**, such as titanium (Ti) or titanium nitride (TiN) layer having a thickness between 1 nm to 50 nm, at the sidewall of its electroplated copper layer **156** and between its electroplated copper layer **156** and its insulating lining layer **153**, and (4) an electroplating seed layer **155**, such as copper seed layer **155** having a thickness between 3 nm and 200 nm, at the sidewall of its electroplated copper layer **156** and between its electroplated copper layer **156** and its adhesion layer **154**. For the third type of semiconductor chip **100**, the electroplated copper layer **156** of each of its through silicon vias (TSV) **157** may have a backside surface coplanar to a backside **2b** of its semiconductor substrate **2**, and the insulating lining layer **153** of said each of its through silicon vias (TSV) **157** surrounds the adhesion layer **154**, electroplating seed layer **155** and electroplated copper layer **156** of said each of its through silicon vias (TSV) **157**. The third type of semiconductor chip **100** may further include a passivation layer **14** on the backside **2b** of its semiconductor substrate **2**, wherein multiple openings **14a** in its passivation layer **14** on the backside **2b** of its semiconductor substrate **2** may be aligned with and

under the backside of the electroplated copper layer **156** of its through silicon vias (TSV) **157**. The passivation layer **14** on the backside **2b** of its semiconductor substrate **2** may include a silicon-nitride, SiON or SiCN layer having a thickness greater than 0.3 μm for example and, alternatively, a polymer layer having a thickness between 1 and 10 μm . The third type of semiconductor chip **100** may further include multiple micro-bumps or micro-pillars **570** on the backside of the electroplated copper layer **156** of its through silicon vias (TSV) **157**. The micro-bumps or micro-pillars **570** may be of various types. A first type of micro-bumps or micro-pillars **570** may include, as seen in FIG. **14C**, (1) an adhesion layer **26a**, such as titanium (Ti) or titanium nitride (TiN) layer having a thickness of between 1 nm and 50 nm, on and under the electroplated copper layer **156** of the through silicon vias (TSV) **157** of the third type of semiconductor chip **100**, (2) a seed layer **26b**, such as copper, on and under its adhesion layer **26a** and (3) a copper layer **32** having a thickness of between 1 μm and 60 μm on and under its seed layer **26b**. Alternatively, a second type of micro-bumps or micro-pillars **570** may include the adhesion layer **26a**, seed layer **26b** and copper layer **32** as mentioned above, and may further include a tin-containing solder cap **33** made of tin or a tin-silver alloy, which has a thickness of between 1 μm and 50 μm on and under its copper layer **32**. Alternatively, a third type of micro-bumps or micro-pillars **570** may be thermal compression bumps, including the adhesion layer **26a** and seed layer **26b** as mentioned above, and may further include, as seen in FIGS. **22C** and **22D**, a copper layer **37** having a thickness t_3 of between 2 μm and 20 μm , such as 3 μm , and a largest transverse dimension w_3 , such as diameter in a circular shape, between 1 μm and 15 μm , such as 3 μm , on its seed layer **26b** and a solder cap **38** made of a tin-silver alloy, a tin-gold alloy, a tin-copper alloy, a tin-indium alloy, indium or tin, which has a thickness of between 1 μm and 15 μm , such as 2 μm , and a largest transverse dimension, such as diameter in a circular shape, between 1 μm and 15 μm , such as 3 μm , on its copper layer **37**. A pitch between neighboring two of its third type of micro-bumps or micro-pillars **570** may be between 3 μm and 20 μm . Alternatively, a fourth type of micro-bumps or micro-pillars **570** may be thermal compression pads, including the adhesion layer **26a** and seed layer **26b** as mentioned above, and further including, as seen in FIGS. **16A** and **16B**, a copper layer **48** having a thickness t_2 of between 1 μm and 10 μm or between 2 and 10 micrometers and a largest transverse dimension w_2 , such as diameter in a circular shape, between 1 μm and 15 μm , such as 5 μm , on its seed layer **26b** and a metal cap **49** made of a tin-silver alloy, a tin-gold alloy, a tin-copper alloy, a tin-indium alloy, indium, tin or gold, which has a thickness of between 0.1 μm and 5 μm , such as 1 μm , on its copper layer **48**. Neighboring two of its fourth type of micro-bumps or micro-pillars **570** may have a pitch between 3 μm and 20 μm .

4. Fourth Type of Semiconductor Chip

[0305] FIG. **14D** is a schematically cross-sectional view showing a fourth type of semiconductor chip in accordance with an embodiment of the present application. Referring to FIG. **14D**, a fourth type of semiconductor chip **100** may have similar structure as illustrated in FIG. **14A**. For an element indicated by the same reference number shown in FIGS. **14A** and **14D**, the specification of the element as seen in FIG. **14D** may be referred to that of the element as illustrated in FIG. **14A**. The difference between the first and fourth types of semiconductor chips **100** is that the fourth type of semiconductor chip **100** may be provided with (1) an insulating bonding layer **52** at its active side and on the topmost one of the insulating dielectric layers **12** of its first interconnection scheme for a chip (FISC) **20** and (2) multiple metal pads **6a** at its active side and in multiple openings **52a** in its insulating bonding layer **52** and on the topmost one of the interconnection metal layers **6** of its first interconnection scheme for a chip (FISC) **20**, instead of the second interconnection scheme for a chip (SISC) **29**, the passivation layer **14** and micro-bumps or micro-pillars **34** as seen in FIG. **14A**. For the fourth type of semiconductor chip **100**, its insulating bonding layer **52** may include a silicon-oxide layer having a thickness between 0.1 and 2 μm . Each of its metal pads **6a** may include (1) a copper layer **24** having a thickness of between 3 nm and 500 nm in one of the openings **52a** in its insulating bonding layer **52**, (2) an adhesion layer **18**, such as titanium or

titanium nitride having a thickness of between 1 nm and 50 nm, at a bottom and sidewall of the copper layer **24** of said each of its metal pads **6a** and on the topmost one of the interconnection metal layers **6** of its first interconnection scheme for a chip (FISC) **20**, and (3) a seed layer **22**, such as copper, between the copper layer **24** and adhesion layer **18** of said each of its metal pads **6a**, wherein the copper layer **24** of said each of its metal pads **6a** may have a top surface substantially coplanar with a top surface of the silicon-oxide layer of its insulating bonding layer **52**.

5. Fifth Type of Semiconductor Chip

FIG. **14E** is a schematically cross-sectional view showing a fifth type of semiconductor chip in accordance with an embodiment of the present application. Referring to FIG. **14E**, a fifth type of semiconductor chip **100** may have similar structure as illustrated in FIG. **14D**. For an element indicated by the same reference number shown in FIGS. **14D** and **14E**, the specification of the element as seen in FIG. **14D** may be referred to that of the element as illustrated in FIG. **14E**. The difference between the fourth and fifth types of semiconductor chips **100** is that the fifth type of semiconductor chip **100** may further include multiple through silicon vias (TSV) **157** in its semiconductor substrate **2**, wherein each of its through silicon vias (TSV) **157** may couple to one or more of its semiconductor devices **4** through one or more the interconnection metal layers **6** of its first interconnection scheme for a chip (FISC) **20**.

[0306] Referring to FIG. **14E**, each of the through silicon vias (TSV) **157** may include (1) an electroplated copper layer **156** having a depth, for example, between 10 nm and 3,000 nm, between 10 nm and 1,000 nm or between 10 nm and 500 nm in the semiconductor substrate **2** of the fifth type of semiconductor chip **100**, (2) an insulating lining layer **153**, such as thermally grown silicon oxide (SiO.sub.2) and/or CVD silicon nitride (Si.sub.3N.sub.4) at a bottom and sidewall of its electroplated copper layer **156**, (3) an adhesion layer **154**, such as titanium (Ti) or titanium nitride (TiN) layer having a thickness between 1 nm to 50 nm, at the bottom and sidewall of its electroplated copper layer **156** and between its electroplated copper layer **156** and its insulating lining layer **153**, and (4) an electroplating seed layer **155**, such as copper seed layer **155** having a thickness between 3 nm and 200 nm, at the bottom and sidewall of its electroplated copper layer **156** and between its electroplated copper layer **156** and its adhesion layer **154**.

6. Sixth Type of Semiconductor Chip

[0307] FIG. **14F** is a schematically cross-sectional view showing a sixth type of semiconductor chip in accordance with an embodiment of the present application. Referring to FIG. **14F**, a sixth type of semiconductor chip **100** may have similar structure as illustrated in FIG. **14D**. For an element indicated by the same reference number shown in FIGS. **14D** and **14F**, the specification of the element as seen in FIG. **14F** may be referred to that of the element as illustrated in FIG. **14D**. The difference between the fourth and sixth types of semiconductor chips **100** is that the sixth type of semiconductor chip **100** may be provided with the through silicon vias (TSV) **157** in its semiconductor substrate **2**, wherein each of its through silicon vias (TSV) **157** may couple to one or more of its semiconductor devices **4** through one or more the interconnection metal layers **6** of its first interconnection scheme for a chip (FISC) **20**.

[0308] Referring to FIG. **14F**, each of the through silicon vias (TSV) **157** may include (1) an electroplated copper layer **156** having a depth, for example, between 10 nm and 3,000 nm, between 10 nm and 1,000 nm or between 10 nm and 500 nm in the semiconductor substrate **2** of the sixth type of semiconductor chip **100**, (2) an insulating lining layer **153**, such as thermally grown silicon oxide (SiO.sub.2) and/or CVD silicon nitride (Si.sub.3N.sub.4) at the sidewall of its electroplated copper layer **156**, (3) an adhesion layer **154**, such as titanium (Ti) or titanium nitride (TiN) layer having a thickness between 1 nm to 50 nm, at the sidewall of its electroplated copper layer **156** and between its electroplated copper layer **156** and its insulating lining layer **153**, and (4) an electroplating seed layer **155**, such as copper seed layer **155** having a thickness between 3 nm and 200 nm, at the sidewall of its electroplated copper layer **156** and between its electroplated copper layer **156** and its adhesion layer **154**. For the sixth type of semiconductor chip **100**, the

electroplated copper layer **156** of each of its through silicon vias (TSV) **157** may have a backside surface coplanar to a backside **2b** of its semiconductor substrate **2**, and the insulating lining layer **153** of said each of its through silicon vias (TSV) **157** surrounds the adhesion layer **154**, electroplating seed layer **155** and electroplated copper layer **156** of said each of its through silicon vias (TSV) **157**. The sixth type of semiconductor chip **100** may further include (1) an insulating bonding layer **52** at its backside and on the backside **2b** of its semiconductor substrate **2** and (2) multiple metal pads **6a** at its backside, in multiple openings **52a** in its insulating bonding layer **52** at its backside and on the backside of the electroplated copper layer **156** of its through silicon vias (TSV) **157**. For the sixth type of semiconductor chip **100**, its insulating bonding layer **52** at its backside may include a silicon-oxide layer having a thickness between 0.1 and 2 μm . Each of its metal pads **6a** at its backside may include (1) a copper layer **24** having a thickness of between 3 nm and 500 nm in one of the openings **52a** in its insulating bonding layer **52** at its backside, (2) an adhesion layer **18**, such as titanium or titanium nitride having a thickness of between 1 nm and 50 nm, at a top and sidewall of the copper layer **24** of said each of its metal pads **6a** at its backside, and (3) a seed layer **22**, such as copper, between the copper layer **24** and adhesion layer **18** of said each of its metal pads **6a** at its backside, wherein the copper layer **24** of said each of its metal pads **6a** at its backside may have a bottom surface substantially coplanar with a bottom surface of the silicon-oxide layer of its insulating bonding layer **52** at its backside.

Specification for Memory Module (HBM Stacked 3D Chip-Scale-Package (CSP))

First type of Memory Module

[0309] FIG. **15A** is a schematically cross-sectional view showing a first type of memory module in accordance with an embodiment of the present application. For each of the first through third types of standard commodity logic drives **300** as illustrated in FIGS. **10A-10C**, each of its first and/or second memory modules **159-1** and/or **159-2** may be a first type of memory module **159** as seen in FIG. **15A**, including (1) multiple third HBM IC chips **251-3**, such as volatile-memory (VM) integrated circuit (IC) chips for a VM module, dynamic-random-access-memory (DRAM) IC chips for a high-bitwidth memory (HBM) module, statistic-random-access-memory (SRAM) IC chips for a SRAM module, non-volatile memory (NVM) integrated circuit (IC) chips for a NVM module, magnetoresistive random-access-memory (MRAM) IC chips for a MRAM module, resistive random-access-memory (RRAM) IC chips for a RRAM module or phase change random access memory (PCM) chips for a PCM module, vertically stacked together, wherein the number of the third HBM IC chips **251-3** in the first type of memory module **159** may have the number equal to or greater than 2, 4, 8, 16, 32, (2) a control chip **688**, i.e., ASIC or logic chip, under its stacked third HBM IC chips **251-3**, (3) multiple bonded contacts **158** between neighboring two of its third HBM IC chips **251-3** and between the bottommost one of its third HBM IC chips **251-3** and its control chip **688**, and (4) multiple first, second or third type of micro-bumps or micro-pillars **34** as illustrated in FIG. **14A** on an active side of its control chip **688**.

[0310] Referring to FIG. **15A**, each of the third HBM IC chips **251-3** of the first type of memory module **159** may have the structure as illustrated in FIG. **14C**, which may include the through silicon vias (TSV) **157** in its semiconductor substrate **2**, each aligned with and connected to one of the bonded contacts **158** at its backside.

[0311] FIGS. **16A** and **16B** are schematically cross-sectional views showing a process of bonding a thermal compression bump to a thermal compression pad in accordance with an embodiment of the present application. For the first type of memory module **159**, referring to FIGS. **15A**, **16A** and **16B**, in a first case, an upper one of its third HBM IC chips **251-3** may have the third type of micro-bumps or micro-pillars **34** to be bonded to the fourth type of micro-bumps or micro-pillars **570** of a lower one of its third HBM IC chips **251-3**. For example, the third type of micro-bumps or micro-pillars **34** of the upper one of its third HBM IC chips **251-3** may have the solder caps **38** to be thermally compressed, at a temperature between 240 and 300 degrees Celsius, at a pressure between 0.3 and 3 MPa and for a time period between 3 and 15 seconds, onto the metal caps **49** of

the fourth type of micro-bumps or micro-pillars **570** of the lower one of its third HBM IC chips **251-3** into multiple bonded contacts **158** between the upper and lower ones of its third HBM IC chips **251-3**. Each of the third type of micro-bumps or micro-pillars **34** of the upper one of its third HBM IC chips **251-3** may have the copper layer **37** having the thickness t_3 greater than the thickness t_2 of the copper layer **48** of each of the fourth type of micro-bumps or micro-pillars **570** of the lower one of its third HBM IC chips **251-3** and having the largest transverse dimension w_3 equal to between 0.7 and 0.1 times of the largest transverse dimension w_2 of the copper layer **48** of each of the fourth type of micro-bumps or micro-pillars **570** of the lower one of its third HBM IC chips **251-3**. Alternatively, each of the third type of micro-pillars or micro-bumps **34** of the upper one of its third HBM IC chips **251-3** may be provided with the copper layer **37** having a cross-sectional area equal to between 0.5 and 0.01 times of the cross-sectional area of the copper layer **48** of each of the fourth type of micro-bumps or micro-pillars **570** of the lower one of its third HBM IC chips **251-3**.

[0312] For example, referring to FIGS. **15A**, **16A** and **16B**, for the upper one of the third HBM IC chips **251-3** of the first type of memory module **159**, its third type of micro-bumps or micro-pillars **34** may be formed respectively on a front surface of its metal pads **6b** provided by the frontmost one of the interconnection metal layers **27** of its second interconnection scheme for a chip (SISC) **29** or by, if the second interconnection scheme for a chip (SISC) **29** is not provided, the frontmost one of the interconnection metal layers **6** of its first interconnection scheme for a chip (FISC) **20**, wherein each of its metal pads **6b** may have a thickness t_1 between 1 and 10 micrometers or between 2 and 10 micrometers and a largest transverse dimension w_1 , such as diameter in a circular shape, between 1 μm and 15 μm , such as 5 μm , and each of its third type of micro-bumps or micro-pillars **34** may be provided with the copper layer **37** having the thickness t_3 greater than the thickness t_1 of its metal pads **6b** and having the largest transverse dimension w_3 equal to between 0.7 and 0.1 times of the largest transverse dimension w_1 of its metal pads **6b**; alternatively, each of its third type of micro-bumps or micro-pillars **34** may be provided with the copper layer **37** having a cross-sectional area equal to between 0.5 and 0.01 times of the cross-sectional area of its metal pads **6b**.

