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Kim

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(54) **PRINTED CIRCUIT BOARD**

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(2013.01); *H05K 2201/10689* (2013.01); *H05K*
2203/168 (2013.01)

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CPC *H05K 3/40*; *H05K 3/4007*; *H05K 1/113*;
H05K 1/181; *H05K 3/3452*; *H05K*
3/3457

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USPC *174/250*
See application file for complete search history.

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(65) **Prior Publication Data**
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(57) **ABSTRACT**

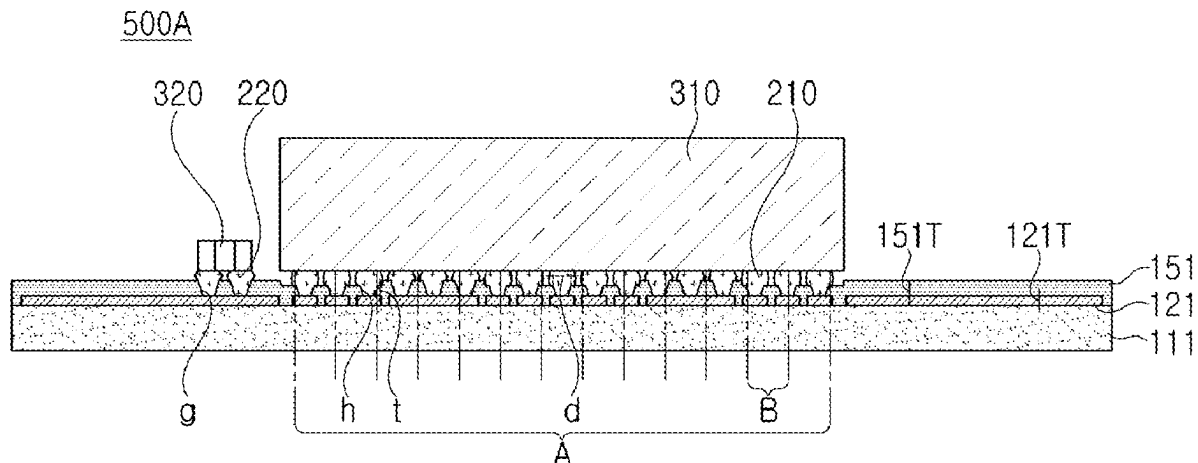
(30) **Foreign Application Priority Data**

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A printed circuit board includes an insulating layer; an interconnection layer disposed on the insulating layer, and including a plurality of metal pads for mounting a semiconductor chip thereon; and a solder resist layer disposed on the insulating layer and covering the interconnection layer, the solder resist layer having a plurality of openings respectively exposing at least a portion of at least one of the plurality of metal pads. A rectangular region created by substantially connecting outer edges of outermost openings among the plurality of openings in a straight line is substantially equally divided into a plurality of cells, and a ratio of areas of the metal pads disposed in each cell to an area of each cell is calculated, and when a maximum value thereof is P_{Max} and a minimum value thereof is P_{Min} , $(P_{Max} - P_{Min}) * 100 \leq 20$.

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H05K 1/11 (2006.01)
H05K 1/18 (2006.01)
H05K 3/34 (2006.01)
(52) **U.S. Cl.**
CPC *H05K 3/4007* (2013.01); *H05K 1/113*
(2013.01); *H05K 1/181* (2013.01); *H05K*
3/3452 (2013.01); *H05K 3/3457* (2013.01);

32 Claims, 6 Drawing Sheets



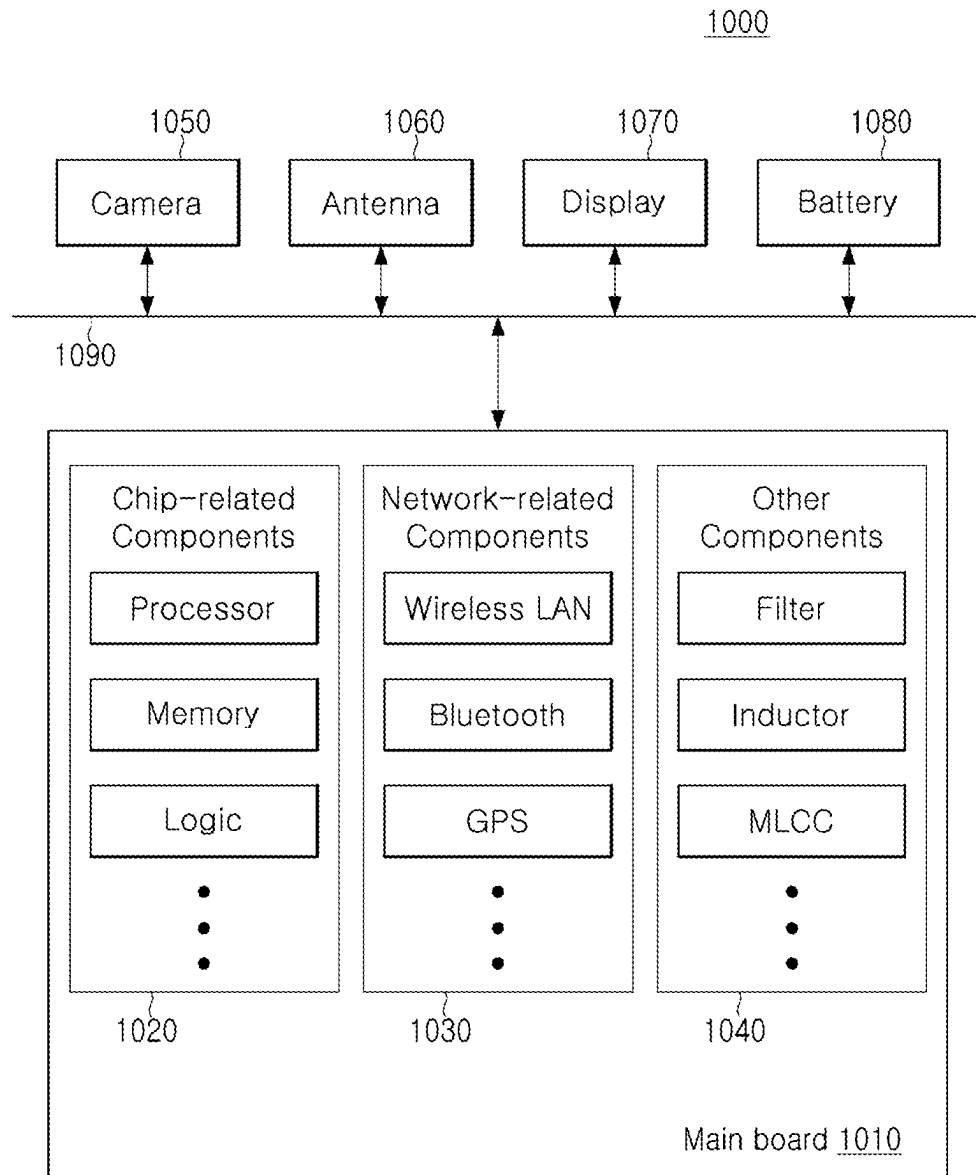


FIG. 1

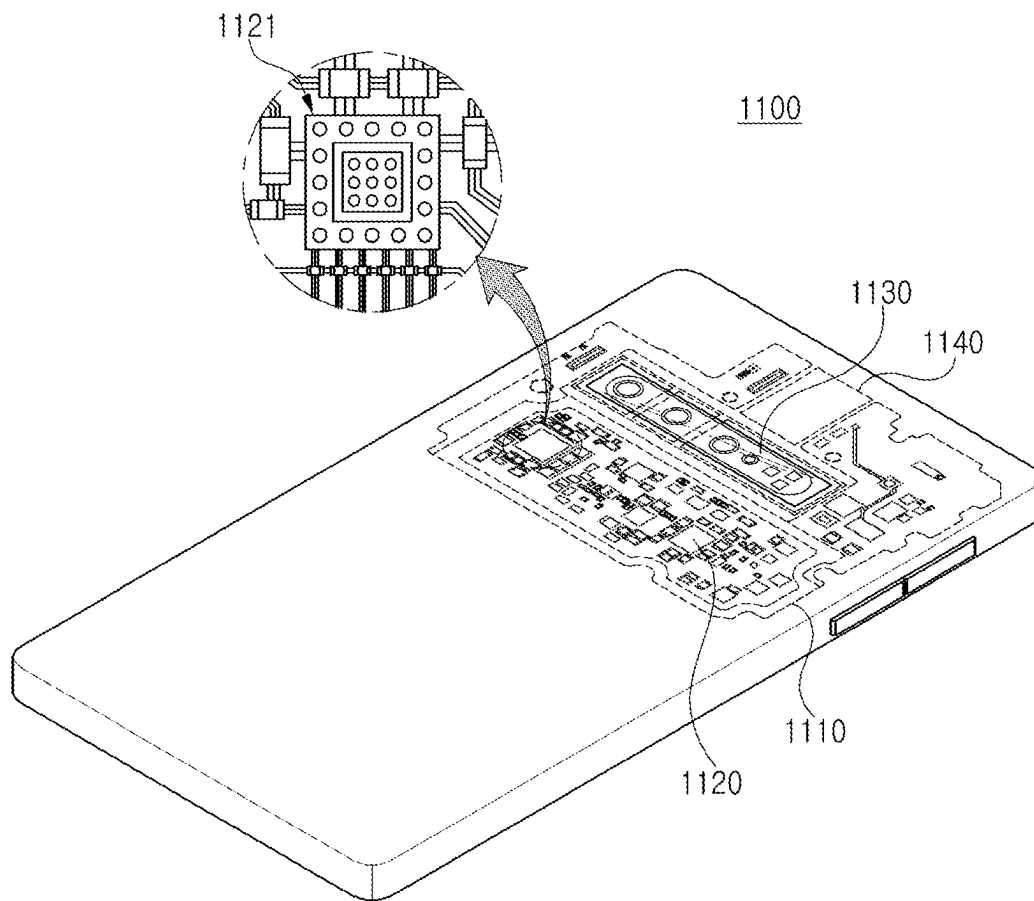


FIG. 2

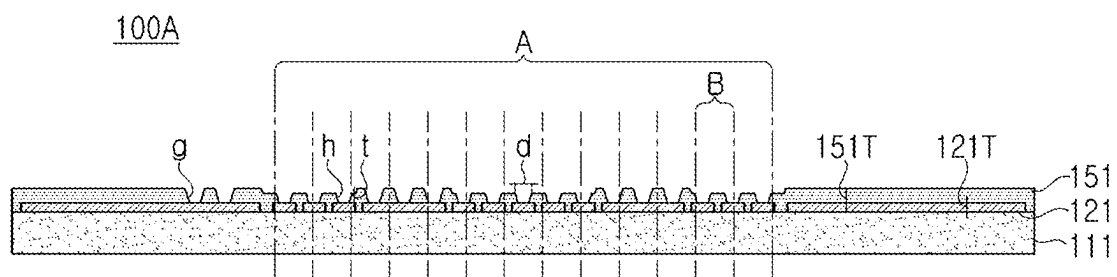


FIG. 3

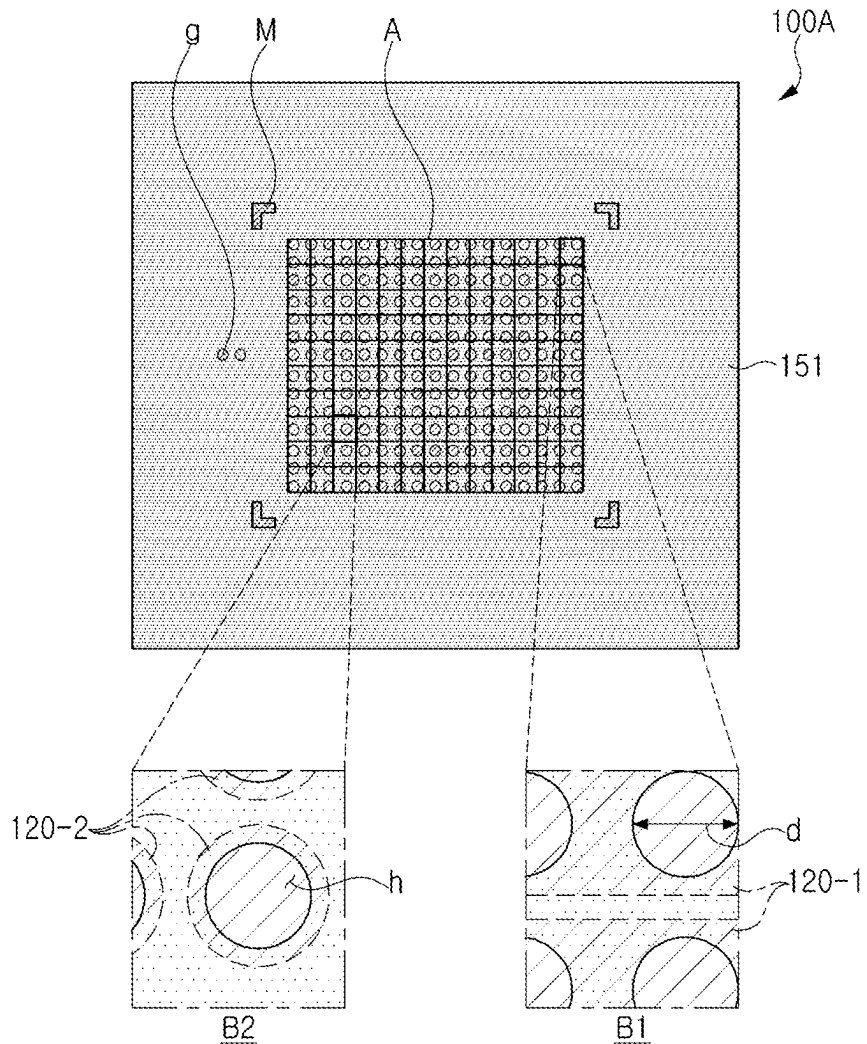


FIG. 4

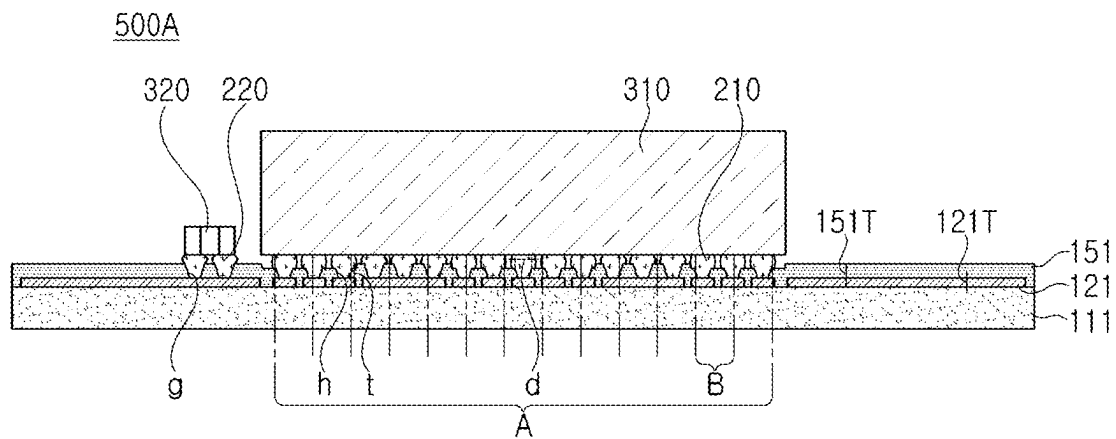


FIG. 5

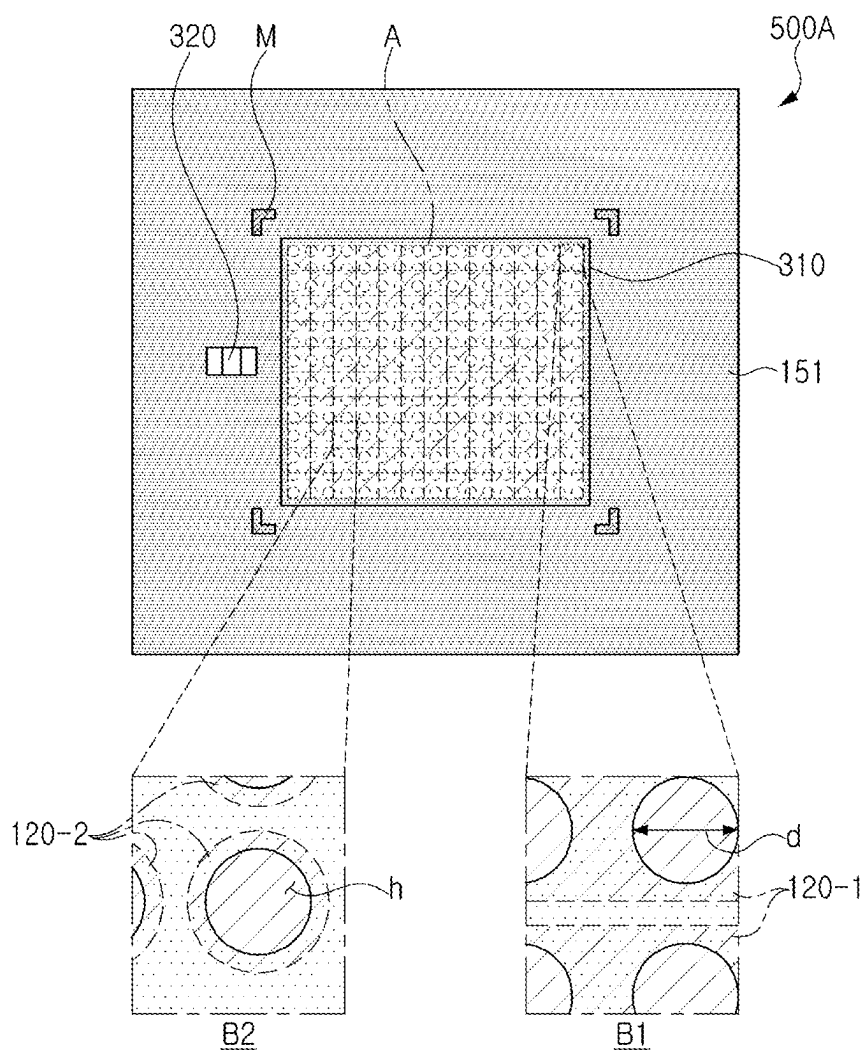


FIG. 6

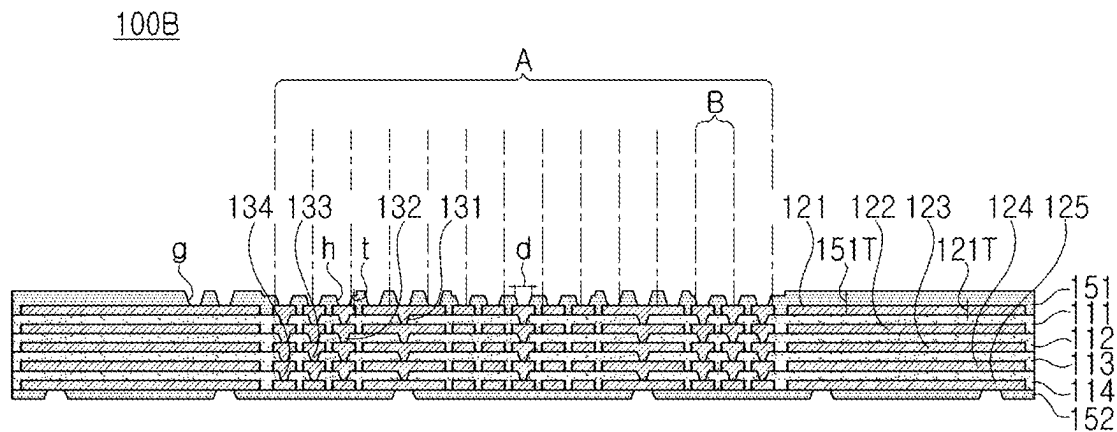


FIG. 7

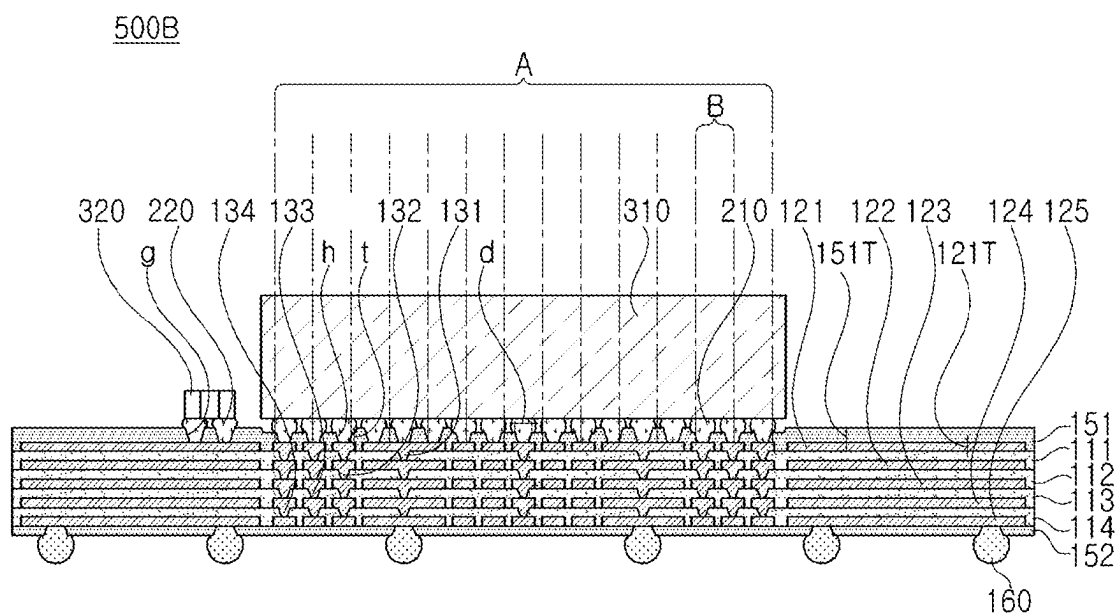
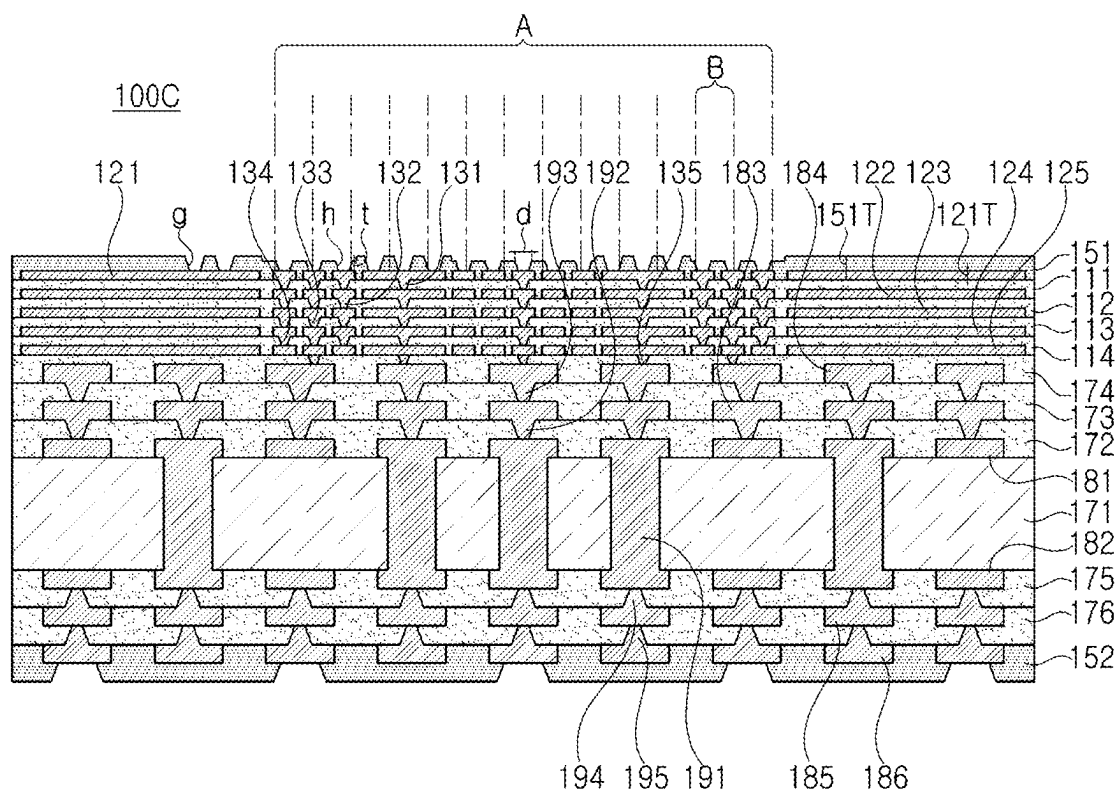


FIG. 8



141 {	111, 112, 113, 114	142 {	171, 172, 173, 174, 175, 176
	121, 122, 123, 124, 125		181, 182, 183, 184, 185, 186
	131, 132, 133, 134, 135		191, 192, 193, 194, 195

FIG. 9

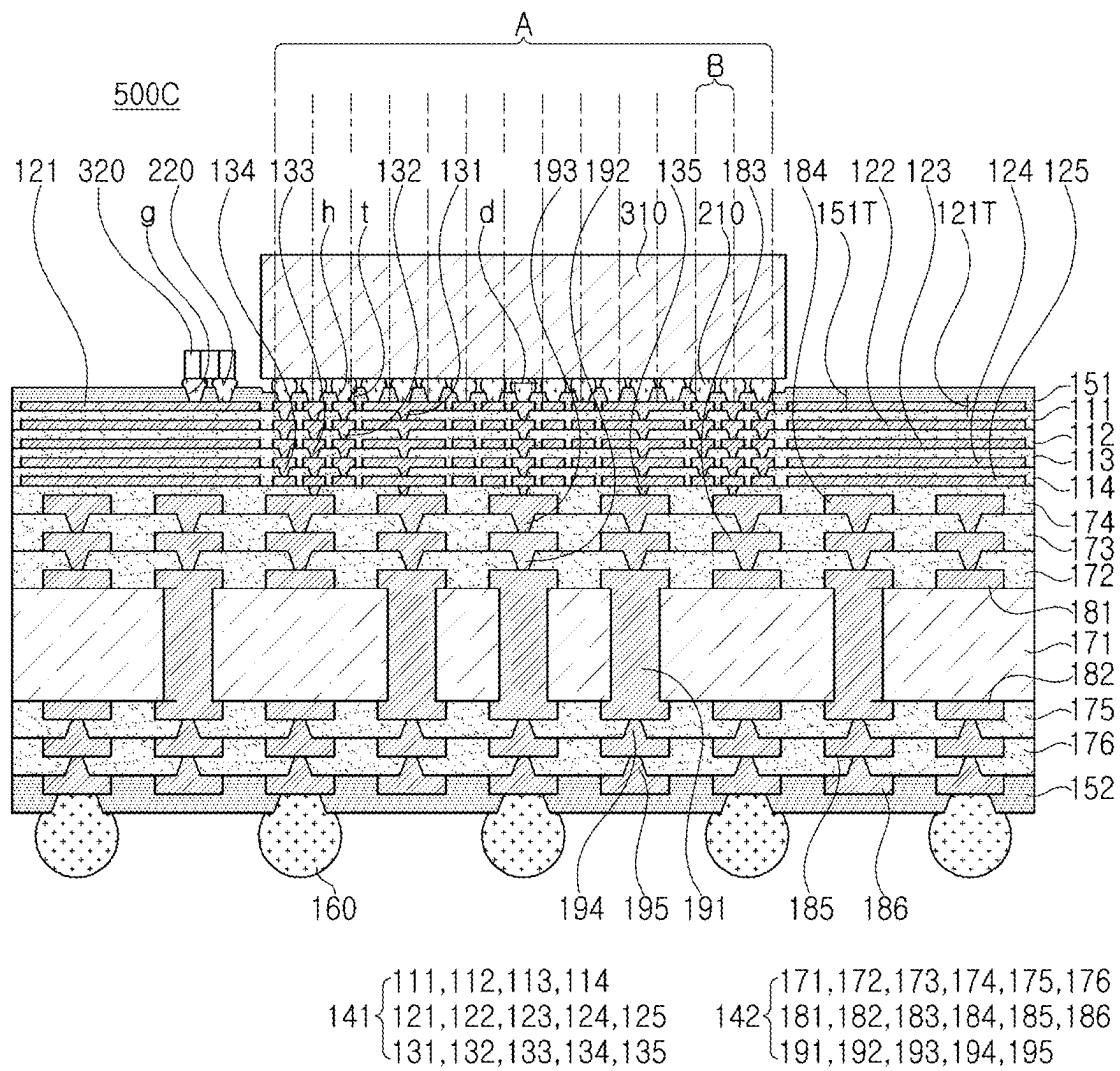


FIG. 10

1

PRINTED CIRCUIT BOARD**CROSS-REFERENCE TO RELATED APPLICATION(S)**

This application claims benefit of priority to Korean Patent Application Nos. 10-2022-0153871 filed on Nov. 16, 2022 in the Korean Intellectual Property Office and 10-2023-0015630 filed on Feb. 6, 2023 in the Korean Intellectual Property Office, the disclosures of which are incorporated herein by reference in their entirety.

TECHNICAL FIELD

The present disclosure relates to a printed circuit board.

BACKGROUND

Due to recent high-speed data processing, an increase in an amount of data, and the like, a demand for flip-chip BGA (FCB) substrates is increasing even in areas other than the existing central processing unit (CPU) market. For example, demand in various markets such as for electric vehicles, servers, and the like, is increasing, and accordingly, a package structure is diversifying from an existing CPU-oriented product structure to a more diverse product structure. Due to the diversification of such products, there is demand for various design package substrates, and density of each layer design is also higher than before. In particular, in the case of server package products, for which demand has particularly increased recently, the substrate size tends to increase. Meanwhile, as the substrate size increases, the number of bumps increases, which makes it more difficult to secure a constant bump height.

SUMMARY