[0313] Referring to FIGS. **15A**, **16A** and **16B**, for the first type of memory module **159**, a bonded solder between the copper layers **37** and **48** of each of its bonded contacts **158** may be mostly kept on a top surface of the copper layer **48** of one of the fourth type of micro-bumps or micro-pillars **570** of the lower one of its third HBM IC chips **251-3** and extends out of the edge of the copper layer **48** of said one of the fourth type of micro-bumps or micro-pillars **570** of the lower one of its third HBM IC chips **251-3** less than 0.5 micrometers. Thus, a short between neighboring two of its bonded contacts **158** even in a fine-pitched fashion may be avoided.

[0314] Alternatively, for the first type of memory module **159**, referring to FIG. **15A**, in a second case, an upper one of its third HBM IC chips **251-3** may have the second type of micro-bumps or micro-pillars **34** to be bonded to the first type of micro-bumps or micro-pillars **570** of a lower one of its third HBM IC chips **251-3**. For example, the second type of micro-bumps or micro-pillars **34** of the upper one of its third HBM IC chips **251-3** may have the solder caps **33** to be bonded onto the electroplated copper layer **32** of the first type of micro-bumps or micro-pillars **570** of the lower one of its third HBM IC chips **251-3** into multiple bonded contacts **158** between the upper and lower ones of its third HBM IC chips **251-3**. Each of the second type of micro-bumps or micro-pillars **34** of the upper one of its third HBM IC chips **251-3** may have the electroplated copper layer **32** having a thickness greater than that of the electroplated copper layer **32** of each of the first type of micro-bumps or micro-pillars **570** of the lower one of its third HBM IC chips **251-3**.

[0315] Alternatively, for the first type of memory module **159**, referring to FIG. **15A**, in a third case, an upper one of its third HBM IC chips **251-3** may have the first type of micro-bumps or micro-pillars **34** to be bonded to the second type of micro-bumps or micro-pillars **570** of a lower one of its third HBM IC chips **251-3**. For example, the first type of micro-bumps or micro-pillars

34 of the upper one of its third HBM IC chips **251-3** may have the electroplated metal layer **32**, e.g. copper layer, to be bonded onto the solder caps **33** of the second type of micro-bumps or micro-pillars **570** of the lower one of its third HBM IC chips **251-3** into multiple bonded contacts **158** between the upper and lower ones of its third HBM IC chips **251-3**. Each of the first type of micro-bumps or micro-pillars **34** of the upper one of its third HBM IC chips **251-3** may have the electroplated copper layer **32** having a thickness greater than that of the electroplated copper layer **32** of each of the second type of micro-bumps or micro-pillars **570** of the lower one of its third HBM IC chips **251-3**.

[0316] Alternatively, for the first type of memory module **159**, referring to FIG. **15A**, in a fourth case, an upper one of its third HBM IC chips **251-3** may have the second type of micro-bumps or micro-pillars **34** to be bonded to the second type of micro-bumps or micro-pillars **570** of a lower one of its third HBM IC chips **251-3**. For example, the second type of micro-bumps or micro-pillars **34** of the upper one of its third HBM IC chips **251-3** may have the solder caps **33** to be bonded onto the solder caps **33** of the second type of micro-bumps or micro-pillars **570** of the lower one of its third HBM IC chips **251-3** into multiple bonded contacts **158** between the upper and lower ones of its third HBM IC chips **251-3**. Each of the second type of micro-bumps or micro-pillars **34** of the upper one of its third HBM IC chips **251-3** may have the electroplated copper layer **32** having a thickness greater than that of the electroplated copper layer **32** of each of the second type of micro-bumps or micro-pillars **570** of the lower one of its third HBM IC chips **251-3**.

[0317] Referring to FIG. **15A**, for the first type of memory module **159**, each of the through silicon vias (TSV) **157** of the topmost one of its third HBM IC chips **251-3** may have its sidewall and backside enclosed by the semiconductor substrate **2** of the topmost one of its third HBM IC chips **251-3**, as seen in FIG. **14B**. The bottommost one of its third HBM IC chips **251-3** may provide the micro-bumps or micro-pillars **34** on its bottom surface to be bonded to the micro-bumps or micro-pillars **570** on a top surface of its control chip **688** into multiple bonded contacts **158** between its control chip **688** and the bottommost one of its third HBM IC chips **251-3**. The specification of its bonded contacts **158** between its control chip **688** and the bottommost one of its third HBM IC chips **251-3** and the process for forming the same may be referred to the specification of those between the upper and lower ones of its third HBM IC chips **251-3** as above illustrated in FIGS. **15A**, **16A** and **16B** and the above-mentioned process for forming the same.

[0318] Referring to FIG. **15A**, for the first type of memory module **159**, the through silicon vias (TSV) **157** in its third HBM IC chips **251-3**, which are aligned in a vertical direction, may couple to each other or one another through its bonded contacts **158** therebetween aligned in the vertical direction and with its through silicon vias (TSV) **157** therein in the vertical direction. Each of its third HBM IC chips **251-3** and control chip **688** may include multiple interconnects **696** each provided by the interconnection metal layers **6** and/or **27** of the first and/or second interconnection scheme for a chip (FISC) **20** and/or (SISC) **29** of said each of its third HBM IC chips **251-3** and control chip **688** to connect one or more of its through silicon vias (TSV) **157** to one or more of its bonded contacts **158** at a bottom surface of said each of its third HBM IC chips **251-3** and control chip **688**. An underfill **694**, e.g., a polymer, may be provided between each neighboring two of its third HBM IC chips **251-3** to enclose its bonded contacts **158** therebetween and between the bottommost one of its third HBM IC chips **251-3** and its control chip **688** to enclose its bonded contacts **158** therebetween. A molding compound **695**, e.g. a polymer, may be formed around its third HBM IC chips **251-3** and over its control chip **688**, wherein the topmost one of its third HBM IC chips **251-3** may have a top surface coplanar with a top surface of its molding compound **695**.

[0319] Referring to FIG. **15A**, for the first type of memory module **159**, each of its third HBM IC chips **251-3** may have a data bit-width, equal or greater than 64, 128, 256, 512, 1024, 2048, 4096, 8K, or 16K, with external circuits of the memory module **159** via its micro-bumps or micro-pillars **34**. The first type of memory module **159** may include multiple vertical interconnects **699** each composed of one of the through silicon vias (TSV) **157** in each of its third HBM IC chips **251-3**.

[0320] Referring to FIG. 15A, for each of the vertical interconnects 699 of the first type of memory module 159, its through silicon vias (TSV) 157 in the third HBM IC chips 251-3 of the first type of memory module 159 are aligned with each other or one another and are connected to one or more transistors of the semiconductor devices 4 of the third HBM IC chips 251-3 of the first type of memory module 159.

[0321] Referring to FIG. 15A, for the first type of memory module 159, each of its third HBM IC chips 251-3 and control chip 688 may be provided with one or more small I/O circuits, having driving capability, loading, output capacitance or input capacitance between 0.05 pF and 2 pF, or 0.05 pF and 1 pF, or smaller than 2 pF or 1 pF, coupling to one of its vertical interconnects 699.

[0322] Referring to FIG. 15A, for the first type of memory module 159, its control chip 688 may be configured to control data access to its third HBM IC chips 251-3. Its control chip 688 may be used for buffering and controlling its third HBM IC chips 251-3. Its control chip 688 may include the through silicon vias (TSV) 157 in the semiconductor substrate 2 of its control chip 688, each aligned with and connected to one of its micro-bumps or micro-pillars 34 on the bottom surface of its control chip 688.

Second type of Memory Module

[0323] Alternatively, FIG. 15B is a schematically cross-sectional view showing a second type of memory module in accordance with another embodiment of the present application. For each of the first through third types of standard commodity logic drives 300 as illustrated in FIGS. 10A-10C, each of its first and/or second memory modules 159-1 and/or 159-2 may be a second type of memory module 159 as seen in FIG. 15B. The second type of memory module 159 may have a structure similar to the first type of memory module 159 as illustrated in FIG. 15A. For an element indicated by the same reference number shown in FIGS. 15A and 15B, the specification of the element as seen in FIG. 15B may be referred to that of the element as illustrated in FIG. 15A. The difference between the first and second types of memory modules 159 as seen in FIGS. 15A and 15B is that a direct bonding process may be performed for the second type of memory module 159 as seen in FIG. 15B. FIGS. 16C and 16D are schematically cross-sectional views showing a direct bonding process in accordance with an embodiment of the present application. Referring to FIGS. 15B, 16C and 16D, each of the third HBM IC chips 251-3 and control chip 688 of the second type of memory module 159 may have the structure as illustrated in FIG. 14F, which may include the through silicon vias (TSV) 157 in its semiconductor substrate 2, each aligned with its metal pads 6a at its active side and backside.

[0324] Referring to FIGS. 15B, 16C and 16D, for the second type of memory module 159, an upper one of its third HBM IC chips 251-3 may join a lower one of its third HBM IC chips 251-3 and control chip 688 by (1) activating a joining surface, i.e., silicon oxide, of the insulating bonding layer 52 at the active side of the upper one of its third HBM IC chips 251-3 and a joining surface, i.e., silicon oxide, of the insulating bonding layer 52 at the backside of the lower one of its third HBM IC chips 251-3 and control chip 688 with nitrogen plasma for increasing hydrophilic property thereof, (2) next rinsing the joining surface of the insulating bonding layer 52 at the active side of the upper one of its third HBM IC chips 251-3 and the joining surface of the insulating bonding layer 52 at the backside of the lower one of its third HBM IC chips 251-3 and control chip 688 with deionized water for water adsorption and cleaning, (3) next placing the upper one of its third HBM IC chips 251-3 onto the lower one of its third HBM IC chips 251-3 and control chip 688 with each of the metal pads 6a at the active side of the upper one of its third HBM IC chips 251-3 in contact with one of the metal pads 6a at the backside of the lower one of its third HBM IC chips 251-3 and control chip 688 and with the joining surface of the insulating bonding layer 52 at the active side of the upper one of its third HBM IC chips 251-3 in contact with the joining surface of the insulating bonding layer 52 at the backside of the lower one of its third HBM IC chips 251-3 and control chip 688, and (4) next performing a direct bonding process including (a) oxide-to-oxide bonding at a temperature between 100 and 200 degrees Celsius and for a time period between 5 and

20 minutes to bond the joining surface of the insulating bonding layer **52** at the active side of the upper one of its third HBM IC chips **251-3** to the joining surface of the insulating bonding layer **52** at the backside of the lower one of its third HBM IC chips **251-3** and control chip **688** and (b) copper-to-copper bonding at a temperature between 300 and 350 degrees Celsius and for a time period between 10 and 60 minutes to bond the copper layer **24** of each of the metal pads **6a** at the active side of the upper one of its third HBM IC chips **251-3** to the copper layer **24** of one of the metal pads **6a** at the backside of the lower one of its third HBM IC chips **251-3** and control chip **688**, wherein the oxide-to-oxide bonding may be caused by water desorption from reaction between the joining surface of the insulating bonding layer **52** at the active side of the upper one of its third HBM IC chips **251-3** and the joining surface of the insulating bonding layer **52** at the backside of the lower one of its third HBM IC chips **251-3**, and the copper-to-copper bonding may be caused by metal inter-diffusion between the copper layer **24** of the metal pads **6a** at the active side of the upper one of its third HBM IC chips **251-3** and the copper layer **24** of the metal pads **6a** at the backside of the lower one of its third HBM IC chips **251-3** and control chip **688**.

Process for Fabricating Operation Module (FPGA/HBM stacked 3D Chip-Scale-Package (CSP)) [0325] FIGS. **17A-17G** are schematic views showing a process for forming first and second types of operation modules, i.e., FPGA/HBM stacked 3D chip scale packages (CSP), in accordance with an embodiment of the present application. Referring to FIG. **17A**, a semiconductor wafer **100b** may be provided with (1) a semiconductor substrate **2**, such as silicon substrate, (2) multiple semiconductor devices **4**, such as transistors or passive devices, on its semiconductor substrate **2**, which may compose the multiplexer **211** of the programmable logic cells (LC) **2014**, the memory cells **490** of the programmable logic cells (LC) **2014**, the memory cells **362** for the cross-point switches **379** and the small I/O circuits **203**, as illustrated in FIGS. **1A-8B**, for standard commodity FPGA IC chips **200**, (3) an interconnection scheme **561**, composed of multiple interconnection metal layers **6** and insulating dielectric layers **12** similar to those for the first interconnection scheme for a chip (FISC) **20** as illustrated in FIG. **14A** and/or multiple interconnection metal layers **27** and polymer layers **42** similar to those for the second interconnection scheme for a chip (SISC) **29** as illustrated in FIG. **14A**, over its semiconductor substrate **2**, wherein each of its semiconductor devices **4** may couple to the interconnection metal layers **6** and/or **27** of its first and/or second interconnection scheme(s) for a chip (FISC and/or SISC) **20** and/or **29**, and (4) multiple first, second or fourth type of micro-bumps or micro-pillars **34** as illustrated in FIG. **14A** on its first and/or second interconnection scheme for a chip (FISC and/or SISC) **20** and/or **29**. Further, the semiconductor wafer **100b** may be provided with multiple through silicon vias (TSV) **157** in its semiconductor substrate **2**, wherein each of its through silicon vias (TSV) **157** may couple to one or more of its semiconductor devices **4** through one or more the interconnection metal layers **6** of its first interconnection scheme for a chip (FISC) **20**. Each of the through silicon vias (TSV) **157** may include (1) an electroplated copper layer **156** having a depth, for example, between 10 nm and 3,000 nm, between 10 nm and 1,000 nm or between 10 nm and 500 nm in the semiconductor substrate **2** of the semiconductor wafer **100b**, (2) an insulating lining layer **153**, such as thermally grown silicon oxide (SiO.sub.2) and/or CVD silicon nitride (Si.sub.3N.sub.4) at a bottom and sidewall of its electroplated copper layer **156**, (3) an adhesion layer **154**, such as titanium (Ti) or titanium nitride (TiN) layer having a thickness between 1 nm to 50 nm, at the bottom and sidewall of its electroplated copper layer **156** and between its electroplated copper layer **156** and its insulating lining layer **153**, and (4) an electroplating seed layer **155**, such as copper seed layer **155** having a thickness between 3 nm and 200 nm, at the bottom and sidewall of its electroplated copper layer **156** and between its electroplated copper layer **156** and its adhesion layer **154**.

[0326] Referring to FIGS. **17A** and **17B**, multiple first type of second memory modules **159-2** (only one is shown) each having the structure as illustrated in FIG. **15A** may be provided, each having the first, second or third type of micro-bumps or micro-pillars **34** to be bonded to the first, second or fourth type of micro-bumps or micro-pillars **34** preformed at an active side of the semiconductor

wafer **100b** into multiple bonded contacts **563** therebetween. Alternatively, each of the first type of second memory modules **159-2** may be replaced with a known-good memory chip, such as second HBM IC chips **251-2**, having the structure as illustrated in FIG. **14A** or **14B**. Each of the known-good second HBM IC chips **251-2** may have the first, second or third type of micro-bumps or micro-pillars **34** to be bonded to the first, second or fourth type of micro-bumps or micro-pillars **34** preformed at the active side of the semiconductor wafer **100b** into multiple bonded contacts **563** therebetween.