An aspect of the present disclosure is to provide a printed circuit board capable of improving process capability by securing flatness of a bump region.

According to an aspect of the present disclosure, provided is a printed circuit board, the printed circuit board including: an insulating layer; an interconnection layer disposed on the insulating layer, and including a plurality of metal pads for mounting a semiconductor chip thereon; and a solder resist layer disposed on the insulating layer and covering the interconnection layer, the solder resist layer having a plurality of openings respectively exposing at least a portion of at least one of the plurality of metal pads. A rectangular region created by substantially connecting outer edges of outermost openings among the plurality of openings in a straight line is substantially equally divided into a plurality of cells, and a ratio of areas of the metal pads disposed in each cell to an area of each cell is calculated, and when a maximum value thereof is P_{Max} and a minimum value thereof is P_{Min} , $(P_{Max}-P_{Min})*100 \leq 20$.

According to an aspect of the present disclosure, provided is a printed circuit board, the printed circuit board including: an insulating portion; a plurality of metal pads disposed on the insulating portion, and for mounting a semiconductor chip thereon; and a first solder resist layer disposed on the insulating portion and covering the plurality of metal pads, the first solder resist layer having a plurality of first openings respectively exposing at least a portion of at least one of the plurality of metal pads. A rectangular region created by substantially connecting outer edges of outermost first openings among the plurality of first openings in a straight line

2

is substantially equally divided into n cells within a range having a horizontal length of 1.7 mm to 2.0 mm and a vertical length of 1.7 mm to 2.0 mm, and a ratio of areas of the metal pads disposed in each cell to a total area of the rectangular region is calculated, and when a maximum value thereof is Q_{Max} and a minimum value thereof is Q_{Min} , $n*(Q_{Max}-Q_{Min})*100 \leq 20$, where n is a positive integer.

According to an aspect of the present disclosure, provided is a printed circuit board, the printed circuit board including: an insulating layer; an interconnection layer disposed on the insulating layer, and including a plurality of metal pads for mounting a semiconductor chip thereon; and a solder resist layer disposed on the insulating layer and covering the interconnection layer, the solder resist layer having a plurality of openings respectively exposing at least a portion of at least one of the plurality of metal pads. A rectangular region created by substantially connecting outer edges of outermost openings among the plurality of openings in a straight line is substantially equally divided into a plurality of cells, an average depth of the openings in each of the plurality of cells is t_1, t_2, \dots, t_n , respectively, and a ratio of an area of the metal pads disposed in each cell to an area of each cell are P_1, P_2, \dots, P_n , respectively, where n is an integer equal to or greater than 3, t_1, t_2, \dots, t_n substantially satisfy a relationship of $0.22*(P_1, P_2, \dots, P_n)*100*(\mu m)+m*(\mu m)$, respectively, where, m is a rational number equal to or greater than 0.

According to an aspect of the present disclosure, provided is a printed circuit board, the printed circuit board including: an insulating portion; a plurality of metal pads disposed on the insulating portion, and for mounting a semiconductor chip thereon; and a solder resist layer disposed on the insulating portion and covering the plurality of metal pads, the solder resist layer having a plurality of openings respectively exposing at least a portion of at least one of the plurality of metal pads. A rectangular region created by substantially connecting outer edges of outermost openings among the plurality of openings in a straight line is substantially equally divided into n cells within a range having a horizontal length of 1.7 mm to 2.0 mm and a vertical length of 1.7 mm to 2.0 mm, an average depth of the openings in each of the plurality of cells is t_1, t_2, \dots, t_n , respectively, and a ratio of an area of the metal pads disposed in each cell to a total area of the rectangular region is Q_1, Q_2, \dots, Q_n , respectively, where n is an integer equal to or greater than 3, t_1, t_2, \dots, t_n substantially satisfies a relationship of $0.22*n*(Q_1, Q_2, \dots, Q_n)*100*(\mu m)+k*(\mu m)$, respectively, where k is a rational number equal to or greater than 0.

According to an aspect of the present disclosure, provided is a method to determine whether a printed circuit board is suitable for a semiconductor chip mounted thereon. The printed circuit board includes an insulating layer, a plurality of metal pads disposed on the insulating layer, and a solder resist layer disposed on the insulating layer and having a plurality of openings respectively exposing at least a portion of at least one of the plurality of metal pads. The method includes: substantially equally dividing a rectangular region created by substantially connecting outer edges of outermost openings among the plurality of openings in a straight line into a plurality of cells; calculating a ratio of areas of the metal pads disposed in each cell to an area of each cell; and determining that the printed circuit board is suitable for the semiconductor chip mounted thereon based on a result that $(P_{Max}-P_{Min})*100$ is equal to or less than a predetermined value, where P_{Max} is a maximum value among the ratios for the plurality of cells and P_{Min} is a minimum value among the ratios for the plurality of cells.

BRIEF DESCRIPTION OF DRAWINGS

The above and other aspects, features, and advantages of the present disclosure will be more clearly understood from the following detailed description taken in conjunction with the accompanying drawings.

FIG. 1 is a block diagram schematically illustrating an example of an electronic device system.

FIG. 2 is a perspective view schematically illustrating an example of an electronic device.

FIG. 3 is a cross-sectional view schematically illustrating an example of a printed circuit board.

FIG. 4 is a plan view illustrating a schematic top view of the printed circuit board of FIG. 3.

FIG. 5 is a schematic cross-sectional view of a modified example of the printed circuit board of FIG. 3.

FIG. 6 is a plan view illustrating a schematic top view of the printed circuit board of FIG. 5.

FIG. 7 is a schematic cross-sectional view of another example of a printed circuit board.

FIG. 8 is a schematic cross-sectional view of a modified example of the printed circuit board of FIG. 7.

FIG. 9 is a schematic cross-sectional view of another example of a printed circuit board.

FIG. 10 is a schematic cross-sectional view of a modified example of the printed circuit board of FIG. 9.

DETAILED DESCRIPTION

Hereinafter, exemplary embodiments of the present disclosure will be described in detail with reference to the accompanying drawings. Further, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the disclosure to those skilled in the art.

Electronic Device

FIG. 1 is a block diagram schematically illustrating an example of an electronic device system.

Referring to FIG. 1, an electronic device **1000** may accommodate a mainboard **1010**. The mainboard **1010** may include chip-related components **1020**, network-related components **1030**, other components **1040**, or the like, physically or electrically connected thereto. These components may be connected to others to be described below to form various signal lines **1090**.

The chip-related components **1020** may include a memory chip such as a volatile memory (for example, a dynamic random access memory (DRAM)), a non-volatile memory (for example, a read only memory (ROM)), a flash memory, or the like; an application processor chip such as a central processor (for example, a central processing unit (CPU)), a graphics processor (for example, a graphics processing unit (GPU)), a digital signal processor, a cryptographic processor, a microprocessor, a microcontroller, or the like; and a logic chip such as an analog-to-digital converter, an application-specific integrated circuit (ASIC), or the like, or the like. However, the chip-related components **1020** are not limited thereto, and may include other types of chip-related components. In addition, the chip-related components **1020** may be combined with each other. The chip-related components **1020** may be in the form of a package including the chips or electronic components described above.

The network-related components **1030** may include protocols such as wireless fidelity (Wi-Fi) (Institute of Electrical And Electronics Engineers (IEEE) 802.11 family, or the like), worldwide interoperability for microwave access (WiMAX) (IEEE 802.16 family, or the like), IEEE 802.20,

long term evolution (LTE), evolution data only (Ev-DO), high speed packet access+ (HSPA+), high speed downlink packet access+ (HSDPA+), high speed uplink packet access+ (HSUPA+), enhanced data GSM environment (EDGE), global system for mobile communications (GSM), global positioning system (GPS), general packet radio service (GPRS), code division multiple access (CDMA), time division multiple access (TDMA), digital enhanced cordless telecommunications (DECT), Bluetooth®, 3G, 4G, and 5G protocols, and any other wireless and wired protocols, designated after the abovementioned protocols. However, the network-related components **1030** are not limited thereto, and may also include a variety of other wireless or wired standards or protocols. In addition, the network-related components **1030** may be combined with each other, together with the chip-related components **1020** described above.

Other components **1040** may include a high frequency inductor, a ferrite inductor, a power inductor, ferrite beads, a low temperature co-fired ceramic (LTCC), an electromagnetic interference (EMI) filter, a multilayer ceramic capacitor (MLCC), or the like. However, other components **1040** are not limited thereto, and may also include passive components used for various other purposes, or the like. In addition, other components **1040** may be combined with each other, together with the chip-related components **1020** or the network-related components **1030** described above.

Depending on a type of the electronic device **1000**, the electronic device **1000** may include other components that may or may not be physically or electrically connected to the mainboard **1010**. These other components may include, for example, a camera **1050**, an antenna **1060**, a display **1070**, a battery **1080**, an audio codec (not illustrated), a video codec (not illustrated), a power amplifier (not illustrated), a compass (not illustrated), an accelerometer (not illustrated), a gyroscope (not illustrated), a speaker (not illustrated), a mass storage unit (for example, a hard disk drive) (not illustrated), a compact disk (CD) drive (not illustrated), a digital versatile disk (DVD) drive (not illustrated), or the like. However, these other components are not limited thereto, but may also include other components used for various purposes depending on a type of electronic device **1000**, or the like.

The electronic device **1000** may be a smartphone, a personal digital assistant (PDA), a digital video camera, a digital still camera, a network system, a computer, a monitor, a tablet PC, a laptop PC, a netbook PC, a television, a video game machine, a smartwatch, an automotive component, or the like. However, the electronic device **1000** is not limited thereto, and may be any other electronic device able to process data.

FIG. 2 is a perspective view schematically illustrating an example of an electronic device.

Referring to FIG. 2, an electronic device may be, for example, a smartphone **1100**. A motherboard **1110** is accommodated inside the smartphone **1100**, and various components **1120** are physically and/or electrically connected to the motherboard **1110**. In addition, other components that may or may not be physically and/or electrically connected to the motherboard **1110** are accommodated therein, such as the camera module **1130** and/or the speaker **1140**. A portion of the component **1120** may be the aforementioned chip-related component, for example, a component package **1121**, but an embodiment thereof is not limited thereto. The component package **1121** may be in a form of a printed

5

circuit board on which an electronic component including an active component and/or a passive component are surface-mounted.

Alternatively, the component package **1121** may be in a form of a printed circuit board in which an active component and/or a passive component are embedded. Meanwhile, the electronic device is not necessarily limited to the smart-phone **1100**, and may be other electronic devices as described above.

Printed Circuit Board

FIG. **3** is a cross-sectional view schematically illustrating an example of a printed circuit board.

FIG. **4** is a plan view illustrating a schematic top view of the printed circuit board of FIG. **3**.

Referring to FIGS. **3** and **4**, a printed circuit board **100A** according to an example may include an insulating layer **111**, an interconnection layer **121** disposed on the insulating layer **111**, and a solder resist layer **151** disposed on the insulating layer **111** and covering the interconnection layer **121** and having a plurality of openings (h and g) respectively exposing at least a portion of the interconnection layer **121**. The interconnection layer **121** may include a plurality of metal pads for mounting a semiconductor chip, and may further include a plurality of metal pads for mounting a passive component, if necessary. The solder resist layer **151** may cover a plurality of metal pads. The plurality of openings h may respectively expose at least a portion of at least one of the plurality of metal pads for mounting a semiconductor chip. The plurality of openings g may respectively expose at least a portion of at least one of the plurality of metal pads for mounting a passive component. Each of the plurality of metal pads may include copper (Cu). The solder resist layer **151** may further have a reference mark M for mounting a semiconductor chip. The reference mark M may penetrate through at least a portion of the solder resist layer **151**, and may expose at least a portion of the insulating layer **111** and/or the interconnection layer **121**.