[0327] FIGS. **18A** and **18B** are schematically cross-sectional views showing a process of bonding a thermal compression bump to a thermal compression pad in accordance with an embodiment of the present application. For a first case, referring to FIGS. **17A**, **17B**, **18A** and **18B**, each of the first type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**, may have the third type of micro-bumps or micro-pillars **34** to be bonded to the fourth type of micro-bumps or micro-pillars **34** of the semiconductor wafer **100b**. For example, the third type of micro-bumps or micro-pillars **34** of said each of the first type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**, may have the solder caps **38** to be thermally compressed, at a temperature between 240 and 300 degrees Celsius, at a pressure between 0.3 and 3 Mpa and for a time period between 3 and 15 seconds, onto the metal caps **49** of the fourth type of micro-bumps or micro-pillars **34** of the semiconductor wafer **100b** into multiple bonded contacts **563** between said each of the first type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**, and the semiconductor wafer **100b**. Each of the third type of micro-bumps or micro-pillars **34** of said each of the first type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**, may have the copper layer **37** having the thickness t_3 greater than the thickness t_2 of the copper layer **48** of each of the fourth type of micro-bumps or micro-pillars **34** of the semiconductor wafer **100b** and having the largest transverse dimension w_3 equal to between 0.7 and 0.1 times of the largest transverse dimension w_2 of the copper layer **48** of each of the fourth type of micro-bumps or micro-pillars **34** of the semiconductor wafer **100b**. Alternatively, each of the third type of micro-pillars or micro-bumps **34** of said each of the first type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**, may be provided with the copper layer **37** having a cross-sectional area equal to between 0.5 and 0.01 times of the cross-sectional area of the copper layer **48** of each of the fourth type of micro-bumps or micro-pillars **34** of the semiconductor wafer **100b**.

[0328] For example, referring to FIGS. **17A**, **17B**, **18A** and **18B**, for each of the first type of second memory modules **159-2** to be bonded to the semiconductor wafer **100b**, its third type of micro-bumps or micro-pillars **34** may be formed respectively on a front surface of the metal pads **6b** provided by the frontmost one of the interconnection metal layers **27** of the second interconnection scheme for a chip (SISC) **29** of its control chip **688** or by, if the second interconnection scheme for a chip (SISC) **29** is not provided for its control chip **688**, the frontmost one of the interconnection metal layers **6** of the first interconnection scheme for a chip (FISC) **20** of its control chip **688**, wherein each of its third type of micro-bumps or micro-pillars **34** may be provided with the copper layer **37** having the thickness t_3 greater than the thickness t_1 of each of the metal pads **6b** of its control chip **688** and having the largest transverse dimension w_3 equal to between 0.7 and 0.1 times of the largest transverse dimension w_1 of each of the metal pads **6b** of its control chip **688**; alternatively, each of its third type of micro-bumps or micro-pillars **34** may be provided with the copper layer **37** having a cross-sectional area equal to between 0.5 and 0.01 times of the cross-sectional area of each of the metal pads **6b** of its control chip **688**; each of the metal pads **6b** of its control chip **688** may have a thickness t_1 between 1 and 10 micrometers or between 2 and 10 micrometers and a largest transverse dimension w_1 , such as diameter in a circular shape, between 1 μm and 15 μm , such as 5 μm .

[0329] Referring to FIGS. **17A**, **17B**, **18A** and **18B**, for each of the known-good second HBM IC chips **251-2** to be bonded to the semiconductor wafer **100b**, its third type of micro-bumps or micro-

pillars **34** may be formed respectively on a front surface of its metal pads **6b** provided by the frontmost one of the interconnection metal layers **27** of its second interconnection scheme for a chip (SISC) **29** or by, if the second interconnection scheme for a chip (SISC) **29** is not provided, the frontmost one of the interconnection metal layers **6** of its first interconnection scheme for a chip (FISC) **20**, wherein each of its third type of micro-bumps or micro-pillars **34** may be provided with the copper layer **37** having the thickness t_3 greater than the thickness t_1 of its metal pads **6b** and having the largest transverse dimension w_3 equal to between 0.7 and 0.1 times of the largest transverse dimension w_1 of its metal pads **6b**; alternatively, each of its third type of micro-bumps or micro-pillars **34** may be provided with the copper layer **37** having a cross-sectional area equal to between 0.5 and 0.01 times of the cross-sectional area of its metal pads **6b**; each of its metal pads **6b** may have a thickness t_1 between 1 and 10 micrometers or between 2 and 10 micrometers and a largest transverse dimension w_1 , such as diameter in a circular shape, between 1 μm and 15 μm , such as 5 μm .

[0330] Referring to FIGS. **17A**, **17B**, **18A** and **18B**, a bonded solder between the copper layers **37** and **48** of each of the bonded contacts **563** may be mostly kept on a top surface of the copper layer **48** of one of the fourth type of micro-bumps or micro-pillars **34** of the semiconductor wafer **100b** and extends out of the edge of the copper layer **48** of said one of the fourth type of micro-bumps or micro-pillars **34** of the semiconductor wafer **100b** less than 0.5 micrometers. Thus, a short between neighboring two of the bonded contacts **563** even in a fine-pitched fashion may be avoided.

[0331] Alternatively, for a second case, referring to FIGS. **17A** and **17B**, each of the first type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**, may have the second type of micro-bumps or micro-pillars **34** to be bonded to the first type of micro-bumps or micro-pillars **34** of the semiconductor wafer **100b**. For example, the second type of micro-bumps or micro-pillars **34** of said each of the first type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**, may have the solder caps **33** to be bonded onto the electroplated copper layer **32** of the first type of micro-bumps or micro-pillars **34** of the semiconductor wafer **100b** into multiple bonded contacts **563** between said each of the first type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**, and the semiconductor wafer **100b**. Each of the second type of micro-bumps or micro-pillars **34** of said each of the first type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**, may have the electroplated copper layer **32** having a thickness greater than that of the electroplated copper layer **32** of each of the first type of micro-bumps or micro-pillars **34** of the semiconductor wafer **100b**.

[0332] Alternatively, for a third case, referring to FIGS. **17A** and **17B**, each of the first type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**, may have the first type of micro-bumps or micro-pillars **34** to be bonded to the second type of metal bumps or pillars **34** of the semiconductor wafer **100b**. For example, the first type of micro-bumps or micro-pillars **34** of said each of the first type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**, may have the electroplated metal layer **32**, e.g. copper layer, to be bonded onto the solder caps **33** of the second type of micro-bumps or micro-pillars **34** of the semiconductor wafer **100b** into multiple bonded contacts **563** between said each of the first type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**, and the semiconductor wafer **100b**. Each of the first type of micro-bumps or micro-pillars **34** of said each of the first type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**, may have the electroplated copper layer **32** having a thickness greater than that of the electroplated copper layer **32** of each of the second type of micro-bumps or micro-pillars **34** of the semiconductor wafer **100b**.

[0333] Alternatively, for a fourth case, referring to FIGS. **17A** and **17B**, each of the first type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**, may have the second type of micro-bumps or micro-pillars **34** to be bonded to the second type of micro-bumps or micro-pillars **34** of the semiconductor wafer **100b**. For example, the second type of micro-bumps or micro-pillars **34** of said each of the first type of second memory modules **159-2**, or known-good

second HBM IC chips **251-2**, may have the solder caps **33** to be bonded onto the solder caps **33** of the second type of micro-bumps or micro-pillars **34** of the semiconductor wafer **100b** into multiple bonded contacts **563** between said each of the first type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**, and the semiconductor wafer **100b**. Each of the second type of micro-bumps or micro-pillars **34** of said each of the first type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**, may have the electroplated copper layer **32** having a thickness greater than that of the electroplated copper layer **32** of each of the second type of micro-bumps or micro-pillars **34** of the semiconductor wafer **100b**.

[0334] Next, referring to FIG. **17B**, an underfill **564**, such as epoxy resins or compounds, may be filled into a gap between each of the first type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**, and the semiconductor wafer **100b** to enclose the bonded contacts **563** therebetween. The underfill **564** may be cured at temperature equal to or above 100, 120 or 150 degrees Celsius.

[0335] Alternatively, FIGS. **19A-19G** are cross-sectional views showing a process for fabricating first and second types of operation modules, i.e., FPGA/HBM stacked 3D chip scale packages (CSP), in accordance with another embodiment of the present application. Referring to FIGS. **19A** and **19B**, a semiconductor wafer **100c** may be provided with (1) a semiconductor substrate **2**, such as silicon substrate, (2) multiple semiconductor devices **4**, such as transistors or passive devices, on its semiconductor substrate **2**, (3) the first interconnection scheme for a chip (FISC) **20**, composed of multiple interconnection metal layers **6** and insulating dielectric layers **12** as illustrated in FIG. **14A**, over its semiconductor substrate **2**, wherein each of its semiconductor devices **4** may couple to the interconnection metal layers **6** of its first interconnection scheme for a chip (FISC) **20**, (4) an insulating bonding layer **52** at its active side and on the topmost one of the insulating dielectric layers **12** of its first interconnection scheme for a chip (FISC) **20** and (5) multiple metal pads **6a** at its active side and in multiple openings **52a** in its insulating bonding layer **52** and on the topmost one of the interconnection metal layers **6** of its first interconnection scheme for a chip (FISC) **20**. The specification of the insulating bonding layer **52** and metal pads **6a** may be referred to that as illustrated in FIG. **14D**. Further, the semiconductor wafer **100c** may be provided with multiple through silicon vias (TSV) **157** in its semiconductor substrate **2**, wherein each of its through silicon vias (TSV) **157** may couple to one or more of its semiconductor devices **4** through one or more the interconnection metal layers **6** of its first interconnection scheme for a chip (FISC) **20**. Each of its through silicon vias (TSV) **157** may have the structure as illustrated in FIG. **17A**.

[0336] Referring to FIGS. **19A** and **19B**, multiple second type of second memory modules **159-2** (only one is shown) each having the structure as illustrated in FIG. **15B** may be provided, each having the insulating bonding layer **52** at their bottoms to be bonded to the insulating bonding layer **52** preformed at an active side of the semiconductor wafer **100c** and the metal pads **6a** at their bottoms to be bonded to the metal pads **6a** preformed at an active side of the semiconductor wafer **100c**. Alternatively, each of the second type of second memory modules **159-2** may be replaced with a known-good memory chip, such as second HBM IC chips **251-2**, having the structure as illustrated in FIG. **14D** or **14E**. Each of the known-good second HBM IC chips **251-2** may have the insulating bonding layer **52** at their bottoms to be bonded to the insulating bonding layer **52** preformed at an active side of the semiconductor wafer **100c** and the metal pads **6a** at their bottoms to be bonded to the metal pads **6a** preformed at an active side of the semiconductor wafer **100c**. Before the second type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**, join the semiconductor wafer **100c**, a joining surface, i.e., silicon oxide, of the insulating bonding layer **52** at the active side of the semiconductor wafer **100c** may be activated with nitrogen plasma for increasing a hydrophilic property thereof, and then the joining surface of the insulating bonding layer **52** at the active side of the semiconductor wafer **100c** may be rinsed with deionized water for water adsorption and cleaning. Further, a joining surface, i.e., silicon oxide, of the insulating bonding layer **52** at the active side of the control chip **688** of each of the second type of

second memory modules **159-2** or at the active side of each of the known-good second HBM IC chips **251-2** may be activated with nitrogen plasma for increasing a hydrophilic property thereof, and then the joining surface of the insulating bonding layer **52** at the active side of the control chip **688** of each of the second type of second memory modules **159-2**, or at the active side of each of the known-good second HBM IC chips **251-2**, may be rinsed with deionized water for water adsorption and cleaning.

[0337] Next, referring to FIGS. **19A** and **19B**, the second type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**, may join the semiconductor wafer **100c** by (1) picking up each of the second type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**, to be placed on the semiconductor wafer **100c** with each of the metal pads **6a** at the active side of the control chip **688** of each of the second type of second memory modules **159-2**, or at the active side of each of the known-good second HBM IC chips **251-2**, in contact with one of the metal pads **6a** at the active side of the semiconductor wafer **100c** and with the joining surface of the insulating bonding layer **52** at the active side of the control chip **688** of each of the second type of second memory modules **159-2**, or at the active side of each of the known-good second HBM IC chips **251-2**, in contact with the joining surface of the insulating bonding layer **52** at the active side of the semiconductor wafer **100c**, and (2) next performing a direct bonding process including (a) oxide-to-oxide bonding at a temperature between 100 and 200 degrees Celsius and for a time period between 5 and 20 minutes to bond the joining surface of the insulating bonding layer **52** at the active side of the control chip **688** of each of the second type of second memory modules **159-2**, or at the active side of each of the known-good second HBM IC chips **251-2**, to the joining surface of the insulating bonding layer **52** at the active side of the semiconductor wafer **100c** and (b) copper-to-copper bonding at a temperature between 300 and 350 degrees Celsius and for a time period between 10 and 60 minutes to bond the copper layer **24** of each of the metal pads **6a** at the active side of the control chip **688** of each of the second type of second memory modules **159-2**, or at the active side of each of the known-good second HBM IC chips **251-2**, to the copper layer **24** of one of the metal pads **6a** at the active side of the semiconductor wafer **100c**, wherein the oxide-to-oxide bonding may be caused by water desorption from reaction between the joining surface of the insulating bonding layer **52** at the active side of the control chip **688** of each of the second type of second memory modules **159-2**, or at the active side of each of the known-good second HBM IC chips **251-2**, and the joining surface of the insulating bonding layer **52** at the active side of the semiconductor wafer **100c**, and the copper-to-copper bonding may be caused by metal inter-diffusion between the copper layer **24** of the metal pads **6a** at the active side of the control chip **688** of each of the second type of second memory modules **159-2**, or at the active side of each of the known-good second HBM IC chips **251-2**, and the copper layer **24** of the metal pads **6a** at the active side of the semiconductor wafer **100c**.

[0338] Next, referring to FIGS. **17B** and **19B**, a polymer layer **565**, e.g., resin or compound, may be applied to fill the gaps between neighboring two of the first or second type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**, and to cover a backside of each of the first or second type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**, by methods, for example, spin-on coating, screen-printing, dispensing or molding. The polymer layer **565** may be, for example, polyimide, BenzoCycloButene (BCB), parylene, epoxy-based material or compound, photo epoxy SU-8, elastomer, or silicone. The polymer layer **565** may be cured or cross-linked at a temperature higher than or equal to 50, 70, 90, 100, 125, 150, 175, 200, 225, 250, 275 or 300 degrees Celsius.

[0339] Next, referring to FIGS. **17C** and **19C**, a chemical mechanical polishing (CMP), polishing or grinding process may be applied to remove a top portion of the polymer layer **565**, a top portion of each of the first or second type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**, to planarize a top surface of the polymer layer **565**, a top surface of each of the first or second type of second memory modules **159-2**, or known-good second HBM IC chips **251-2**,

and to expose a top surface of the topmost one of the third HBM IC chips **251-3** of said each of the first or second type of second memory modules **159-2**, or the top surface of said each of the known-good second HBM IC chips **251-2**. Next, a chemical mechanical polishing (CMP), polishing or grinding process may be applied to remove a bottom portion of the semiconductor substrate **2** of the semiconductor wafer **100b** or **100c** to expose a backside of the electroplated copper layer **156** of each of the through silicon vias (TSV) **157** of the semiconductor wafer **100b** or **100c**. For each of the through silicon vias (TSV) **157** of the semiconductor wafer **100b** or **100c**, its insulating lining layer **153**, adhesion layer **154** and electroplating seed layer **155** at its bottom is removed to expose the backside of its electroplated copper layer **156**.