Meanwhile, a rectangular region A created by substantially connecting outer edges of outermost openings among the plurality of openings h in a straight line is substantially equally divided into a plurality of cells B, and a ratio of an area of an interconnection layer **121** disposed in each cell B to an area of each cell B, is calculated, and in this case, when a ratio of an area of a metal pad **120-1** for mounting a semiconductor chip to an area of a cell B1 having the largest area ratio, wherein B1 is a cell in which the metal pad **120-1** for mounting a semiconductor chip is formed to be the largest is P_{Max} , and when a ratio of an area of a metal pad **120-2** for mounting a semiconductor chip to an area of a cell B2 having the smallest area ratio, wherein B2 is a cell in which the metal pad **120-2** for mounting a semiconductor chip is formed to be the smallest is P_{Min} , $(P_{Max}-P_{Min}) * 100 \leq 20$.

In this case, when an average depth (t) of the openings (h) in each cell B, is t_1, t_2, \dots, t_n , respectively, and a ratio P of an area of the interconnection layer **121** disposed in each cell B to the area of each cell B, for example, the area of the metal pad for mounting a semiconductor chip is calculated, is P_1, P_2, \dots, P_n , respectively, where n is an integer equal to or greater than 3, t_1, t_2, \dots, t_n may substantially satisfy a relationship of $0.22 * \{(P_1, P_2, \dots, P_n) * 100\} * (\mu m) + m * (\mu m)$, respectively where m may be a rational number equal to or greater than 0.

Alternatively, a rectangular region A created by substantially connecting outer edges of outermost openings among the plurality of openings h in a straight line is substantially equally divided into n cells B, and a ratio of the intercon-

6

nection layer **121** disposed in each cell B to a total area of the rectangular region A, for example, the area of the metal pad for mounting a semiconductor chip is calculated, and in this case, when a ratio of an area of a metal pad **120-1** for mounting a semiconductor chip to a total area of the rectangular region A in a cell B1 having the largest area ratio, wherein B1 is a cell in which the metal pad **120-1** for mounting a semiconductor chip is formed to be the largest is Q_{Max} , and when a ratio of an area of a metal pad **120-2** for mounting a semiconductor chip to a total area of the rectangular region A in a cell B2 having the smallest area ratio, wherein B2 is a cell in which the metal pad **120-2** for mounting semiconductor chip is formed to be the smallest is Q_{Min} , $n * (Q_{Max} - Q_{Min}) * 100 \leq 20$, where n may be a positive integer.

In this case, when an average depth (t) of the opening (h) in each cell B, is t_1, t_2, \dots, t_n , respectively, and a ratio P of an area of the interconnection layer **121** disposed in each cell B to the total area of each cell B, for example, the area of the metal pad for mounting a semiconductor chip is calculated, is Q_1, Q_2, \dots, Q_n , respectively, and when n is an integer equal to or greater than 3, t_1, t_2, \dots, t_n may substantially satisfy a relationship of $0.22 * n * \{(Q_1, Q_2, \dots, Q_n) * 100\} * (\mu m) + k * (\mu m)$, respectively, where k may be a rational number equal to or greater than 0.

Meanwhile, when defining the rectangular region A, a portion partially protruding or partially recesses, of the outer edges of the outermost openings among the plurality of openings (h) on a plane may be excluded when drawing a virtual line. In addition, an angle at which different virtual straight lines meet may be substantially a right angle. For example, the rectangular region A may have a substantially rectangular or square shape on a plane. As will be described later, the rectangular region A may be a bump region in which a solder bump for mounting a semiconductor chip is formed. Therefore, when defining the rectangular region A, a plurality of openings (g) or a reference mark (M) may be excluded. For example, the reference mark M is for mounting a semiconductor chip, and may be respectively formed at at least one corner, preferably near four corners, of the rectangular region A in which the semiconductor chip is mounted, and the plurality of openings (g) is a region for exposing a metal pad for mounting passive components, and may be formed around the rectangular region A.

Meanwhile, the plurality of cells (B) are regions, obtained by equally dividing the rectangular region (A), and a horizontal and/or vertical size, which is a criterion for division, may be determined in a range of 1.7 mm to 2.0 mm, respectively, and when there are several cases, a case that can be divided into the smallest sizes may be adopted. For example, in the case of dividing a rectangular region A having a horizontal and/or vertical length of 31 mm, each cell B may be divided into a case of having a horizontal and/or vertical length of about 1.72 mm (18 divisions), 1.82 mm (17 divisions), 1.94 mm (16 divisions), and the like, and the above-described parameters according to the present disclosure may be calculated by dividing the rectangular region A into 1.72 m (18 divisions), in which the rectangular region A is divided into the smallest sizes thereamong. According to analysis and experimentation, a relation of the above-described parameters according to the present disclosure can be derived preferably when dividing the cell B into this range.

Meanwhile, in the printed circuit board **100A** according to an example, the parameters according to the present disclosure described above may be calculated by defining a rectangular region A and a plurality of cells B, and measur-

ing areas thereof, and then penetrating a solder resist layer **151** and measuring an area of an interconnection layer **121** disposed in each cell (B) region, for example, an area of a metal pad, or removing the solder resist layer **151** and then measuring the interconnection layer **121** disposed in each cell (B) region, for example, the area of the metal pad. When measuring the area, a scanning microscope or an optical microscope may be used, but the measuring method is not limited thereto.

Meanwhile, an average thickness **121T** of the interconnection layer **121** may be in a range of 1.0 μm to 18 μm , and a difference between a maximum thickness and a minimum thickness in the interconnection layer **121** may be within about 5 μm . In addition, an average thickness **151T** of the solder resist layer **151** may be 15 μm to 23 μm , and a difference between the maximum thickness and the minimum thickness in the solder resist layer **151** may be within about 7 μm . In addition, an average diameter (d) of the plurality of openings (h) may be 50 μm to 100 μm , and a difference in diameters between an opening having the largest diameter and an opening having the smallest diameter among the plurality of openings (h) may be within about 10 μm . When the thickness, diameter, depth, and the like, satisfy these conditions, the relationship of the above-described parameters according to the present disclosure may be preferably derived.

Meanwhile, the average thickness **121T** of the interconnection layer **121**, the average thickness **151T** of the solder resist layer **151**, the average diameter (d) of the plurality of openings (h), the average depth (t) of the plurality of openings (h), and the like may be measured using a scanning microscope or an optical microscope, but the measuring equipment is not limited thereto. If necessary, these values may be measured based on the polished or cut cross-section of the printed circuit board **1001**. The average thickness, average diameter average depth, and the like, may be calculated as an average value of values measured at five arbitrary points. When each opening has a tapered shape, the diameter of each opening can be calculated as an average value of the uppermost and lowermost diameters of each opening.

Meanwhile, in the case of a method of forming bumps on a substrate using microballs, since a size of the balls is almost constant, a height of the bumps may be determined by a volume of an opening region of the solder resist layer on which the bumps are mounted. In this case, a depth of the opening region of the solder resist layer may be determined by a design of the lower region, for example, a metal ratio of the interconnection layer. Therefore, adjustment of the metal ratio of the interconnection layer in the bump region on which the semiconductor chip is mounted may be an important factor for controlling a distribution of the height of the bump. According to analysis and experimentation, when the above-described parameters according to the present disclosure are satisfied, it is possible to more easily control the distribution of the height of the bump, so that flatness of the bump region of a large-area product may be secured, and accordingly, a deviation in the height of the bump may be reduced by improving process capability. Thereby, it is possible to improve yield and quality of the assembly. In addition, it is possible to remove a fundamental cause of defects in a bump height during manufacturing a substrate, thereby improving the yield.

For example, in the case of forming solder bumps using microballs is, respectively, on the plurality of openings h of the printed circuit board **100A** according to an example, when n openings h are formed to satisfy a relationship of

$t_1 \dots t_n \approx 0.22 * \{(P_1 \dots P_n) * 100\} + m$ and/or $t_1 \dots t_n \approx 0.22 * n * \{(Q_1 \dots Q_n) * 100\} + k$, and as in Experimental Examples 1 to 5 of [Table 1] and [Table 2] below, when $(P_{Max} - P_{Min}) * 100$ and/or $n * (Q_{Max} - Q_{Min}) * 100$ are 20 or less, a tolerance of the solder bump is within $\pm 10 \mu\text{m}$, so a sufficient margin can be secured, so that the specifications required for the package substrate before mounting the semiconductor chip can be satisfied.

On the other hand, as in Experimental Examples 6 to 7 in [Table 1] and [Table 2] below, when the value of $(P_{Max} - P_{Min}) * 100$ and/or $n * (Q_{Max} - Q_{Min}) * 100$ exceeds 20, a height tolerance of the solder bump exceeds $\pm 10 \mu\text{m}$, and as a result, defects that do not meet the delivery standards may occur, such as not being able to satisfy the specifications required for the package substrate before mounting the semiconductor chip.

TABLE 1

	Division		
	Area of rectangular region (Horizontal size * Longitudinal size)	Area of each cell (Horizontal size * Longitudinal size)	The number of cells, N (Horizontal size * Longitudinal size)
Experimental Example 1	31 mm * 31 mm	1.72 mm * 1.72 mm	18 * 18
Experimental Example 2	31 mm * 31 mm	1.72 mm * 1.72 mm	18 * 18
Experimental Example 3	31 mm * 31 mm	1.72 mm * 1.72 mm	18 * 18
Experimental Example 4	31 mm * 31 mm	1.72 mm * 1.72 mm	18 * 18
Experimental Example 5	31 mm * 31 mm	1.72 mm * 1.72 mm	18 * 18
Experimental Example 6	31 mm * 31 mm	1.72 mm * 1.72 mm	18 * 18
Experimental Example 7	31 mm * 31 mm	1.72 mm * 1.72 mm	18 * 18

TABLE 2

	Division			Whether or not defects occurred
	$P_{Max} - P_{Min}$	$Q_{Max} - Q_{Min}$	Bump height range	
Experimental Example 1	0.05	$1.54 * 10^{-4}$	17 μm	—
Experimental Example 2	0.10	$3.09 * 10^{-4}$	18 μm	—
Experimental Example 3	0.15	$4.63 * 10^{-4}$	19 μm	—
Experimental Example 4	0.19	$5.86 * 10^{-4}$	20 μm	—
Experimental Example 5	0.20	$6.17 * 10^{-4}$	20 μm	—
Experimental Example 6	0.21	$6.48 * 10^{-4}$	21 μm	Defects occurred
Experimental Example 7	0.25	$7.72 * 10^{-4}$	22 μm	Defects occurred

Meanwhile, in the samples of the printed circuit board in Experimental Examples 1 to 7 described above, an average thickness **121T** of the interconnection layer **121** was about 15 μm , a difference between a maximum thickness and a minimum thickness was about 3 μm , an average thickness **151T** of the solder resist layer **151** was about 20 μm , a difference between a maximum thickness and a minimum thickness was about 4 μm , an average diameter (d) of the

plurality of openings (h) was about 75 μm , and a difference between a maximum diameter and a minimum diameter was about 5 μm . In addition, an ABF was used as the material of the insulating layer **111**, the interconnection layer **121** was formed by chemical copper plating and electrolytic copper plating, and a product name AUE703 was used as the material of the solder resist layer **151**.