[0340] Next, referring to FIGS. **17D** and **19D**, a passivation layer **14** containing a silicon-nitride, SiON or SiCN layer having a thickness greater than 0.3 μm for example and, alternatively, a polymer layer having a thickness between 1 and 10 μm may be formed on a backside of the semiconductor substrate **2** of the semiconductor wafer **100b** or **100c**, which is defined as a portion of the semiconductor wafer **100b** or **100c**. Multiple openings in the passivation layer **14** on the backside of the semiconductor substrate **2** of the semiconductor wafer **100b** or **100c** may be aligned with and under the backside of the electroplated copper layer **156** of the through silicon vias (TSV) **157** of the semiconductor wafer **100b** or **100c**. Next, multiple micro-bumps or micro-pillars **570** may be formed on the backside of the electroplated copper layer **156** of the through silicon vias (TSV) **157** of the semiconductor wafer **100b** or **100c**. The micro-bumps or micro-pillars **570** at the backside of the semiconductor wafer **100b** or **100c** may be of first through third types, which may have the same specification as the first through third types of micro-bumps or micro-pillars **570** of the third type of semiconductor chip **100** as illustrated in FIG. **14C**.

[0341] Alternatively, referring to FIGS. **17F** and **19F**, after the chemical mechanical polishing (CMP), polishing or grinding process is applied as illustrated in FIGS. **17C** and **19C** to remove a bottom portion of the semiconductor substrate **2** of the semiconductor wafer **100b** or **100c**, an insulating bonding layer **52** containing a silicon-oxide layer having a thickness between 0.1 and 2 μm may be formed on the backside of the semiconductor substrate **2** of the semiconductor wafer **100b** or **100c** to be defined as a portion of the semiconductor wafer **100b** or **100c**. Multiple openings **52a** may be formed in the insulating bonding layer **52** of the semiconductor wafer **100b** or **100c** to expose the backside of the electroplated copper layer **156** of the through silicon vias (TSV) **157** of the semiconductor wafer **100b** or **100c**. Next, multiple metal pads **6a** may be formed in the openings **52a** in the insulating bonding layer **52** at the backside of the semiconductor wafer **100b** or **100c** and on the backside of the electroplated copper layer **156** of the through silicon vias (TSV) **157** of the semiconductor wafer **100b** or **100c** to be defined as a portion of the semiconductor wafer **100b** or **100c**. For the semiconductor wafer **100b** or **100c**, each of its metal pads **6a** at its backside may include (1) a copper layer **24** having a thickness of between 3 nm and 500 nm in one of the openings **52a** in its insulating bonding layer **52** at its backside, (2) an adhesion layer **18**, such as titanium or titanium nitride having a thickness of between 1 nm and 50 nm, at a top and sidewall of the copper layer **24** of said each of its metal pads **6a** at its backside and on and under the backside of the electroplated copper layer **156** of its through silicon vias (TSV) **157**, and (3) a seed layer **22**, such as copper, between the copper layer **24** and adhesion layer **18** of said each of its metal pads **6a** at its backside, wherein the copper layer **24** of said each of its metal pads **6a** at its backside may have a bottom surface substantially coplanar with a bottom surface of the silicon-oxide layer of its insulating bonding layer **52** at its backside.

[0342] Next, the semiconductor wafer **100b** or **100c** and polymer layer **565** as seen in FIG. **17D** or **19D** may be cut or diced to separate multiple individual first type of operation modules **190** or FPGA/HBM stacked 3D chip scale packages (CSP) as shown in FIG. **17E** or **19E** respectively by a laser cutting process or by a mechanical cutting process. The semiconductor wafer **100b** or **100c** and polymer layer **565** as seen in FIG. **17F** or **19F** may be cut or diced to separate multiple individual second type of operation modules **190** or FPGA/HBM stacked 3D chip scale packages

(CSP) as shown in FIG. 17G or 19G respectively by a laser cutting process or by a mechanical cutting process. At this time, the semiconductor wafer **100b** or **100c** may be cut or diced into multiple semiconductor chips that may be field-programmable-gate-array (FPGA) integrated-circuit (IC) chips **200**.

[0343] For each of the first type of operation modules **190** as shown in FIG. 17E or 19E and the second type of operation modules **190** as shown in FIG. 17G or 19G, a data bus between its first or second type of second memory module **159-2**, or known-good second HBM IC chip **251-2**, and its FPGA IC chip **200** may have a data bit-width, equal or greater than 64, 128, 256, 512, 1024, 2048, 4096, 8K, or 16K. Each of the third HBM IC chips **251-2** of its first or second type of second memory module **159-2**, or known-good second HBM IC chip **251-2**, may have the small I/O circuits **203** as seen in FIGS. 5B and 12 each coupling to one of the small I/O circuits **203** of its FPGA IC chip **200** through one of the bonded contacts **563** as seen in FIG. 17E or 17G between its FPGA IC chip **200** and its first type of second memory module **159-2**, or known-good second HBM IC chip **251-2** or through one of the bonded structures as seen in FIG. 19E or 19G each made from the bonding of one the metal pads **6a** of its FPGA IC chip **200** and one of the metal pads **6a** of its second type of second memory module **159-2**, or known-good second HBM IC chip **251-2**.

[0344] For each of the first type of operation modules **190** as shown in FIG. 17E or 19E, its first or second type of second memory module **159-2**, or known-good second HBM IC chip **251-2**, may couple to one of its micro-bumps or micro-pillars **570** at the backside of its FPGA IC chip **200** for signal transmission or power or ground delivery through the interconnection metal layers **6** and/or **27** of the first and/or second interconnection scheme for a chip (FISC) **20** and/or (SISC) **29** of its FPGA IC chip **200** and one of the through silicon vias (TSV) **157** of its FPGA IC chip **200**.

[0345] For each of the second type of operation modules **190** as shown in FIG. 17G or 19G, its first or second type of second memory module **159-2**, or known-good second HBM IC chip **251-2**, may couple to one of its metal pads **6a** at the backside of its FPGA IC chip **200** for signal transmission or power or ground delivery through the interconnection metal layers **6** and/or **27** of the first and/or second interconnection scheme for a chip (FISC) **20** and/or (SISC) **29** of its FPGA IC chip **200** and one of the through silicon vias (TSV) **157** of its FPGA IC chip **200**.

Embodiment for Interposer

First Type of Interposer

[0346] FIG. 20A is schematically cross-sectional view showing a first type of interposer in accordance with an embodiment of the present application. One or more first or second type of semiconductor chips **100** as seen in FIG. 14A or 14B, first type of first memory modules **159-1** as seen in FIG. 15A and first type of operation modules **190** as seen in FIG. 17E or 19E may be packaged with a first type of interposer **551** as seen in FIG. 20A. Referring to FIG. 20A, the first type of interposer **551** may be provided with high density interconnects for fan-out of the first or second type of semiconductor chips **100**, first type of first memory modules **159-1** and first type of operation modules **190**. The first type of interposer **551** may include (1) a semiconductor substrate **2**, such as silicon wafer; (2) multiple metal vias **157** in its semiconductor substrate **2**, wherein the specification and process for its through silicon vias (TSV) **157** may be referred to those for the through silicon vias (TSV) **157** as illustrated in FIG. 17A; (3) a first interconnection scheme for an interposer (FISIP) **560** over its semiconductor substrate **2**, provided with one or more interconnection metal layers **6** coupling to its metal vias **157** and one or more insulating dielectric layers **12** each between neighboring two of the interconnection metal layers **6**, wherein the specification and process for the interconnection metal layers **6** and insulating dielectric layers **12** for the first interconnection scheme for an interposer (FISIP) **560** may be referred to those for the first interconnection scheme for a chip (FISC) **20** as illustrated in FIG. 14A; (4) a passivation layer **14** over its first interconnection scheme for an interposer (FISIP) **560**, wherein multiple openings in the passivation layer **14** may be aligned with and over multiple metal pads of the topmost one of the interconnection metal layers **6** of the first interconnection scheme for an interposer (FISIP) **560**.

respectively, wherein the specification and process for its passivation layer **14** may be referred to those for the passivation layer **14** as illustrated in FIG. **14A**; (5) a second interconnection scheme for an interposer (SISIP) **588** optionally provided over its passivation layer **14**, provided with one or more interconnection metal layers **27** coupling to the interconnection metal layers **6** of its first interconnection scheme for an interposer (FISIP) **560** through the openings in its passivation layer **14** and one or more polymer layers **42** each between neighboring two of its interconnection metal layers **27**, under a bottommost one of its interconnection metal layers **27** or over a topmost one of its interconnection metal layers **27**, wherein multiple openings **42a** in the topmost one of its polymer layers **42** may be aligned with and over multiple metal pads of the topmost one of the interconnection metal layers **27** of its second interconnection scheme for an interposer (SISIP) **588**, wherein the specification and process for the interconnection metal layers **27** and polymer layers **42** for the second interconnection scheme for an interposer (SISIP) **588** may be referred to those for the second interconnection scheme for a chip (SISC) **29** as illustrated in FIG. **14A**; (6) multiple first, second or fourth type of micro-bumps or micro-pillars **34** as illustrated in FIG. **14A** on the topmost one of the interconnection metal layers **27** of its second interconnection scheme for an interposer (SISIP) **588** or, if the second interconnection scheme for an interposer (SISIP) **588** is not provided, on the topmost one of the interconnection metal layers **6** of its first interconnection scheme for an interposer (FISIP) **560**; and (7) multiple through package vias (TPVs) **582** (only one is shown) on the topmost one of the interconnection metal layers **27** of its second interconnection scheme for an interposer (SISIP) **588** or, if the second interconnection scheme for an interposer (SISIP) **588** is not provided, on the topmost one of the interconnection metal layers **6** of its first interconnection scheme for an interposer (FISIP) **560**, wherein each of its through package vias (TPVs) **582** may include an adhesion layer **26a**, such as titanium (Ti) or titanium nitride (TiN) layer having a thickness of between 1 nm and 50 nm, on the topmost one of the interconnection metal layers **27** of its second interconnection scheme for an interposer (SISIP) **588** or, if the second interconnection scheme for an interposer (SISIP) **588** is not provided, on the topmost one of the interconnection metal layers **6** of its first interconnection scheme for an interposer (FISIP) **560**, a seed layer **26b**, such as copper, on its adhesion layer **26a** and a copper layer **581** having a thickness of between 5 μm and 300 μm on its seed layer **26b**.

Second Type of Interposer

FIG. **20B** is schematically cross-sectional view showing a second type of interposer in accordance with another embodiment of the present application. One or more fourth or fifth type of semiconductor chips **100** as seen in FIG. **14D** or **14E**, second type of first memory modules **159-1** as seen in FIG. **15B** and second type of operation modules **190** as seen in FIG. **17G** or **19G** may be packaged with a second type of interposer **551** as seen in FIG. **20B**. Referring to FIG. **20B**, the second type of interposer **551** may be provided with high density interconnects for fan-out of the fourth or fifth type of semiconductor chips **100**, second type of first memory modules **159-1** and second type of operation modules **190**. The second type of interposer **551** may include the semiconductor substrate **2**, through silicon vias **157** and first interconnection scheme for an interposer (FISIP) **560** as illustrated in FIG. **20A**. Further, the second type of interposer **551** may include an insulating bonding layer **52** on the topmost one of the insulating dielectric layers **12** of its first interconnection scheme for an interposer (FISIP) **560** and (2) multiple metal pads **6a** in multiple openings **52a** in its insulating bonding layer **52** and on the topmost one of the interconnection metal layers **6** of its first interconnection scheme for an interposer (FISIP) **560**. Its insulating bonding layer **52** may include a silicon-oxide layer having a thickness between 0.1 and 2 μm on the topmost one of the insulating dielectric layers **12** of its first interconnection scheme for an interposer (FISIP) **560**. Each of its metal pads **6a** may include (1) a copper layer **24** having a thickness of between 3 nm and 500 nm in one of the openings **52a** in its insulating bonding layer **52**, (2) an adhesion layer **18**, such as titanium or titanium nitride having a thickness of between 1 nm and 50 nm, at a bottom and sidewall of the copper layer **24** of said each of its metal pads **6a** and

on the topmost one of the interconnection metal layers **6** of its first interconnection scheme for an interposer (FISIP) **560**, and (3) a seed layer **22**, such as copper, between the copper layer **24** and adhesion layer **18** of said each of its metal pads **6a**, wherein the copper layer **24** of said each of its metal pads **6a** may have a top surface substantially coplanar with a top surface of the silicon-oxide layer of its insulating bonding layer **52**. Further, the second type of interposer **551** may include multiple through package vias (TPVs) **582** (only one is shown) on its metal pads **6a**, wherein each of its through package vias (TPVs) **582** may include an adhesion layer **26a**, such as titanium (Ti) or titanium nitride (TiN) layer having a thickness of between 1 nm and 50 nm, on the copper layer **24** of its metal pads **6a**, a seed layer **26b**, such as copper, on its adhesion layer **26a** and a copper layer **581** having a thickness of between 5 μm and 300 μm on its seed layer **26b**.

Chip/Module-On-Interposer (COIP) Package

[0347] FIGS. **21A-21E** are cross-sectional views showing a process for fabricating a first type of chip/module-on-interposer package in accordance with an embodiment of the present application. A first type of chip/module-on-interposer package may be provided to form the first, second, third or fourth type of standard commodity logic drive **300** as illustrated in FIG. **10A, 10B, 10C** or **10D**. Referring to FIGS. **21A** and **21B**, one or more first and/or second types of semiconductor chips **100** as illustrated in FIGS. **14A** and **14B** and first type of first memory modules **159-1** as seen in FIG. **15A** (only one is shown) may be provided, each having the first, second or third type of micro-bumps or micro-pillars **34** to be bonded to the first, second or fourth type of micro-bumps or micro-pillars **34** preformed on the first type of interposer **551** into multiple bonded contacts **563** therebetween. Each of the first and/or second types of semiconductor chips **100** may be the DPIIC chip **410**, IAC chip **402**, dedicated control and input/output (I/O) chip **265**, NVM IC chip **250**, first HBM IC chip **251-1**, PCIC chip **269**, GPU chip **269a** or CPU chip **269b** for the first, second, third or fourth type of standard commodity logic drive **300**. The first type of interposer **551** is shown with an interconnection scheme **561**, composed of the interconnection metal layers **6** and insulating dielectric layers **12** of its first interconnection scheme for an interposer (FISIP) **560** and/or the interconnection metal layers **27** and polymer layers **42** of its second interconnection scheme for an interposer (SISIP) **588** as illustrated in FIG. **20A**.

[0348] FIGS. **22A** and **22B** are schematically cross-sectional views showing a process of bonding a thermal compression bump to a thermal compression pad in accordance with an embodiment of the present application. For a first case, referring to FIGS. **21A, 21B, 22A** and **22B**, each of the first and/or second types of semiconductor chips **100** and the first type of first memory module **159-1** may have the third type of micro-bumps or micro-pillars **34** to be bonded to the fourth type of micro-bumps or micro-pillars **34** of the first type of interposer **551** as seen in FIG. **20A**. For example, the third type of micro-bumps or micro-pillars **34** of said each of the first and/or second types of semiconductor chips **100** and the first type of first memory module **159-1** may have the solder caps **38** to be thermally compressed, at a temperature between 240 and 300 degrees Celsius, at a pressure between 0.3 and 3 Mpa and for a time period between 3 and 15 seconds, onto the metal caps **49** of the fourth type of micro-bumps or micro-pillars **34** of the first type of interposer **551** into multiple bonded contacts **563** between said each of the first type of semiconductor chips **100** and first type of first memory module **159-1** and the first type of interposer **551**. Each of the third type of micro-bumps or micro-pillars **34** of said each of the first and/or second types of semiconductor chips **100** and the first type of first memory module **159-1** may have the copper layer **37** having the thickness t_3 greater than the thickness t_2 of the copper layer **48** of each of the fourth type of micro-bumps or micro-pillars **34** of the first type of interposer **551** and having the largest transverse dimension w_3 equal to between 0.7 and 0.1 times of the largest transverse dimension w_2 of the copper layer **48** of each of the fourth type of micro-bumps or micro-pillars **34** of the first type of interposer **551**. Alternatively, each of the third type of micro-pillars or micro-bumps **34** of said each of the first and/or second types of semiconductor chips **100** and the first type of first memory module **159-1** may be provided with the copper layer **37** having a cross-sectional

area equal to between 0.5 and 0.01 times of the cross-sectional area of the copper layer **48** of each of the fourth type of micro-bumps or micro-pillars **34** of the first type of interposer **551**.
[0349] For example, referring to FIGS. **21A**, **21B**, **22A** and **22B**, for each of the first and/or second types of semiconductor chips **100** to be bonded to the first type of interposer **551**, its third type of micro-bumps or micro-pillars **34** may be formed respectively on a front surface of its metal pads **6b** provided by the frontmost one of the interconnection metal layers **27** of its second interconnection scheme for a chip (SISC) **29** or by, if the second interconnection scheme for a chip (SISC) **29** is not provided, the frontmost one of the interconnection metal layers **6** of its first interconnection scheme for a chip (FISC) **20**, wherein each of its third type of micro-bumps or micro-pillars **34** may be provided with the copper layer **37** having the thickness t_3 greater than the thickness t_1 of its metal pads **6b** and having the largest transverse dimension w_3 equal to between 0.7 and 0.1 times of the largest transverse dimension w_1 of its metal pads **6b**; alternatively, each of its third type of micro-bumps or micro-pillars **34** may be provided with the copper layer **37** having a cross-sectional area equal to between 0.5 and 0.01 times of the cross-sectional area of its metal pads **6b**; each of its metal pads **6b** may have a thickness t_1 between 1 and 10 micrometers or between 2 and 10 micrometers and a largest transverse dimension w_1 , such as diameter in a circular shape, between 1 μm and 15 μm , such as 5 μm .