Hereinafter, components of the printed circuit board **100A** according to an example will be described in more detail with reference to the drawings.

The insulating layer **111** may include an insulating material. The insulating material may include a thermosetting resin such as an epoxy resin, a thermoplastic resin such as polyimide, or a material including an inorganic filler, an organic filler, and/or glass fiber (glass Cloth, glass Fabric) together with these resins. For example, the insulating material may be a non-photosensitive insulating material such as an Ajinomoto Build-up Film (ABF), prepreg (PPG), but the present disclosure is not limited thereto, and other polymer materials may be used. In addition, the insulating material may be a photosensitive insulating material such as Photo Imageable Dielectric (PID).

The interconnection layer **121** may include a metal. The metal may include copper (Cu), aluminum (Al), silver (Ag), tin (Sn), gold (Au), nickel (Ni), lead (Pb), titanium (Ti), and/or alloys thereof. Preferably, copper (Cu) may be included, but the present disclosure is not limited thereto. The interconnection layer **121** may perform various functions according to the design. For example, the interconnection layer **121** may include a signal pattern, a power pattern, and a ground pattern. Each of these patterns may include a line pattern, a pad pattern, a plane pattern, and the like. The interconnection layer **121** may include an electroless plating layer (or chemical copper) and an electrolytic plating layer (or electrolytic copper), but the present disclosure is not limited thereto. A sputter layer may be formed instead of the electroless plating layer, or both thereof may be included. In addition, copper foil may be further included.

The solder resist layer **151** may include solder resist. The solder resist may be a photosensitive material or may be a liquid type. For example, the solder resist may be a product name of AUS703, SR7300, or the like, but the present disclosure is not limited thereto. The solder resist layer **151** may have a plurality of openings h, and each of the openings h may expose at least a portion of the interconnection layer **121**. Each of the openings (h) may expose at least a portion of the interconnection layer **121** in a solder mask defined (SMD) and/or non-solder mask defined (NSMD) type. Preferably, each of the openings h may expose at least a portion of the interconnection layer **121** in an SMD type.

FIG. 5 is a schematic cross-sectional view of a modified example of the printed circuit board of FIG. 3.

FIG. 6 is a plan view illustrating a schematic top view of the printed circuit board of FIG. 5.

Referring to FIGS. 5 and 6, a printed circuit board **500A** according to a modified example may include an insulating layer **111**, an interconnection layer **121** disposed on the insulating layer **111**, a solder resist layer **151** disposed on the insulating layer and covering at least a portion of the interconnection layer **121** and having a plurality of openings h respectively exposing at least a portion of the interconnection layer **121**, a plurality of solder bumps **210** and **220** respectively disposed on the plurality of openings (h and g) and respectively connected to the at least portion of the exposed interconnection layer **121**; and a semiconductor chip **310** and a passive component **320** disposed on the solder resist layer **151** and respectively connected to the

interconnection layer **121** through the plurality of solder bumps **210** and **220**. For example, the printed circuit board **500A** according to the modified example may have a package shape including the printed circuit board **100A** according to the example. For example, the printed circuit board **500A** according to the modified example may have a semiconductor package structure.

Meanwhile, the plurality of solder bumps **210** and the semiconductor chip **310** may be disposed on a rectangular region A. For example, the rectangular region A may be a bump region in which a plurality of solder bumps **210** for mounting the semiconductor chip **310** are disposed. The printed circuit board **500A** according to the modified example may also satisfy parameters according to the present disclosure described above, and in this case, the plurality of solder bumps **210** before the semiconductor chip **310** is mounted may have excellent flatness. For example, in the plurality of solder bumps **210** before the semiconductor chip **310** is mounted, a difference in heights between a solder bump having a maximum height and a solder bump having a minimum height may be within about 20 μm . In this case, since a deviation in a height of the bump may be reduced by improving process capability, yield and quality of an assembly may be improved, and the yield may be further improved by removing a fundamental cause of defects in the height of the bump during manufacturing a substrate.

Meanwhile, a height of each of the plurality of solder bumps **210** may be measured using a scanning microscope, an optical microscope, or the like, based on the printed circuit board **500A** before the semiconductor chip **310** is mounted, but the measuring equipment is not limited thereto. If necessary, the height of each of the plurality of solder bumps **210** may be measured based on a polished or cut cross-section of the printed circuit board **500A** before the semiconductor chip **310** is mounted.

Hereinafter, components of the printed circuit board **500A** according to the modified example will be described in more detail with reference to the drawings.

Each of the plurality of solder bumps **210** and **220** may be formed of low-melting point metal, for example, solder such as tin (Sn)-aluminum (Al)-copper (Cu), but this is merely an example, and the material thereof is not particularly limited thereto. Each of the plurality of solder bumps **210** may have microball shape, but the present disclosure is not limited thereto.

The semiconductor chip **310** may include an integrated circuit (IC) die in which hundreds to millions of devices or more are integrated into a single chip. In this case, the integrated circuit may include, for example, an application processor (e.g., AP) such as a central processor (e.g., CPU), a graphics processor (e.g., GPU), a field programmable gate array (FPGA), a digital signal processor, a cryptographic processor, a microprocessor, or a microcontroller; a logic chip such as an analog-digital converter, or an application-specific integrated circuit (ASIC), but the present disclosure is not limited thereto; and a memory chip such as a volatile memory (e.g., a dynamic random access memory (DRAM)), a non-volatile memory (e.g., a read only memory (ROM)), a flash memory, or a high bandwidth memory (HBM), or may be other types such as a power management IC (PMIC). The number of semiconductor chips **310** may be plural, and in this case, semiconductor chips of the same type or different types may be respectively disposed on the rectangular region A.

The semiconductor chip **310** may be formed based on an active wafer, and in this case, silicon (Si), germanium (Ge), gallium arsenide (GaAs), or the like may be used as a base

11

material constituting each body. Various circuits may be formed on the body. A connection pad may be formed on each body, and the connection pad may include a conductive material such as aluminum (Al) or copper (Cu). The semiconductor chip **310** may be a bare die, and in this case, metal bumps may be disposed on the connection pad, if necessary. The semiconductor chip **310** may be a packaged die. In this case, a redistribution layer may be additionally formed on the connection pad, and metal bumps may be disposed on the redistribution layer, if necessary.

The passive component **320** may be a component, for example, a high-frequency inductor, a ferrite inductor, a power inductor, ferrite beads, a low temperature co-firing ceramics (LTCC), an electromagnetic interference (EMI), a multi-layer ceramic capacitor (MLCC), and the like, but the present disclosure is not limited thereto.

Other contents are substantially the same as those described in the printed circuit board **100A** according to the example described above, and thus, overlapping contents thereof are omitted.

FIG. 7 is a schematic cross-sectional view of another example of a printed circuit board.

Referring to FIG. 7, a printed circuit board **100B** according to another example may include a plurality of insulating layers **111**, **112**, **113**, and **114**, a plurality of interconnection layers **121**, **122**, **123**, **124**, and **125** disposed on or within the plurality of insulating layers **111**, **112**, **113**, and **114**, a plurality of via layers **131**, **132**, **133**, and **134** respectively penetrating at least one of the plurality of insulating layers **111**, **112**, **113**, and **114** and respectively connected to at least one of the plurality of interconnection layers **121**, **122**, **123**, **124**, and **125**, and first and second solder resist layers **151** and **152** respectively disposed on upper sides and lower sides of the plurality of insulating layers **111**, **112**, **113**, and **114**. Referring to FIG. 7, the printed circuit board **100B** according to another example may be a coreless-type multilayer board, but the present disclosure is not limited thereto, and may be a core-type multilayer board having a core layer if necessary.

Each of the plurality of insulating layers **111**, **112**, **113**, and **114** may include an insulating material. The insulating material may include a thermosetting resin such as an epoxy resin, a thermoplastic resin such as polyimide, or a material including an inorganic filler, an organic filler, and/or a glass fiber (glass cloth, glass fabric), together with these resins. For example, the insulating material may be a non-photosensitive insulating material such as an Ajinomoto Build-up Film (ABF), prepreg (PPG), or the like, but the present disclosure is not limited thereto, and other polymer materials may be used. In addition, the insulating material may be a photosensitive insulating material such as a Photo Imageable Dielectric (PID).

Each of the plurality of interconnection layers **121**, **122**, **123**, **124**, and **125** may include a metal. The metal may include copper (Cu), aluminum (Al), silver (Ag), tin (Sn), gold (Au), nickel (Ni), lead (Pb), titanium (Ti), and/or alloys thereof. Preferably, the metal may include copper (Cu), but the present disclosure is not limited thereto. Each of the plurality of interconnection layers **121**, **122**, **123**, **124**, and **125** may perform various functions according to the design. For example, it may include a signal pattern, a power pattern, a ground pattern, and the like. Each of these patterns may have various shapes such as a line pattern, a plane pattern, a pad pattern, and the like. Each of the plurality of interconnection layers **121**, **122**, **123**, **124**, and **125** may include an electroless plating layer (chemical copper) and an electrolytic plating layer (or electrolytic copper). Altern-

12

tively, a metal foil (or copper foil) and an electrolytic plating layer (or electrolytic copper) may be included. Alternatively, a metal foil copper foil), an electroless plating layer (or chemical copper), and an plating layer (or electrolytic copper) may be included. A sputter layer may be included instead of the electroless plating layer (or chemical copper), and both thereof may be included if necessary.

Each of the plurality of via layers **131**, **132**, **133**, and **134** may include a metal. The metal may include copper (Cu), aluminum (Al), silver (Ag), tin (Sn), gold (Au), nickel (Ni), lead (Pb), titanium (Ti), and/or alloys thereof. Preferably, the metal may include copper (Cu), but the present disclosure is not limited thereto. Each of the plurality of via layers **131**, **132**, **133**, and **134** may include a filled via filling a via hole, but may also include a conformal via disposed along a wall surface of the via hole. Vias respectively included in the plurality of via layers **131**, **132**, **133**, and **134** may perform various functions according to the design. For example, the vias may include a ground via, a power via, a signal via, and the like. The vias respectively included in the plurality of via layers **131**, **132**, **133**, and **134** may have a tapered shape in the same direction on a cross-section, for example, a tapered shape in which diameters thereof decrease substantially from an upper side toward a lower side thereof. Each of the plurality of via layers **131**, **132**, **133**, and **134** may include an electroless plating layer (or chemical copper) and an electrolytic plating layer (or electrolytic copper). A sputter layer may be included instead of the electroless plating layer (or chemical copper), and both thereof may be included if necessary.