[0350] Referring to FIGS. **21A**, **21B**, **22A** and **22B**, for the first type of first memory module **159-1** to be bonded to the first type of interposer **551**, its third type of micro-bumps or micro-pillars **34** may be formed respectively on a front surface of the metal pads **6b** provided by the frontmost one of the interconnection metal layers **27** of the second interconnection scheme for a chip (SISC) **29** of its control chip **688** or by, if the second interconnection scheme for a chip (SISC) **29** is not provided for its control chip **688**, the frontmost one of the interconnection metal layers **6** of the first interconnection scheme for a chip (FISC) **20** of its control chip **688**, wherein each of its third type of micro-bumps or micro-pillars **34** may be provided with the copper layer **37** having the thickness t_3 greater than the thickness t_1 of each of the metal pads **6b** of its control chip **688** and having the largest transverse dimension w_3 equal to between 0.7 and 0.1 times of the largest transverse dimension w_1 of each of the metal pads **6b** of its control chip **688**; alternatively, each of its third type of micro-bumps or micro-pillars **34** may be provided with the copper layer **37** having a cross-sectional area equal to between 0.5 and 0.01 times of the cross-sectional area of each of the metal pads **6b** of its control chip **688**; each of the metal pads **6b** of its control chip **688** may have a thickness t_1 between 1 and 10 micrometers or between 2 and 10 micrometers and a largest transverse dimension w_1 , such as diameter in a circular shape, between 1 μm and 15 μm , such as 5 μm .

[0351] Referring to FIGS. **21A**, **21B**, **22A** and **22B**, a bonded solder between the copper layers **37** and **48** of each of the bonded contacts **563** may be mostly kept on a top surface of the copper layer **48** of one of the fourth type of micro-bumps or micro-pillars **34** of the first type of interposer **551** and extends out of the edge of the copper layer **48** of said one of the fourth type of micro-bumps or micro-pillars **34** of the first type of interposer **551** less than 0.5 micrometers. Thus, a short between neighboring two of the bonded contacts **563** even in a fine-pitched fashion may be avoided.

[0352] Alternatively, for a second case, referring to FIGS. **21A** and **21B**, each of the first and/or second types of semiconductor chips **100** and the first type of first memory module **159-1** may have the second type of micro-bumps or micro-pillars **34** to be bonded to the first type of micro-bumps or micro-pillars **34** of the first type of interposer **551**. For example, the second type of micro-bumps or micro-pillars **34** of said each of the first and/or second types of semiconductor chips **100** and the first type of first memory module **159-1** may have the solder caps **33** to be bonded onto the electroplated copper layer **32** of the first type of micro-bumps or micro-pillars **34** of the first type of interposer **551** into multiple bonded contacts **563** between said each of the first and/or second types of semiconductor chips **100** and the first type of first memory module **159-1** and the first type of interposer **551**. Each of the second type of micro-bumps or micro-pillars **34** of

said each of the first and/or second types of semiconductor chips **100** and the first type of first memory module **159-1** may have the electroplated copper layer **32** having a thickness greater than that of the electroplated copper layer **32** of each of the first type of micro-bumps or micro-pillars **34** of the first type of interposer **551**.

[0353] Alternatively, for a third case, referring to FIGS. **21A** and **21B**, each of the first and/or second types of semiconductor chips **100** and the first type of first memory module **159-1** may have the first type of micro-bumps or micro-pillars **34** to be bonded to the second type of metal bumps or pillars **34** of the first type of interposer **551**. For example, the first type of micro-bumps or micro-pillars **34** of said each of the first and/or second types of semiconductor chips **100** and the first type of first memory module **159-1** may have the electroplated metal layer **32**, e.g. copper layer, to be bonded onto the solder caps **33** of the second type of micro-bumps or micro-pillars **34** of the first type of interposer **551** into multiple bonded contacts **563** between said each of the first and/or second types of semiconductor chips **100** and the first type of first memory module **159-1** and the first type of interposer **551**. Each of the first type of micro-bumps or micro-pillars **34** of said each of the first and/or second types of semiconductor chips **100** and the first type of first memory module **159-1** may have the electroplated copper layer **32** having a thickness greater than that of the electroplated copper layer **32** of each of the second type of micro-bumps or micro-pillars **34** of the first type of interposer **551**.

[0354] Alternatively, for a fourth case, referring to FIGS. **21A** and **21B**, each of the first and/or second types of semiconductor chips **100** and the first type of first memory module **159-1** may have the second type of micro-bumps or micro-pillars **34** to be bonded to the second type of micro-bumps or micro-pillars **34** of the first type of interposer **551**. For example, the second type of micro-bumps or micro-pillars **34** of said each of the first and/or second types of semiconductor chips **100** and the first type of first memory module **159-1** may have the solder caps **33** to be bonded onto the solder caps **33** of the second type of micro-bumps or micro-pillars **34** of the first type of interposer **551** into multiple bonded contacts **563** between said each of the first and/or second types of semiconductor chips **100** and the first type of first memory module **159-1** and the first type of interposer **551**. Each of the second type of micro-bumps or micro-pillars **34** of said each of the first and/or second types of semiconductor chips **100** and the first type of first memory module **159-1** may have the electroplated copper layer **32** having a thickness greater than that of the electroplated copper layer **32** of each of the second type of micro-bumps or micro-pillars **34** of the first type of interposer **551**.

[0355] FIGS. **22C** and **22D** are schematically cross-sectional views showing a process of bonding a thermal compression bump to a thermal compression pad in accordance with an embodiment of the present application. For a first case, referring to FIGS. **21A**, **21B**, **22C** and **22D**, multiple first type of operation modules **190** (only one is shown) as illustrated in FIG. **17E** or **19E** may have the third type of micro-bumps or micro-pillars **570** to be bonded to the fourth type of micro-bumps or micro-pillars **34** of the first type of interposer **551** as seen in FIG. **20A**. For example, the third type of micro-bumps or micro-pillars **570** of each of the first type of operation modules **190** may have the solder caps **38** to be thermally compressed, at a temperature between 240 and 300 degrees Celsius, at a pressure between 0.3 and 3 Mpa and for a time period between 3 and 15 seconds, onto the metal caps **49** of the fourth type of micro-bumps or micro-pillars **34** of the first type of interposer **551** into multiple bonded contacts **563** between said each of the first type of operation modules **190** and the first type of interposer **551**. Each of the third type of micro-bumps or micro-pillars **570** of said each of the first type of operation modules **190** may have the copper layer **37** having the thickness t_3 greater than the thickness t_2 of the copper layer **48** of each of the fourth type of micro-bumps or micro-pillars **34** of the first type of interposer **551** and having the largest transverse dimension w_3 equal to between 0.7 and 0.1 times of the largest transverse dimension w_2 of the copper layer **48** of each of the fourth type of micro-bumps or micro-pillars **34** of the first type of interposer **551**. Alternatively, each of the third type of micro-pillars or micro-bumps **570** of said

each of the first type of operation modules **190** may be provided with the copper layer **37** having a cross-sectional area equal to between 0.5 and 0.01 times of the cross-sectional area of the copper layer **48** of each of the fourth type of micro-bumps or micro-pillars **34** of the first type of interposer **551**. A bonded solder between the copper layers **37** and **48** of each of the bonded contacts **563** may be mostly kept on a top surface of the copper layer **48** of one of the fourth type of micro-bumps or micro-pillars **34** of the first type of interposer **551** and extends out of the edge of the copper layer **48** of said one of the fourth type of micro-bumps or micro-pillars **34** of the first type of interposer **551** less than 0.5 micrometers. Thus, a short between neighboring two of the bonded contacts **563** even in a fine-pitched fashion may be avoided.

[0356] Alternatively, for a second case, referring to FIGS. **21A** and **21B**, each of the first type of operation modules **190** may have the second type of micro-bumps or micro-pillars **570** to be bonded to the first type of micro-bumps or micro-pillars **34** of the first type of interposer **551**. For example, the second type of micro-bumps or micro-pillars **570** of said each of the first type of operation modules **190** may have the solder caps **33** to be bonded onto the electroplated copper layer **32** of the first type of micro-bumps or micro-pillars **34** of the first type of interposer **551** into multiple bonded contacts **563** between said each of the first type of operation modules **190** and the first type of interposer **551**. Each of the second type of micro-bumps or micro-pillars **570** of said each of the first type of operation modules **190** may have the electroplated copper layer **32** having a thickness greater than that of the electroplated copper layer **32** of each of the first type of micro-bumps or micro-pillars **34** of the first type of interposer **551**.

[0357] Alternatively, for a third case, referring to FIGS. **21A** and **21B**, each of the first type of operation modules **190** may have the first type of micro-bumps or micro-pillars **570** to be bonded to the second type of metal bumps or pillars **34** of the first type of interposer **551**. For example, the first type of micro-bumps or micro-pillars **570** of said each of the first type of operation modules **190** may have the electroplated metal layer **32**, e.g. copper layer, to be bonded onto the solder caps **33** of the second type of micro-bumps or micro-pillars **34** of the first type of interposer **551** into multiple bonded contacts **563** between said each of the first type of operation modules **190** and the first type of interposer **551**. Each of the first type of micro-bumps or micro-pillars **570** of said each of the first type of operation modules **190** may have the electroplated copper layer **32** having a thickness greater than that of the electroplated copper layer **32** of each of the second type of micro-bumps or micro-pillars **34** of the first type of interposer **551**.

[0358] Alternatively, for a fourth case, referring to FIGS. **21A** and **21B**, each of the first type of operation modules **190** may have the second type of micro-bumps or micro-pillars **570** to be bonded to the second type of micro-bumps or micro-pillars **34** of the first type of interposer **551**. For example, the second type of micro-bumps or micro-pillars **570** of said each of the first type of operation modules **190** may have the solder caps **33** to be bonded onto the solder caps **33** of the second type of micro-bumps or micro-pillars **34** of the first type of interposer **551** into multiple bonded contacts **563** between said each of the first type of operation modules **190** and the first type of interposer **551**. Each of the second type of micro-bumps or micro-pillars **34** of said each of the first type of operation modules **190** may have the electroplated copper layer **32** having a thickness greater than that of the electroplated copper layer **32** of each of the second type of micro-bumps or micro-pillars **34** of the first type of interposer **551**.

[0359] Next, referring to FIG. **21B**, an underfill **564**, such as epoxy resins or compounds, may be filled into a gap between each of the first and/or second types of semiconductor chips **100** and the first type of first memory module **159-1** and the first type of interposer **551** to enclose the bonded contacts **563** therebetween and a gap between each of the first type of operation modules **190** and the first type of interposer **551** to enclose the bonded contacts **563** therebetween. The underfill **564** may be cured at temperature equal to or above 100, 120 or 150 degrees Celsius.

[0360] Alternatively, FIGS. **23A-23E** are cross-sectional views showing a process for fabricating a second type of chip/module-on-interposer package in accordance with various embodiments of the

present application. A second type of chip/module-on-interposer package may be provided to form the first, second, third or fourth type of standard commodity logic drive **300** as illustrated in FIG. **10A**, **10B**, **10C** or **10D**. Referring to FIGS. **23A** and **23B**, one or more fourth and/or fifth types of semiconductor chips **100** as seen in FIGS. **14E** and **14F**, second type of first memory modules **159-1** as seen in FIG. **15B** and second type of operation modules **190** as seen in FIG. **17G** or **19G** may be provided, each having the insulating bonding layer **52** at their bottoms to be bonded to the insulating bonding layer **52** preformed on the second type of interposer **551** as seen in FIG. **20B** and the metal pads **6a** at their bottoms to be bonded to the metal pads **6a** preformed on the second type of interposer **551**. Each of the fourth and/or fifth types of semiconductor chips **100** may be the FPGA IC chip **200**, DPIIC chip **410**, IAC chip **402**, dedicated control and input/output (I/O) chip **265**, NVM IC chip **250**, first HBM IC chip **251-1**, PCIC chip **269**, GPU chip **269a** or CPU chip **269b** for the first, second, third or fourth type of standard commodity logic drive **300**.

[0361] Referring to FIGS. **23A** and **23B**, before the fourth and/or fifth types of semiconductor chips **100**, second type of first memory module **159-1** and second type of operation modules **190** join the second type of interposer **551**, a joining surface, i.e., silicon oxide, of the insulating bonding layer **52** of the second type of interposer **551** may be activated with nitrogen plasma for increasing a hydrophilic property thereof, and then the joining surface of the insulating bonding layer **52** of the second type of interposer **551** may be rinsed with deionized water for water adsorption and cleaning. Further, a joining surface, i.e., silicon oxide, of the insulating bonding layer **52** at the active side of each of the fourth and/or fifth types of semiconductor chips **100**, a joining surface, i.e., silicon oxide, of the insulating bonding layer **52** at the active side of the control chip **688** of the second type of first memory module **159-1** and a joining surface, i.e., silicon oxide, of the insulating bonding layer **52** at the backside of the FPGA IC chip **200** of each of the second type of operation modules **190** may be activated with nitrogen plasma for increasing a hydrophilic property thereof, and then the joining surface of the insulating bonding layer **52** at the active side of said each of the fourth and/or fifth types of semiconductor chips **100**, the joining surface of the insulating bonding layer **52** at the active side of the control chip **688** of the second type of first memory module **159-1** and the joining surface of the insulating bonding layer **52** at the backside of the FPGA IC chip **200** of said each of the second type of operation modules **190** may be rinsed with deionized water for water adsorption and cleaning.