Each of the first and second solder resist layers **151** and **152** may include solder resist. The solder resist may be a photosensitive material, or may be a liquid type. For example, the solder resist may be a product name of AUS703, SR7300, or the like, but the present disclosure is not limited thereto. The first solder resist layer **151** may have a plurality of openings (h and g), and each of the openings (h and g) may expose at least a portion of an uppermost interconnection layer **121**. Each of the openings (h and g) may expose a pattern solder mask defined (SMD) type and/or a non-solder mask defined (NSMD) type, and preferably, expose a pattern in the SMD type. The second solder resist layer **152** may also have a plurality of openings, and each of the openings may expose at least a portion of a lowermost interconnection layer **125**. Each of the openings may expose at least a portion of the lowermost interconnection layer **125** in a solder mask defined (SMD) and/or non solder mask defined (NSMD) type, and preferably expose at least a portion of the lowermost interconnection layer **186** in the SMD type.

Meanwhile, each of the insulating layer **111**, the interconnection layer **121**, and the solder resist layer **151** of the printed circuit board **100A** according to an example may be an insulating layer **111** disposed on an uppermost layer among the plurality of insulating layers **111**, **112**, **113**, and **114**, an interconnection layer **121** disposed on an uppermost layer among the plurality of interconnection layers **121**, **122**, **123**, **124** and **125**, and a first solder resist layer **151** of the first and second solder resist layers **151** and **152** of the printed circuit board **100B** according to another example.

Other contents are substantially the same as those described in the printed circuit board **100A** according to the example described above, and thus, overlapping contents thereof are omitted.

FIG. 8 is a schematic cross-sectional view of a modified example of the printed circuit board of FIG. 7.

13

Referring to FIG. 8, a printed circuit board **500B** according to a modified example may include a plurality of insulating layers **111**, **112**, **113**, and **114**, a plurality of interconnection layers **121**, **122**, **123**, **124**, and **125** respectively disposed on or within the plurality of insulating layers **111**, **112**, **113**, and **114**, a plurality of via layers **131**, **132**, **133**, and **134** respectively penetrating at least one of the plurality of insulating layers **111**, **112**, **113**, and **114** and respectively connected to at least one of the plurality of interconnection layers **121**, **122**, **123**, **124**, and **125**, first and second solder resist layers **151** and **152** respectively disposed on upper sides and lower sides of the plurality of insulating layers **111**, **112**, **113**, and **114**, a plurality of solder bumps **210** and **220** respectively disposed on a plurality of openings (h and g) of the first solder resist layer **151** and respectively connected to at least a portion of an exposed portion of an uppermost interconnection layer **121**, a semiconductor chip **310** and a passive component **320** disposed on the first solder resist layer **151** and respectively connected to the uppermost interconnection layer **121** through the plurality of solder bumps **210** and **220**, and a plurality of electrical connection metal members **160** respectively disposed on a plurality of openings of the second solder resist layer **152** and respectively connected to at least a portion of an exposed portion of a lowermost interconnection layer **125**.

The plurality of electrical connection metal members **160** are provided for connecting the printed circuit board **500B** to a mainboard, other substrates, or the like, of electronic devices. The plurality of electrical connection metal members **160** may be respectively connected to at least a portion of the lowermost interconnection layer **125**. If necessary, the plurality of electrical connection metal members **160** may be respectively disposed through a plurality of under bump metal members. The plurality of electrical connection metal members **160** may be formed of a conductive material, for example, solder, but this is merely an example, and the material is not particularly limited thereto. The plurality of electrical connection metal members **160** may be lands, balls, pins, or the like, respectively. Each of the electrical connection metal members **160** may be formed as a multilayer or a single layer. When the plurality of electrical connection metal **160** are formed as a multilayer, the electrical connection metal members **160** may include a copper pillar and solder formed on the copper pillar, and when the plurality of electrical connection metal **160** are formed as a single layer, the electrical connection metal members **160** may include tin-silver solder or copper, but the present disclosure is not limited thereto.

Other contents are substantially the same as those described in the printed circuit boards **100A**, **100B**, and **500A**, described above, and thus overlapping contents thereof are omitted.

FIG. 9 is a schematic cross-sectional view of another example of a printed circuit board.

Referring to FIG. 9, a printed circuit board **100C** according to another example may include a core type of first substrate portion **141**, a coreless type of second substrate portion **142** disposed on the first substrate portion **141**, and first and second solder resist layers **151** and **152** respectively disposed on the first and second substrate portions **141** and **142**. The second substrate portion **142** may have interconnection density, higher than that of the first substrate portion **141**. For example, the second substrate portion **142** may include high-density interconnection with a relatively finer pitch than the first substrate portion **141**, and the first substrate portion **141** may have low-density interconnection

14

relatively lower than the second substrate portion **142**. For example, the interconnection of the second substrate portion **142** may have a relatively smaller thickness, line/space, pitch, and the like than the interconnection of the first substrate portion **141**. In addition, an insulation distance between interconnections disposed on different layers may be smaller. For example, the printed circuit board **100C** may be a 2.nD-type package board.

The first substrate portion **141** may be a core-type multilayer substrate. For example, the first substrate portion **141** may include a core insulating layer **171**, first and second core interconnection layers **181** and **182** respectively disposed on an upper surface and a lower surface of the core insulating layer **171**, a core via layer **191** penetrating the core insulating layer **171** and connecting the first and second core interconnection layers **181** and **182**, a plurality of first buildup insulating layers **172**, **173**, and **174** disposed on an upper surface of the core insulating layer **171**, a plurality of first build-up interconnection layers **183** and **184** respectively disposed on or within the plurality of first build-up insulating layers **172**, **173**, and **174**, a plurality of first build-up via layers **192** and **193** penetrating at least one of the plurality of first build-up insulating layers **172**, **173**, and **174** and respectively connected to at least one of the plurality of first build-up interconnection layers **183** and **184**, a plurality of second build-up insulating layers **175** and **176** disposed on a lower surface of the core insulating layer **171**, a plurality of second build-up interconnection layers **185** and **186** respectively disposed of or within the plurality of second build-up insulating layers **175** and **176**, and a plurality of second build-up via layers **194** and **195** respectively penetrating at least one of the plurality of second build-up insulating layers **175** and **176** and respectively connected to at least one of the plurality of second build-up interconnection layers **185** and **186**.

The core insulating layer **171** may include an insulating material. The insulating material may include a thermosetting resin such as an epoxy resin, a thermoplastic resin such as polyimide, or a material in which these insulating resins are mixed with an inorganic filler such as silica, or the like, or a resin impregnated into a core material such as glass fiber (glass cloth, glass fabric), or the like, together with the inorganic for example, an insulating material such as copper clad laminate (CCL), or the like, but the present disclosure is not limited thereto. The core insulating layer **171** may be formed to be thicker than each of the plurality of first and second build-up insulating layers **172**, **173**, **174**, **175**, and **176**, but the present disclosure is not limited thereto.

Each of the plurality of first and second build-up insulating layers **172**, **173**, **174**, **175**, and **176** may include an insulating material. The insulating material may include a thermosetting resin such as an epoxy resin, a thermoplastic resin such as polyimide, or a material in which these insulating resins are mixed with an inorganic filler such as silica, or the like, or a resin impregnated into a core material such as glass fiber, or the like, together with the inorganic filler, for example, an insulating material such as Ajinomoto Build-up Film (ABF), prepreg, resin coated copper (RCC), or the like, but the present disclosure is not limited thereto. The number of layers of each of the plurality of first and second build-up insulating layers **172**, **173**, **174**, **175**, and **176** is not particularly limited.

Each of the first and second core interconnection layers **181** and **182** may include a metal. The metal may include copper (Cu), aluminum (Al), silver (Ag), tin (Sn), gold (Au), nickel (Ni), lead (Pb), titanium (Ti), and/or alloys thereof. Preferably, the metal may include copper (Cu). Each of the

15

first and second core interconnection layers **181** and **182** may include an electroless plating layer (chemical copper) and an electrolytic plating layer (or electrolytic copper), but the present disclosure is not limited thereto. The electroless plating layer may include a sputter layer instead of chemical copper, and include both thereof. If necessary, copper foil may be further included. Each of the first and second core interconnection layers **181** and **182** may perform various functions according to the design of the corresponding layer. For example, it may include a ground pattern, a power pattern, a signal pattern, and the like. Each of these patterns may include a line pattern, a plane pattern, and/or a pad pattern.

Each of the plurality of first and second build-up interconnection layers **183**, **184**, **185**, and **186** may include a metal. The metal may include copper (Cu), aluminum (Al), silver (Ag), tin (Sn), gold (Au), nickel (Ni), lead (Pb), titanium (Ti), and/or alloys thereof. Preferably, the metal may include copper (Cu). Each of the plurality of first and second build-up interconnection layers **183**, **184**, **185**, and **186** may include an electroless plating layer (chemical copper) and an electrolytic plating layer (or electrolytic copper), but the present disclosure is not limited thereto. The electroless plating layer may include a sputter layer instead of chemical copper, and include both thereof. If necessary, copper foil may be further included. Each of the first and second build-up interconnection layers **183**, **184**, **185**, and **186** may perform various functions according to the design of the corresponding layer. For example, it may include a ground pattern, a power pattern, a signal pattern, and the like. Each of these patterns may include a line pattern, a plane pattern, and/or a pad pattern.

The core via layer **191** may include a through-via. The through-via may include a metal layer formed on a wall surface of the through-hole and a plug filling the metal layer. The metal layer may include copper (Cu), aluminum (Al), silver (Ag), tin (Sn), gold (Au), nickel (Ni), lead (Pb), titanium (Ti), and/or alloys thereof. Preferably, the metal layer may include copper (Cu). The plug may include ink formed of an insulating material. The metal layer may include an electroless plating layer (or chemical copper) and an electrolytic plating layer (or electrolytic copper), but the present disclosure is not limited thereto. The electroless plating layer may include a sputter layer instead of chemical copper, and include both thereof. If necessary, the core via layer **191** may perform various functions according to the design. For example, the core via layer **191** may include a ground via, a power via, a signal via, and the like. The core via layer **191** may have a substantially cylindrical shape, but the present disclosure is not limited thereto, and may have a substantially hourglass shape.