[0362] Next, referring to FIGS. **23A** and **23B**, the fourth and/or fifth types of semiconductor chips **100**, the second type of first memory module **159-1** and the second type of operation modules **190** may join the second type of interposer **551** by (1) picking up each of the fourth and/or fifth types of semiconductor chips **100** to be placed on the second type of interposer **551** with each of the metal pads **6a** of said each of the fourth and/or fifth types of semiconductor chips **100** at its active side in contact with one of the metal pads **6a** of the second type of interposer **551** and with the joining surface of the insulating bonding layer **52** of said each of the fourth and/or fifth types of semiconductor chips **100** at its active side in contact with the joining surface of the insulating bonding layer **52** of the second type of interposer **551**, picking up the second type of first memory module **159-1** to be placed on the second type of interposer **551** with each of the metal pads **6a** of the control chip **688** of the second type of first memory module **159-1** at its active side in contact with one of the metal pads **6a** of the second type of interposer **551** and with the joining surface of the insulating bonding layer **52** of the control chip **688** of the second type of first memory module **159-1** at its active side in contact with the joining surface of the insulating bonding layer **52** of the second type of interposer **551**, and picking up each of the second type of operation modules **190** to be placed on the second type of interposer **551** with each of the metal pads **6a** of the FPGA IC chip **200** of said each of the second type of operation modules **190** at its backside in contact with one of the metal pads **6a** of the second type of interposer **551** and with the joining surface of the insulating bonding layer **52** of the FPGA IC chip **200** of said each of the second type of operation modules **190** at its backside in contact with the joining surface of the insulating bonding layer **52** of the

second type of interposer **551**, and (2) next performing a direct bonding process including (a) oxide-to-oxide bonding at a temperature between 100 and 200 degrees Celsius and for a time period between 5 and 20 minutes to bond the joining surface of the insulating bonding layer **52** of said each of the fourth and/or fifth types of semiconductor chips **100** at its active side to the joining surface of the insulating bonding layer **52** of the second type of interposer **551**, to bond the joining surface of the insulating bonding layer **52** of the control chip **688** of the second type of first memory module **159-1** at its active side to the joining surface of the insulating bonding layer **52** of the second type of interposer **551** and to bond the joining surface of the insulating bonding layer **52** of the FPGA IC chip **200** of said each of the second type of operation modules **190** at its backside to the joining surface of the insulating bonding layer **52** of the second type of interposer **551**, and (b) copper-to-copper bonding at a temperature between 300 and 350 degrees Celsius and for a time period between 10 and 60 minutes to bond the copper layer **24** of each of the metal pads **6a** of said each of the fourth and/or fifth types of semiconductor chips **100** at its active side to the copper layer **24** of one of the metal pads **6a** of the second type of interposer **551**, to bond the copper layer **24** of each of the metal pads **6a** of the control chip **688** of the second type of first memory module **159-1** at its active side to the copper layer **24** of one of the metal pads **6a** of the second type of interposer **551** and to bond the copper layer **24** of each of the metal pads **6a** of the FPGA IC chip **200** of said each of the second type of operation modules **190** at its backside to the copper layer **24** of one of the metal pads **6a** of the second type of interposer **551**, wherein the oxide-to-oxide bonding may be caused by water desorption from reaction between the joining surface of the insulating bonding layer **52** of said each of the fourth and/or fifth types of semiconductor chips **100** at its active side and the joining surface of the insulating bonding layer **52** of the second type of interposer **551**, between the joining surface of the insulating bonding layer **52** of the control chip **688** of the second type of first memory module **159-1** at its active side and the joining surface of the insulating bonding layer **52** of the second type of interposer **551** and between the joining surface of the insulating bonding layer **52** of the FPGA IC chip **200** of said each of the second type of operation modules **190** at its backside and the joining surface of the insulating bonding layer **52** of the second type of interposer **551**, and the copper-to-copper bonding may be caused by metal inter-diffusion between the copper layer **24** of the metal pads **6a** of said each of the fourth and/or fifth types of semiconductor chips **100** at its active side and the copper layer **24** of the metal pads **6a** of the second type of interposer **551**, between the copper layer **24** of the metal pads **6a** of the control chip **688** of the second type of first memory module **159-1** at its active side and the copper layer **24** of the metal pads **6a** of the second type of interposer **551** and between the copper layer **24** of the metal pads **6a** of the FPGA IC chip **200** of said each of the second type of operation modules **190** at its backside and the copper layer **24** of the metal pads **6a** of the second type of interposer **551**.

[0363] Next, referring to FIGS. **21B** and **23B**, a polymer layer **565**, e.g., resin or compound, may be applied by methods, for example, spin-on coating, screen-printing, dispensing or molding to fill the gaps between neighboring two of the first and/or second types or fourth and/or fifth types of semiconductor chips **100**, first or second type of first memory module **159-1** and first or second type of operation modules **190** and to cover a backside of each of the first and/or second types or fourth and/or fifth types of semiconductor chips **100**, a backside of the first or second type of first memory modules **159-1** and a backside of each of the first or second type of operation modules **190**. The polymer layer **565** may be, for example, polyimide, BenzoCycloButene (BCB), parylene, epoxy-based material or compound, photo epoxy SU-8, elastomer, or silicone. The polymer layer **565** may be cured or cross-linked at a temperature higher than or equal to 50, 70, 90, 100, 125, 150, 175, 200, 225, 250, 275 or 300 degrees Celsius.

[0364] Next, referring to FIGS. **21C** and **23C**, a chemical mechanical polishing (CMP), polishing or grinding process may be applied to remove a top portion of the polymer layer **565**, a top portion of said each of the first and/or second types or fourth and/or fifth types of semiconductor chips **100**, a top portion of the first or second type of first memory module **159-1** and a top portion of said

each of first or second type of operation modules **190** to expose a top surface of said each of the first and/or second types or fourth and/or fifth types of semiconductor chips **100**, a top surface of the first or second type of first memory module **159-1**, a top surface of said each of the first or second type of operation modules **190** and a top surface of each of the through package vias (TPVs) **582** and to planarize a top surface of the polymer layer **565**, the top surface of said each of the first and/or second types or fourth and/or fifth types of semiconductor chips **100**, the top surface of the first or second type of first memory module **159-1**, the top surface of said each of the first or second type of operation modules **190** and the top surface of said each of the through package vias (TPVs) **582**.

[0365] Next, a chemical mechanical polishing (CMP), polishing or grinding process may be applied to remove a bottom portion of the semiconductor substrate **2** of the first or second type of interposer **551** to expose a backside of the electroplated copper layer **156** of each of the through silicon vias (TSV) **157** of the first or second type of interposer **551**. For each of the through silicon vias (TSV) **157** of the first or second type of interposer **551**, its insulating lining layer **153**, adhesion layer **154** and electroplating seed layer **155** at its bottom is removed to expose the backside of its electroplated copper layer **156**.

[0366] Next, referring to FIGS. **21D** and **23D**, a passivation layer **14** containing a silicon-nitride, SiON or SiCN layer having a thickness greater than 0.3 μm for example and, alternatively, a polymer layer having a thickness between 1 and 10 μm may be formed on a backside of the semiconductor substrate **2** of the first or second type of interposer **551**, which is defined as a portion of the first or second type of interposer **551**. Multiple openings in the passivation layer **14** on the backside of the semiconductor substrate **2** of the first or second type of interposer **551** may be aligned with and under the backside of the electroplated copper layer **156** of the through silicon vias (TSV) **157** of the first or second type of interposer **551**. Next, multiple metal bumps or pillars **583** may be formed on the backside of the electroplated copper layer **156** of the through silicon vias (TSV) **157** of the first or second type of interposer **551**. Each of the metal bumps or pillars **583** may include (1) an adhesion layer **26a**, such as titanium (Ti) or titanium nitride (TiN) layer having a thickness of between 1 nm and 50 nm, on and under the electroplated copper layer **156** of the through silicon vias (TSV) **157** of the first or second type of interposer **551**, (2) a seed layer **26b**, such as copper, on and under its adhesion layer **26a**, (3) a copper layer **32** having a thickness of between 1 μm and 60 μm on and under its seed layer **26b**, and (4) a tin-containing solder cap **33** made of tin or a tin-silver alloy, which has a thickness of between 1 μm and 50 μm on and under its copper layer **32**.

[0367] Next, the first or second type of interposer **551** and polymer layer **565** as seen in FIG. **21D** or **23D** may be cut or diced by a laser cutting process or by a mechanical cutting process to separate multiple first or second type of chip/module-on-interposer (COIP) packages as shown in FIG. **21E** or **23E** respectively for the first, second, third or fourth type of standard commodity logic drive **300** as illustrated in FIG. **10A**, **10B**, **10C** or **10D**.

[0368] FIG. **21F** is a cross-sectional view showing a package-on-package (POP) assembly for a first type of chip/module-on-interposer package in accordance with an embodiment of the present application. FIG. **23F** is a cross-sectional view showing a package-on-package (POP) assembly for a second type of chip/module-on-interposer package in accordance with an embodiment of the present application. Referring to FIG. **21F**, multiple first type of chip/module-on-interposer packages as illustrated in FIG. **21E** may be provided to be stacked together to form a first type of package-on-package (POP) assembly **311**. Referring to FIG. **23F**, multiple second type of chip/module-on-interposer packages as illustrated in FIG. **23E** may be provided to be stacked together to form a second type of package-on-package (POP) assembly **311**.

[0369] For forming the first or second type of package-on-package (POP) assembly **311** as seen in FIG. **21F** or **23F**, a circuit carrier substrate may be first provided. Next, the bottommost one of the first or second type of chip/module-on-interposer packages **300** may have the metal bumps or

pillars **583** to be bonded to the circuit carrier substrate. Next, an underfill **564** may be filled into a gap between the bottommost one of the first or second type of chip/module-on-interposer packages **300** and the circuit carrier substrate to enclose the metal bumps or pillars **583** of the bottommost one of the first or second type of chip/module-on-interposer packages **300**.

[0370] Next, referring to FIG. **21F** or **23F**, in a first step, a tin-containing solder **112** may be formed on the top surface of the through package vias **582** of the lower one of the first or second type of chip/module-on-interposer packages **300**. Next, in a second step, an upper one of the first or second type of chip/module-on-interposer packages **300** may have the metal bumps or pillars **583** to be bonded to the tin-containing solder **112**. Next, in a third step, the tin-containing solder **112** may be reflowed to bond each of the metal bumps or pillars **583** of the upper one of the first or second type of chip/module-on-interposer packages **300** to one of the through package vias **582** of the lower one of the first or second type of chip/module-on-interposer packages **300**. Next, in a fourth step, an underfill **564** may be filled into a gap between the upper and lower ones of the first or second type of chip/module-on-interposer packages **300** to enclose the metal bumps or pillars **583** of the upper one of the first or second type of chip/module-on-interposer packages **300**.

[0371] Next, referring to FIG. **21F** or **23F**, the above first through fourth steps may be sequentially repeated multiple times to stack, one by one, multiple of the first or second type of chip/module-on-interposer packages **300** having the number greater than or equal to two, such as four or eight. For a case, all of the first or second type of chip/module-on-interposer packages **300** stacked as seen in FIG. **21F** or **23F** may be the same.

[0372] Next, referring to FIG. **21F** or **23F**, multiple solder balls **325** may be planted on a bottom surface of the circuit carrier substrate. Next, the circuit carrier structure may be separated, cut or diced into multiple individual substrate units **113**, such as printed circuit boards (PCBs), ball-grid-array (BGA) substrates, flexible circuit films or tapes, or ceramic circuit substrates, by a laser cutting process or by a mechanical cutting process.

[0373] Alternatively, FIG. **21G** is a schematically cross-sectional view showing a third type of chip/module-on-interposer package in accordance with an embodiment of the present application. FIG. **23G** is a schematically cross-sectional view showing a fourth type of chip/module-on-interposer package in accordance with an embodiment of the present application. For forming the third or fourth type of chip/module-on-interposer package **300** as seen in FIG. **21G** or **23G**, after the chemical mechanical polishing (CMP), polishing or grinding process is applied to remove the top portion of the polymer layer **565**, the top portion of said each of the first and/or second types or fourth and/or fifth types of semiconductor chips **100**, the top portion of the first or second type of first memory module **159-1** and the top portion of said each of first or second type of operation modules **190** as illustrated in FIGS. **21C** and **23C**, a backside interconnection scheme for a logic drive (BISD) **79** as seen in FIG. **21G** or **23G** may be formed over the top surface of the polymer layer **565**, the top surface of said each of the first and/or second types or fourth and/or fifth types of semiconductor chips **100**, the top surface of the first or second type of first memory module **159-1**, the top surface of said each of first or second type of operation modules **190** and the top surface of each of the through package vias (TPVs) **582**. The backside interconnection scheme for a logic drive (BISD) **79** may include one or more interconnection metal layers **27** coupling to each of the through package vias (TPVs) **582** and one or more polymer layers **42** each between neighboring two of its interconnection metal layers **27**, under the bottommost one of its interconnection metal layers **27** or over the topmost one of its interconnection metal layers **27**, wherein an upper one of its interconnection metal layers **27** may couple to a lower one of its interconnection metal layers **27** through an opening in one of its polymer layers **42** between the upper and lower ones of its interconnection metal layers **27**. The bottommost one of its polymer layers **42** may be between the bottommost one of its interconnection metal layers **27** and the polymer layer **565** and between the bottommost one of its interconnection metal layers **27** and the top surface of each of the first and/or second types or fourth and/or fifth types of semiconductor chips **100**, the first or second type of

first memory module **159-1** and the first or second type of operation modules **190**. Each opening in the bottommost one of its polymer layers **42** may be over the top surface of one of the through package vias (TPVs) **582**, that is, the top surface of the electroplated copper layer of each of some or all of the through package vias (TPVs) **582** may be at a bottom of one of the openings in the bottommost one of its polymer layers **42**. Each of its interconnection metal layers **27** may extend horizontally across an edge of each of the first and/or second types or fourth and/or fifth types of semiconductor chips **100**, the first or second type of first memory module **159-1** and the first or second type of operation modules **190**. The topmost one of its interconnection metal layers **27** may have multiple metal pads **27a** at bottoms of multiple respective openings **42a** in the topmost one of its polymer layers **42**.

[0374] Referring to FIG. **21G** or **23G**, for the backside interconnection scheme for a logic drive (BISD) **79**, each of its polymer layers **42** may be a layer of polyimide, BenzoCycloButene (BCB), parylene, epoxy-based material or compound, photo epoxy SU-8, elastomer or silicone, having a thickness between, for example, 0.3 μm and 30 μm , 0.5 μm and 20 μm , 1 μm and 10 μm , or 0.5 μm and 5 μm , or thicker than or equal to 0.3 μm , 0.5 μm , 0.7 μm , 1 μm , 1.5 μm , 2 μm , 3 μm or 5 μm . Each of its interconnection metal layers **27** may be provided with multiple metal traces or lines each including (1) a copper layer **40** having one or more lower portions in openings in one of its polymer layers **42** having a thickness between 0.3 μm and 20 μm , and an upper portion having a thickness 0.3 μm and 20 μm over said one of its polymer layers **42**, (2) an adhesion layer **28a**, such as titanium or titanium nitride having a thickness between 1 nm and 50 nm, at a bottom and sidewall of each of the one or more lower portions of the copper layer **40** of said each of the metal traces or lines and at a bottom of the upper portion of the copper layer **40** of said each of the metal traces or lines, and (3) a seed layer **28b**, such as copper, between the copper layer **40** and adhesion layer **28a** of said each of the metal traces or lines, wherein the upper portion of the copper layer **40** of said each of the metal traces or lines may have a sidewall not covered by the adhesion layer **28a** of said each of the metal traces or lines. Each of its interconnection metal layers **27** may provide multiple metal lines or traces with a thickness between, for example, 0.3 μm and 30 μm , 0.5 μm and 20 μm , 1 μm and 10 μm , or 0.5 μm and 5 μm , or thicker than or equal to 0.3 μm , 0.5 μm , 0.7 μm , 1 μm , 1.5 μm , 2 μm , 3 μm or 5 μm , and a width between, for example, 0.3 μm and 30 μm , 0.5 μm and 20 μm , 1 μm and 10 μm , or 0.5 μm and 5 μm , or wider than or equal to 0.3 μm , 0.5 μm , 0.7 μm , 1 μm , 1.5 μm , 2 μm , 3 μm or 5 μm .

[0375] Referring to FIG. **21G** or **23G**, after the backside interconnection scheme for a logic drive (BISD) **79** is formed, the chemical mechanical polishing (CMP), polishing or grinding process is applied to remove the bottom portion of the semiconductor substrate **2** of the first or second type of interposer **551**, as illustrated in FIG. **21C** or **23C**. Next, the passivation layer **14** may be formed on the backside of the semiconductor substrate **2** of the first or second type of interposer **551**, as illustrated in FIG. **21D** or **23D**. Next, the metal bumps or pillars **583** may be formed on the backside of the electroplated copper layer **156** of the through silicon vias (TSV) **157** of the first or second type of interposer **551**, as illustrated in FIG. **21D** or **23D**. Next, the first or second type of interposer **551**, polymer layer **565** and backside interconnection scheme for a logic drive (BISD) **79** may be cut or diced by a laser cutting process or by a mechanical cutting process to separate multiple third or fourth type of chip/module-on-interposer (COIP) packages as shown in FIG. **21G** or **23G** respectively for the first, second, third or fourth type of standard commodity logic drive **300** as illustrated in FIG. **10A**, **10B**, **10C** or **10D**.

[0376] Alternatively, FIG. **21H** is a schematically cross-sectional view showing a fifth type of chip/module-on-interposer package in accordance with an embodiment of the present application. FIG. **23H** is a schematically cross-sectional view showing a sixth type of chip/module-on-interposer package in accordance with an embodiment of the present application. For forming the fifth or sixth type of chip/module-on-interposer package **300** as seen in FIG. **21H** or **23H**, after the polymer layer **565** is applied as illustrated in FIG. **21B** or **23B**, a chemical mechanical polishing

(CMP), polishing or grinding process may be applied as seen in FIG. 21H or 23H (1) to remove a top portion of the polymer layer **565**, a top portion of said each of the first and/or second types or fourth and/or fifth types of semiconductor chips **100**, a top portion of the first or second type of first memory module **159-1** and a top portion of said each of first or second type of operation modules **190**, (2) to expose a top surface of said each of the first and/or second types or fourth and/or fifth types of semiconductor chips **100**, a top surface of the first or second type of first memory module **159-1**, a top surface of said each of the first or second type of operation modules **190** and a top surface of each of the through package vias (TPVs) **582**, (3) to expose a backside of the electroplated copper layer **156** of each of the through silicon vias (TSV) **157** of each of the second or fifth type of semiconductor chips **100**, a backside of the electroplated copper layer **156** of each of the through silicon vias (TSV) **157** of the topmost one of the third HBM IC chips **251-3** of the first or second type of first memory module **159-1** and a backside of the electroplated copper layer **156** of each of the through silicon vias (TSV) **157** of the topmost one of the third HBM IC chips **251-3** of the first or second type of second memory module **159-2**, or the known-good second HBM IC chip **251-2**, of said each of the first or second type of operation modules **190**, and (4) to planarize a top surface of the polymer layer **565**, the top surface of said each of the first and/or second types or fourth and/or fifth types of semiconductor chips **100**, the top surface of the first or second type of first memory module **159-1**, the top surface of said each of the first or second type of operation modules **190**, the top surface of said each of the through package vias (TPVs) **582**, the backside of the electroplated copper layer **156** of each of the through silicon vias (TSV) **157** of each of the second or fifth type of semiconductor chips **100**, the backside of the electroplated copper layer **156** of each of the through silicon vias (TSV) **157** of the topmost one of the third HBM IC chips **251-3** of the first or second type of first memory module **159-1** and the backside of the electroplated copper layer **156** of each of the through silicon vias (TSV) **157** of the topmost one of the third HBM IC chips **251-3** of the first or second type of second memory module **159-2**, or the known-good second HBM IC chip **251-2**, of said each of the first or second type of operation modules **190**.

[0377] Next, referring to FIG. 21H or 23H, the backside interconnection scheme for a logic drive (BISD) **79** as illustrated in FIG. 21G or 23G may be formed over the top surface of the polymer layer **565**, the top surface of said each of the first and/or second types or fourth and/or fifth types of semiconductor chips **100**, the top surface of the first or second type of first memory module **159-1**, the top surface of said each of first or second type of operation modules **190** and the top surface of each of the through package vias (TPVs) **582**. Besides the specification for the backside interconnection scheme for a logic drive (BISD) **79** as illustrated in FIG. 21G or 23G, each opening in the bottommost one of its polymer layers **42** may be over (1) the backside of the electroplated copper layer **156** of one of the through silicon vias (TSV) **157** of one of the second or fifth type of semiconductor chips **100**, (2) the backside of the electroplated copper layer **156** of one of the through silicon vias (TSV) **157** of the topmost one of the third HBM IC chips **251-3** of the first or second type of first memory module **159-1**, (3) the backside of the electroplated copper layer **156** of each of the through silicon vias (TSV) **157** of the topmost one of the third HBM IC chips **251-3** of the first or second type of second memory module **159-2**, or the known-good second HBM IC chip **251-2**, of one of the first or second type of operation modules **190**, or (4) the top surface of one of the through package vias (TPVs) **582**; that is, the backside of the electroplated copper layer **156** of each of some or all of the through silicon vias (TSV) **157** of each of the second or fifth type of semiconductor chips **100** may be at a bottom of one of the openings in the bottommost one of its polymer layers **42**, the backside of the electroplated copper layer **156** of each of some or all of the through silicon vias (TSV) **157** of the topmost one of the third HBM IC chips **251-3** of the first or second type of first memory module **159-1** may be at a bottom of one of the openings in the bottommost one of its polymer layers **42**, the backside of the electroplated copper layer **156** of each of some or all of the through silicon vias (TSV) **157** of the topmost one of the third HBM IC chips

251-3 of the first or second type of second memory module **159-2**, or the known-good second HBM IC chip **251-2**, of each of the first or second type of operation modules **190** may be at a bottom of one of the openings in the bottommost one of its polymer layers **42**, and the top surface of the electroplated copper layer of each of some or all of the through package vias (TPVs) **582** may be at a bottom of one of the openings in the bottommost one of its polymer layers **42**. The bottommost one of its interconnection metal layers **27** may couple to the through silicon vias (TSV) **157** of each of the second or fifth type of semiconductor chips **100**, the through silicon vias (TSV) **157** of the topmost one of the third HBM IC chips **251-3** of the first or second type of first memory module **159-1**, the through silicon vias (TSV) **157** of the topmost one of the third HBM IC chips **251-3** of the first or second type of second memory module **159-2**, or the known-good second HBM IC chip **251-2**, of each of the first or second type of operation modules **190** and the through package vias (TPVs) **582** through the openings in the bottommost one of its polymer layers **42**. [0378] Referring to FIG. **21H** or **23H**, after the backside interconnection scheme for a logic drive (BISD) **79** is formed, the chemical mechanical polishing (CMP), polishing or grinding process is applied to remove the bottom portion of the semiconductor substrate **2** of the first or second type of interposer **551**, as illustrated in FIG. **21C** or **23C**. Next, the passivation layer **14** may be formed on the backside of the semiconductor substrate **2** of the first or second type of interposer **551**, as illustrated in FIG. **21D** or **23D**. Next, the metal bumps or pillars **583** may be formed on the backside of the electroplated copper layer **156** of the through silicon vias (TSV) **157** of the first or second type of interposer **551**, as illustrated in FIG. **21D** or **23D**. Next, the first or second type of interposer **551**, polymer layer **565** and backside interconnection scheme for a logic drive (BISD) **79** may be cut or diced by a laser cutting process or by a mechanical cutting process to separate multiple fifth or sixth type of chip/module-on-interposer (COIP) packages as shown in FIG. **21H** or **23H** respectively for the first, second, third or fourth type of standard commodity logic drive **300** as illustrated in FIG. **10A**, **10B**, **10C** or **10D**.

[0379] FIG. **21I** is a cross-sectional view showing a package-on-package (POP) assembly for a fifth type of chip/module-on-interposer package in accordance with an embodiment of the present application. FIG. **23I** is a cross-sectional view showing a package-on-package (POP) assembly for a sixth type of chip/module-on-interposer package in accordance with an embodiment of the present application. Referring to FIG. **21I**, multiple fifth type of chip/module-on-interposer packages as illustrated in FIG. **21H** may be provided to be stacked together to form a third type of package-on-package (POP) assembly **311**. Referring to FIG. **23I**, multiple sixth type of chip/module-on-interposer packages as illustrated in FIG. **23H** may be provided to be stacked together to form a fourth type of package-on-package (POP) assembly **311**.

[0380] For forming the third or fourth type of package-on-package (POP) assembly **311** as seen in FIG. **21I** or **23I**, a circuit carrier substrate may be first provided. Next, the bottommost one of the fifth or sixth type of chip/module-on-interposer packages **300** may have the metal bumps or pillars **583** to be bonded to the circuit carrier substrate. Next, an underfill **564** may be filled into a gap between the bottommost one of the fifth or sixth type of chip/module-on-interposer packages **300** and the circuit carrier substrate to enclose the metal bumps or pillars **583** of the bottommost one of the fifth or sixth type of chip/module-on-interposer packages **300**.

[0381] Next, referring to FIG. **21I** or **23I**, in a first step, a tin-containing solder **112** may be formed on the top surface of the through package vias **582** of the lower one of the fifth or sixth type of chip/module-on-interposer packages **300**. Next, in a second step, an upper one of the fifth or sixth type of chip/module-on-interposer packages **300** may have the metal bumps or pillars **583** to be bonded to the tin-containing solder **112**. Next, in a third step, the tin-containing solder **112** may be reflowed to bond each of the metal bumps or pillars **583** of the upper one of the fifth or sixth type of chip/module-on-interposer packages **300** to one of the through package vias **582** of the lower one of the fifth or sixth type of chip/module-on-interposer packages **300**. Next, in a fourth step, an underfill **564** may be filled into a gap between the upper and lower ones of the fifth or sixth type of

chip/module-on-interposer packages **300** to enclose the metal bumps or pillars **583** of the upper one of the fifth or sixth type of chip/module-on-interposer packages **300**.

[0382] Next, referring to FIG. **21I** or **23I**, the above first through fourth steps may be sequentially repeated multiple times to stack, one by one, multiple of the fifth or sixth type of chip/module-on-interposer packages **300** having the number greater than or equal to two, such as four or eight. For a case, all of the fifth or sixth type of chip/module-on-interposer packages **300** stacked as seen in FIG. **21I** or **23I** may be the same.

[0383] Next, referring to FIG. **21I** or **23I**, multiple solder balls **325** may be planted on a bottom surface of the circuit carrier substrate. Next, the circuit carrier structure may be separated, cut or diced into multiple individual substrate units **113**, such as printed circuit boards (PCBs), ball-grid-array (BGA) substrates, flexible circuit films or tapes, or ceramic circuit substrates, by a laser cutting process or by a mechanical cutting process.

[0384] For each of the first through sixth types of chip/module-on-interposer packages **300** as seen in FIGS. **21E**, **23E**, **21G**, **23G**, **21H** and **23H** respectively, each of its through package vias (TPV) may couple to the voltage of power supply (Vcc) for power delivery, the voltage of ground reference (Vss) for ground delivery or a signal source for signal transmission.

Alternative Embodiment for Standard Commodity Logic Drive

[0385] FIG. **24** is a schematically cross-sectional view showing a standard commodity logic drive in accordance with another embodiment of the present application. Referring to FIG. **24**, for forming the first, second, third or fourth type of standard commodity logic drive **300**, the backside interconnection scheme for a logic drive (BISD) **79** may be first formed with the specification as illustrated in FIG. **21G**. Next, the through package vias (TPV) **582** may be formed on the topmost one of the interconnection metal layers **27** of the backside interconnection scheme for a logic drive (BISD) **79** and has the specification as illustrated in FIG. **20A**. Next, each of the first and/or second type of semiconductor chips **100** as illustrated in FIGS. **14A** and **14B** may have the backside attached to a top surface of the backside interconnection scheme for a logic drive (BISD) **79** with its first type of micro-bumps or micro-pillars **34** facing up, the first type of first memory module **159-1** as illustrated in FIG. **15A** may have the backside attached to a top surface of the backside interconnection scheme for a logic drive (BISD) **79** with its first type of micro-bumps or micro-pillars **34** on the active side of its control chip **688** facing up, and/or each of the first type of operation modules **190** as seen in FIG. **17E** or **19E** may have the backside attached to a top surface of the backside interconnection scheme for a logic drive (BISD) **79** with its first type of micro-bumps or micro-pillars **570** on the backside of its FPGA IC chip **200** facing up. Each of the first and/or second types of semiconductor chips **100** may be the DPIIC chip **410**, IAC chip **402**, dedicated control and input/output (I/O) chip **265**, NVM IC chip **250**, first HBM IC chip **251-1**, PCIC chip **269**, GPU chip **269a** or CPU chip **269b** for the first, second, third or fourth type of standard commodity logic drive **300**. Next, the polymer layer **565** may be formed over the top surface of the backside interconnection scheme for a logic drive (BISD) **79** and neighboring two of the first and/or second type of semiconductor chips **100**, the first type of first memory module **159-1** and/or the first type of operation modules **190** to cover said each of the first and/or second type of semiconductor chips **100**, the first type of first memory module **159-1** and/or said each of the first type of operation modules **190** and to cover the first type of micro-bumps or micro-pillars **34** of said each of the first and/or second type of semiconductor chips **100**, the first type of micro-bumps or micro-pillars **34** on the active side of the control chip **688** of the first type of first memory module **159-1** and the first type of micro-bumps or micro-pillars **570** on the backside of the FPGA IC chip **200** of said each of the first type of operation modules **190**. Next, a polishing or grinding process may be performed to remove a top portion of the polymer layer **565** to expose a top surface of the through package vias (TPV) **582** and to expose a top surface of each of the first type of micro-bumps or micro-pillars **34** of said each of the first and/or second type of semiconductor chips **100**, a top surface of each of the first type of micro-bumps or micro-pillars **34** on the active side of

the control chip **688** of the first type of first memory module **159-1** and/or a top surface of each of the first type of micro-bumps or micro-pillars **570** on the backside of the FPGA IC chip **200** of said each of the first type of operation modules **190**. Next, a frontside interconnection scheme for a logic drive (FISD) **101** may be formed over the polymer layer **565** and over the first and/or second type of semiconductor chips **100**, the first type of first memory module **159-1**, and/or each of the first type of operation modules **190**. The frontside interconnection scheme for a logic drive (FISD) **101** may include one or more interconnection metal layers **27** coupling to the through package vias (TPV) **582**, the first type of micro-bumps or micro-pillars **34** of said each of the first and/or second type of semiconductor chips **100**, the first type of micro-bumps or micro-pillars **34** on the active side of the control chip **688** of the first type of first memory module **159-1** and the first type of micro-bumps or micro-pillars **570** on the backside of the FPGA IC chip **200** of said each of the first type of operation modules **190**, and one or more polymer layers **42** each between neighboring two of its interconnection metal layers **27**, under the bottommost one of its interconnection metal layers **27** or over the topmost one of its interconnection metal layers **27**, wherein an upper one of its interconnection metal layers **27** may couple to a lower one of its interconnection metal layers **27** through an opening in one of its polymer layers **42** between the upper and lower ones of its interconnection metal layers **27**. The bottommost one of its polymer layers **42** may be between the bottommost one of its interconnection metal layers **27** and the polymer layer **565**. Each opening in the bottommost one of its polymer layers **42** may be over the top surface of one of the through package vias (TPV) **582**, the top surface of one of the first type of micro-bumps or micro-pillars **34** of said each of the first and/or second type of semiconductor chips **100**, the top surface of each of the first type of micro-bumps or micro-pillars **34** on the active side of the control chip **688** of the first type of first memory module **159-1** or the top surface of each of the first type of micro-bumps or micro-pillars **570** on the backside of the FPGA IC chip **200** of said each of the first type of operation modules **190** to couple to the bottommost one of its interconnection metal layers **27**. Each of its interconnection metal layers **27** may extend horizontally across an edge of each of the first and/or second types of semiconductor chips **100**, the first type of first memory module **159-1** and the first type of operation modules **190**. The topmost one of its interconnection metal layers **27** may have multiple metal pads at bottoms of multiple respective openings **42a** in the topmost one of its polymer layers **42**. Next, the metal bumps **583** may be formed on the topmost one of the interconnection metal layers **27** of the frontside interconnection scheme for a logic drive (FISD) **101** and may have the same specification as illustrated in FIG. **22D**. Next, the frontside and backside interconnection schemes for a logic drive (BISD) **79** and (FISD) **101** and the polymer layer **565** may be diced into multiple first, second, third or fourth type of standard commodity logic drives **300** as illustrated in FIG. **10A**, **10B**, **10C** or **10D**.

[0386] Alternatively, FIG. **25** is a schematically cross-sectional view showing a standard commodity logic drive in accordance with another embodiment of the present application. Referring to FIG. **25**, for the first, second, third or fourth type of standard commodity logic drive **300** as illustrated in FIG. **10A**, **10B**, **10C** or **10D**, instead of the interposer **551** as illustrated in FIGS. **21A-21I**, an interconnection substrate **684** may be provided to carry the first and/or second type of semiconductor chips **100** as illustrated in FIGS. **14A** and **14B**, the first type of first memory module **159-1** as illustrated in FIG. **15A** and/or the first type of operation modules **190** as seen in FIG. **17E** or **19E**. The interconnection substrate **684** may be formed with the first, second or fourth type of micro-bumps or micro-pillars **34** in two groups, i.e., high-density, small-size copper pads (HDP) and low-density, large-size copper pads (LDP), to be bonded respectively, as illustrated in Figs. FIGS. **21A**, **21B** and **22A-22D**, with (1) the first, second or third type of micro-bumps or micro-pillars **34** in two groups, i.e., high-density, small-size micro-bumps (HDB) and low-density, large-size micro-bumps (LDB), of each of the first and/or second type of semiconductor chips **100** into the bonded contacts **563a** and **563b** in two groups, i.e., high-density, small-size bonded contacts **563a** and low-density, large-size bonded contacts **563b**, therebetween, (2) the first, second

or third type of micro-bumps or micro-pillars **34** in two groups, i.e., high-density, small-size micro-bumps (HDB) and low-density, large-size micro-bumps (LDB), on the active side of the control chip **688** of the first type of first memory module **159-1** into the bonded contacts **563a** and **563b** in two groups, i.e., high-density, small-size bonded contacts **563a** and low-density, large-size bonded contacts **563b**, therebetween, and/or (3) the first, second or third type of micro-bumps or micro-pillars **570** in two groups, i.e., high-density, small-size micro-bumps (HDB) and low-density, large-size micro-bumps (LDB), on the backside of the FPGA IC chip **200** of each of the first type of operation module **190** into the bonded contacts **191a** and **191b** in two groups, i.e., high-density, small-size bonded contacts **191a** and low-density, large-size bonded contacts **191b**, therebetween. Referring to FIG. 25, each of the bonded contacts **563a** and **191a** may have the largest dimension in a horizontal cross section (for example, the diameter of a circle shape, or the diagonal length of a square or rectangle shape) between 3 μm and 60 μm , 5 μm and 50 μm , 5 μm and 40 μm , 5 μm and 30 μm , 5 μm and 20 μm , 5 μm and 15 μm , or 3 μm and 10 μm , or smaller than or equal to 60 μm , 50 μm , 40 μm , 30 μm , 20 μm , 15 μm or 10 μm . The smallest space between neighboring two of the bonded contacts **563a** or **191a** may be between, for example, 3 μm and 60 μm , 5 μm and 50 μm , 5 μm and 40 μm , 5 μm and 30 μm , 5 μm and 20 μm , 5 μm and 15 μm , or 3 μm and 10 μm , or smaller than or equal to 60 μm , 50 μm , 40 μm , 30 μm , 20 μm , 15 μm or 10 μm . Each of the bonded contacts **563b** and **191b** may have the largest dimension in a horizontal cross section (for example, the diameter of a circle shape, or the diagonal length of a square or rectangle shape) between, for example, 20 μm and 200 μm , 20 μm and 150 μm , 20 μm and 100 μm , 20 μm and 75 μm , or 20 μm and 50 μm or larger than or equal to 20 μm , 30 μm , 40 μm , or 50 μm . The smallest space between neighboring two of the bonded contacts **563b** and **191b** may be between, for example, 20 μm and 200 μm , 20 μm and 150 μm , 20 μm and 100 μm , 20 μm and 75 μm , or 20 μm and 50 μm or larger than or equal to 20 μm , 30 μm , 40 μm , or 50 μm .

[0387] Referring to FIG. 25, each of the first and/or second types of semiconductor chips **100** may be the DPIIC chip **410**, dedicated control and input/output (I/O) chip **265**, NVM IC chip **250**, first HBM IC chip **251-1**, PCIC chip **269**, GPU chip **269a** or CPU chip **269b** for the first, second, third or fourth type of standard commodity logic drive **300**. The interconnection substrate **684** may include (1) a core layer **661**, such as FR4, containing epoxy or bismaleimide-triazine (BT) resin, wherein FR4 may be a composite material composed of woven fiberglass cloth and an epoxy resin binder, (2) multiple interconnection metal layers **668**, made of copper, over and under the core layer **661**, (3) multiple polymer layers **676** over and under the core layer **661**, wherein each of the polymer layers **676** is between neighboring two of the interconnection metal layers **668**, and (4) two solder masks **683** at the top and bottom of the interconnection substrate **684** to cover the topmost and bottommost ones of the interconnection metal layers **668** respectively, wherein the topmost and bottommost ones of the interconnection metal layers **668** may include multiple metal pads at bottoms and tops of multiple openings in the topmost and bottommost ones of solder masks **683** respectively. The bonded contacts **563a**, **563b**, **191a** and **191b** may be formed on metal pads of the topmost one of the interconnection metal layers **668**. Multiple metal bumps **572**, such as solder bumps, may be formed on the metal pads of the bottommost one of the interconnection metal layers **668** by a screen printing method or a solder-ball mounting method, and then by a solder reflow process. The metal bumps **572** may be a lead-free solder containing tin, copper, silver, bismuth, indium, zinc, antimony, and/or traces of other metals, for example, Sn—Ag—Cu (SAC) solder, Sn—Ag solder, or Sn—Ag—Cu—Zn solder. The interconnection bridge **684** may further include multiple fine-line interconnection bridges (FIB) **690** embedded in the interconnection bridge **684**. Each of the fine-line interconnection bridges (FIB) **690** may have multiple interconnection metal layers, each have the same specification as the interconnection metal layer **6** of the first interconnection scheme for a chip (FISC) **20** as illustrated in FIG. 14A, and multiple insulating dielectric layers, each have the same specification as the insulating dielectric layer **12** of the first interconnection scheme for a chip (FISC) **20** as illustrated in FIG. 14A, each between neighboring

two of its interconnection metal layers. The interconnection metal layers of one of the fine-line interconnection bridges (FIB) **690** may be connected to one of the first and/or second types of semiconductor chips **100** and/or the first type of first memory module **159-1** through the bonded contacts **563a** for signal transmission; the interconnection metal layers of one of the fine-line interconnection bridges (FIB) **690** may be connected to one of the first type of operation modules **190** through the bonded contacts **191a** for signal transmission. The interconnection metal layers of each of the fine-line interconnection bridges (FIB) **690** may include multiple metal lines **693** connecting neighboring two of the first and/or second types of semiconductor chips **100**, the first type of first memory module **159-1** and/or the first type of operation modules **190**, said each of the fine-line interconnection bridges (FIB) **690** may extend across under edges of said neighboring two of the first and/or second types of semiconductor chips **100**, the first type of first memory module **159-1** and/or the first type of operation modules **190**.

[0388] Referring to FIG. **25**, for an element indicated by the same reference number shown in FIGS. **20A** and **21A-211**, the specification of the element as seen in FIG. **25** may be referred to that of the element as illustrated in FIGS. **20A** and **21A-211**.

[0389] The scope of protection is limited solely by the claims, and such scope is intended and should be interpreted to be as broad as is consistent with the ordinary meaning of the language that is used in the claims when interpreted in light of this specification and the prosecution history that follows, and to encompass all structural and functional equivalents thereof.

Claims

1. A chip package comprising: a circuit substrate comprising a first interconnection scheme therein comprising a first interconnection metal layer, a second interconnection metal layer over the first interconnection metal layer and a first insulating dielectric layer between the first and second interconnection metal layers, wherein the circuit substrate further comprises a plurality of first metal contacts at a top of the circuit substrate and a plurality of second metal contacts at a bottom of the circuit substrate, wherein the plurality of second metal contacts comprises seven metal contacts arranged in a row at the bottom of the circuit substrate; and a first stacked chip package over and bonded to the circuit substrate, wherein the first stacked chip package comprises: a first element over and bonded to the circuit substrate, wherein the first element comprises a first silicon substrate, a first through-silicon via vertically in the first silicon substrate, a first transistor at a bottom of the first silicon substrate, a second interconnection scheme under the first silicon substrate and coupling to the first through-silicon via, a third metal contact under the second interconnection scheme, at a bottom of the first element and bonded to one of the plurality of first metal contacts of the circuit substrate, a first insulating bonding layer over the first silicon substrate and at a top of the first element and a first copper pad at the top of the first element, in an opening in the first insulating bonding layer and coupling to the first through-silicon via, wherein the second interconnection scheme comprises a second insulating dielectric layer under the first silicon substrate and a third interconnection metal layer having a first portion in an opening in the second insulating dielectric layer and in contact with a bottom of the first through-silicon via and a second portion under the opening in the second insulating dielectric layer and in contact with a bottom surface of the second insulating dielectric layer, wherein the third interconnection metal layer comprises a first copper layer having a first portion in the opening in the second insulating dielectric layer and a second portion under the opening in the second insulating dielectric layer and the bottom surface of the second insulating dielectric layer, wherein the first and second portions of the first copper layer are integral, wherein the first insulating bonding layer comprises silicon and oxygen, and a first integrated-circuit (IC) chip on a top surface of the first element, wherein the first integrated-circuit (IC) chip comprises a second silicon substrate, a second transistor at a bottom of the second silicon substrate, a third interconnection scheme under the second silicon

substrate, a second insulating bonding layer under the third interconnection scheme and at a bottom of the first integrated-circuit (IC) chip and a second copper pad at the bottom of the first integrated-circuit (IC) chip, in an opening in the second insulating bonding layer and coupling to the third interconnection scheme, wherein the second copper pad has a bottom surface bonded to and in contact with a top surface of the first copper pad of the first element and the second insulating bonding layer has a bottom surface bonded to and in contact with a top surface of the first insulating bonding layer of the first element, wherein the second insulating bonding layer comprises silicon and oxygen.

2. The chip package of claim 1, wherein the first copper pad is vertically over the first through-silicon via.

3. The chip package of claim 1, wherein the first element further comprises a first adhesion metal layer having a first portion at a sidewall of the first copper pad and a second portion at a bottom of the first copper pad and in contact with a top surface of the first through-silicon via.

4. The chip package of claim 3, wherein the first through-silicon via further comprises a second copper layer and a second adhesion metal layer at a sidewall of the second copper layer, wherein the second portion of the first adhesion metal layer is in contact with a top surface of the second copper layer of the first through-silicon via.

5. The chip package of claim 3, wherein the first adhesion metal layer comprises titanium.

6. The chip package of claim 1, wherein the first element comprises a second integrated-circuit (IC) chip comprising the first silicon substrate, first through-silicon via, first transistor and second interconnection scheme therein.

7. The chip package of claim 1, wherein the first integrated-circuit (IC) chip further comprises an adhesion metal layer having a first portion at a sidewall of the second copper pad and a second portion at a top of the second copper pad.

8. The chip package of claim 7, wherein the adhesion metal layer comprises titanium.

9. The chip package of claim 1, wherein the third interconnection scheme of the first integrated-circuit (IC) chip comprises a fourth interconnection metal layer over the second copper pad, wherein the fourth interconnection metal layer comprises a second copper layer and a first adhesion metal layer having a first portion at a sidewall of the second copper layer and a second portion at a top of the second copper layer, wherein the first integrated-circuit (IC) chip further comprises a second adhesion metal layer having a first portion at a sidewall of the second copper pad and a second portion at a top of the second copper pad, between the second copper pad and fourth interconnection metal layer and in contact with a bottom surface of the second copper layer of the fourth interconnection metal layer.

10. The chip package of claim 1, wherein the third metal contact comprises a second copper layer.

11. The chip package of claim 1, wherein each of the plurality of second metal contacts comprises a second copper layer.

12. The multichip package of claim 1, wherein the third interconnection metal layer of the second interconnection scheme of the first element further comprises an adhesion metal layer having a first portion at a sidewall and top of the first portion of the first copper layer and a second portion at a sidewall and top of the second portion of the first copper layer and in contact with the bottom surface of the second insulating dielectric layer, wherein the first and second portions of the adhesion metal layer are integral.

13. The chip package of claim 1, wherein the circuit substrate further comprises a third silicon substrate under the first interconnection scheme, wherein the plurality of first metal contacts are over the third silicon substrate.

14. The chip package of claim 13, wherein the circuit substrate further comprises a plurality of second through-silicon vias vertically in the third silicon substrate, wherein each of the plurality of second metal contacts is on a bottom surface of one of the plurality of second through-silicon vias.

15. The chip package of claim 1, wherein the circuit substrate is an interposer comprising a third

silicon substrate under the first interconnection scheme and a plurality of second through-silicon vias vertically in the third silicon substrate, wherein the plurality of first metal contacts are over the third silicon substrate and each of the plurality of second metal contacts is on a bottom surface of one of the plurality of second through-silicon vias.

16. The chip package of claim 1, wherein each of the plurality of second metal contacts is a metal bump comprising a second copper layer and a tin-containing portion under the second copper layer.

17. The chip package of claim 1 further comprising a sealing layer over the circuit substrate and at a same horizontal level as the first stacked chip package.

18. The multichip package of claim 17, wherein the sealing layer comprises a molding compound.

19. The chip package of claim 1, wherein the first stacked chip package further comprises a sealing layer over the top surface of the first element and at a same horizontal level as the first integrated-circuit (IC) chip.

20. The chip package of claim 19, wherein the sealing layer has a sidewall coplanar, in a vertical direction, with a sidewall of the first element.

21. The multichip package of claim 19, wherein the sealing layer comprises a molding compound.

22. The chip package of claim 1 further comprising a second stacked chip package over the circuit substrate and at a same horizontal level as the first stacked chip package, wherein the second stacked chip package comprises a first memory integrated-circuit (IC) chip and a second memory integrated-circuit (IC) chip over and coupling to the first memory integrated-circuit (IC) chip.

23. The chip package of claim 22, wherein each of the first and second memory integrated-circuit (IC) chips is a high-bandwidth-memory (HBM) integrated-circuit (IC) chip.

24. The chip package of claim 1, wherein the first integrated-circuit (IC) chip is a memory chip.

25. The chip package of claim 1, wherein the first element comprises a logic chip.

26. The chip package of claim 1 further comprising a second stacked chip package over and bonded to the circuit substrate and at a same horizontal level as the first stacked chip package, wherein the second stacked chip package comprises: a second element over and bonded to the circuit substrate, wherein the second element comprises a third silicon substrate, a second through-silicon via vertically in the third silicon substrate, a third transistor at a surface of the third silicon substrate, a fourth interconnection scheme coupling to the second through-silicon via, a fourth metal contact at a bottom of the second element and bonded to one of the plurality of first metal contacts of the circuit substrate, a third insulating bonding layer over the third silicon substrate and at a top of the second element and a third copper pad at the top of the second element and in an opening in the third insulating bonding layer, wherein the third insulating bonding layer comprises silicon and oxygen; and a second integrated-circuit (IC) chip on a top surface of the second element, wherein the second integrated-circuit (IC) chip comprises a fourth silicon substrate, a fourth transistor at a bottom of the fourth silicon substrate, a fifth interconnection scheme under the fourth silicon substrate, a fourth insulating bonding layer under the fifth interconnection scheme and at a bottom of the second integrated-circuit (IC) chip and a fourth copper pad at the bottom of the second integrated-circuit (IC) chip, in an opening in the fourth insulating bonding layer and coupling to the fifth interconnection scheme, wherein the fourth copper pad has a bottom surface bonded to and in contact with a top surface of the third copper pad of the second element and the fourth insulating bonding layer has a bottom surface bonded to and in contact with a top surface of the third insulating bonding layer of the second element, wherein the fourth insulating bonding layer comprises silicon and oxygen.

27. The chip package of claim 26, wherein the second stacked chip package further comprises a scaling layer over the top surface of the second element and at a same horizontal level as the second integrated-circuit (IC) chip.

28. The chip package of claim 27, wherein the scaling layer has a sidewall coplanar, in a vertical direction, with a sidewall of the second element.

29. The multichip package of claim 27, wherein the scaling layer comprises a molding compound.