Each of the plurality of first and second build-up via layers **192**, **193**, **194**, and **195** may include a micro via. The micro via may be a filled via filling a via hole, or a conformal via disposed along a wall surface of the via hole. The micro via may be disposed in a stacked type and/or a staggered type.

Each of the plurality of first and second build-up via layers **192**, **193**, **194**, and **195** may include a metal. The metal may include copper (Cu), aluminum (Al), silver (Ag), tin (Sn), gold (Au), nickel (Ni), lead (Pb), titanium (Ti), and/or alloys thereof. Preferably, the metal may include copper (Cu). Each of the plurality of first and second build-up via layers **192**, **193**, **194**, and **195** may include an electroless plating layer (or chemical copper) and an electrolytic plating layer (or electrolytic copper), but the present disclosure is not limited thereto. The electroless plating layer

16

may include a sputter layer instead of chemical copper, and include both thereof. Each of the plurality of first and second build-up via layers **192**, **193**, **194**, and **195** may perform various functions according to the design of the corresponding layer. For example, it may include a ground via, a power via, a signal via, and the like. The vias of the plurality of first build-up via layers **192** and **193** and the vias of the plurality of second build-up via layers **194** and **195** may have tapered shapes in opposite directions. The second substrate portion **142** may be a coreless-type multilayer build-up substrate including a microcircuit. For example, the second substrate portion **142** may include a plurality of third build-up insulating layers **111**, **112**, **113**, and **114**, a plurality of third build-up interconnection layers **121**, **122**, **123**, **124**, and **125** respectively disposed on or in the plurality of third build-up insulating layers **111**, **112**, **113**, and **114**, and a plurality of third build-up via layers **131**, **132**, **133**, **134**, and **135** respectively penetrating at least one of the plurality of third build-up insulating layers **111**, **112**, **113**, and **114** and respectively connected to at least one of the plurality of third build-up interconnection layers **121**, **122**, **123**, **124**, and **125**.

Each of the plurality of third build-up insulating layers **111**, **112**, **113**, and **114** may include an insulating material. The insulating material may include a thermosetting resin such as an epoxy resin, a thermoplastic resin such as polyimide, or a material in which these insulating resins are mixed with an inorganic filler such as silica, or the like, or a resin impregnated into a core material such as glass fiber, or the like, together with the inorganic filler, for example, an insulating material such as Ajinomoto Build-up Film (ABF), prepreg, resin coated copper (RCC), or the like, but the present disclosure is not limited thereto. The number of layers of the plurality of third build-up insulating layers **111**, **112**, **113**, and **114** is not particularly limited.

Each of the plurality of third build-up interconnection layers **121**, **122**, **123**, **124**, and **125** may include a metal. The metal may include copper (Cu), aluminum (Al), silver (Ag), tin (Sn), gold (Au), nickel (Ni), lead (Pb), titanium (Ti), and/or alloys thereof. Preferably, the metal may include copper (Cu). Each of the plurality of third build-up interconnection layers **121**, **122**, **123**, **124**, and **125** may include an electroless plating layer (chemical copper) and an electrolytic plating layer (or electrolytic copper), but the present disclosure is not limited thereto. The electroless plating layer may include a sputter layer instead of chemical copper, and include both thereof. If necessary, copper foil may be further included. Each of the plurality of third build-up interconnection layers **121**, **122**, **123**, **124**, and **125** may perform various functions according to the design of the corresponding layer. For example, it may include a ground pattern, a power pattern, a signal pattern, and the like. Each of these patterns may include a line pattern, a plane pattern, and/or a pad pattern.

Each of the plurality of third build-up via layers **131**, **132**, **133**, **134**, and **135** may include a micro via. The micro via may be a filled via filling a via hole, or a conformal via disposed along a wall surface of the via hole. The micro via may be disposed in a stacked type and/or a staggered type. Each of the plurality of third build-up via layers **131**, **132**, **133**, **134**, and **135** may include a metal, and the metal may include copper (Cu), aluminum (Al), silver (Ag), tin (Sn), gold (Au), nickel (Ni), lead (Pb), titanium (Ti), and/or alloys thereof. Preferably, the metal may include copper (Cu). Each of the plurality of third build-up via layers **131**, **132**, **133**, **134**, and **135** may include an electroless plating layer (or chemical copper) and an electrolytic plating layer (or electrolytic copper), but the present disclosure is not limited

17

thereto. The electroless plating layer may include a sputter layer instead of chemical copper, and include both thereof. The vias of the plurality of third build-up via layers **131**, **132**, **133**, **134**, and **135** may have a tapered shape in the same direction as each other. The vias of the plurality of the plurality of third build-up via layers **131**, **132**, **133**, **134**, and **135** may have a tapered shape in the same direction as the vias of the plurality of first build-up via layers **192** and **193**, and may have a tapered shape opposite to that of the vias of the second build-up via layers **194** and **195**.

Each of the first and second solder resist layers **151** and **152** may include solder resist the solder resist may be a photosensitive material, or may be a liquid type. For example, the solder resist may be a product name of AUS703, SR7300, or the like, but the present disclosure is not limited thereto. The first solder resist layer **151** may have a plurality of openings (h and g), and each of the openings (h and g) may expose at least a portion of the uppermost third build-up interconnection layer **121**. Each of the openings (h and g) may expose at least a portion of the uppermost third build-up interconnection layer **121** in a solder mask defined (SMD) and/or non-solder mask defined (NSMD) type, and preferably expose at least a portion of the uppermost third build-up interconnection layer **121** in the SMD type. The second solder resist layer **152** may also have a plurality of openings, and each of the openings may expose at least a portion of a lowermost second build-up interconnection layer **186**. Each of the openings may expose at least a portion of the lowermost second build-up interconnection layer **186** in a solder mask defined (SMD) and/or non-solder mask defined (NSMD) type, and preferably expose at least a portion of the lowermost second build-up interconnection layer **186** in the SMD type.

Meanwhile, each of the insulating layer **111**, the interconnection layer **121**, and the solder resist layer **151** of the printed circuit board **100A** according to an example may be an uppermost third build-up insulating layer **111** among the plurality of third build-up insulating layers **111**, **112**, **113**, and **114**, an uppermost third build-up interconnection layer **121** among the plurality of third build-up interconnection layers **121**, **122**, **123**, **124**, and **125**, and a first solder resist layer **151** among the first and second solder resist layers **151** and **152**, of the plurality of printed circuit board **100C** according to another example.

Other contents are substantially the same as those described in the printed circuit board **100A** according to the above-described example, and therefore, redundant contents thereof are omitted.

FIG. **10** is a schematic cross-sectional view of a modified example of the printed circuit board of FIG. **9**.

Referring to FIG. **10**, a printed circuit board **500C** according to a modified example may include a core-type of first substrate portion **141**, a coreless-type of second substrate portion **142** disposed on the first substrate portion **141**, first and second solder resist layers **151** and **152** respectively disposed on the first and second substrate portions **141** and **142**, a plurality of solder bumps **210** and **220** respectively disposed on a plurality of openings (h and g) of the first solder resist layer **151** and respectively connected to at least a portion of an exposed uppermost third build-up interconnection layer **121**, a semiconductor chip **310** disposed on the first solder resist layer **151** and respectively connected to the uppermost interconnection layer **121** through a plurality of solder bumps **210** and **220**, and a plurality of electrical connection metal members **160** respectively disposed on a passive component **320** and a plurality of openings of the second solder resist layer **152** and respectively connected to

18

at least a portion of an exposed lowermost second build-up interconnection layer **186**. For example, the printed circuit board **500C** according to the modified example may have a package form including the printed circuit board **100C** according to another example. For example, the printed circuit board **500C** may have a semiconductor package structure.

The plurality of electrical connection metal members **160** are a configuration for connecting the printed circuit board **500C** to a mainboard, other substrates, or the like, of electronic devices. The plurality of electrical connection metal members **160** may be respectively connected to the at least a portion of a lowermost third build-up interconnection layer **186**. If necessary, the plurality of electrical connection metal members **160** may be respectively disposed through a plurality of under bump metal members. The plurality of electrical connection metal members **160** may be formed of a conductive material, for example, solder, but this is merely an example, and the material is not particularly limited thereto. The plurality of electrical connection metal members **160** may be lands, balls, pins, or the like, respectively. Each of the electrical connection metal members **160** may be formed as a multilayer or a single layer. When the plurality of electrical connection metal **160** are formed as a multilayer, the electrical connection metal members **160** may include a copper pillar and solder formed on the copper pillar, and when the plurality of electrical connection metal **160** are formed as a single layer, the electrical connection metal members **160** may include tin-silver solder or copper, but the present disclosure is not limited thereto.

Other contents are substantially the same as those described in the above-described printed circuit boards **100A**, **100C**, and **500A**, and thus redundant contents thereof are omitted.

In the present disclosure, it may mean substantially including minute differences due to process errors, and the like. For example, a substantially straight line may include a substantially straight line as well as a completely straight line. In addition, a substantially rectangular shape may include a substantially rectangular shape as well as a completely rectangular shape. In addition, substantially equal may include not only completely equal, but also approximately equal.

In the present disclosure, the meaning of “in a cross-section” may mean a cross-sectional shape when an object is vertically cut, or a cross-sectional shape when the object is viewed from a side-view. In addition, the meaning of “on a plane” may be a shape when the object is horizontally cut, or a planar shape when the object is viewed from a top-view or a bottom-view.

In the present disclosure, a lower side, a lower portion, a lower surface, and the like, may be used to mean a direction toward a mounting space of a semiconductor package including an organic interposer, based on a cross-section of the drawing for convenience, and an upper side, an upper portion, an upper surface, and the like may be used to mean a direction opposite thereto. However, this is defined as a direction for convenience of explanation, and the scope of the claims is not particularly limited by the description of this direction.

As used herein, the term “connected” may not only refer to “directly connected” but also include “indirectly connected” by means of an adhesive layer, or the like. The term “electrically connected” may include both of the case in which constitutional elements are “physically connected” and the case in which constitutional elements are “not physically connected.” Further, the terms “first,” “second,”

and the like may be used to distinguish one constitutional element from the other, and may not limit a sequence and/or an importance, or others, in relation to the constitutional elements. In some cases, a first constitutional element may be referred to as a second constitutional element, and similarly, a second constitutional element may be referred to as a first constitutional element without departing from the scope of right of the exemplary embodiments.

As used herein, the term “an embodiment” is provided to emphasize a particular feature, structure, or characteristic, and does not necessarily refer to the same embodiment. Furthermore, the particular characteristics or features may be combined in any suitable manner in one or more embodiments. For example, a context described in a specific exemplary embodiment may be used in other embodiments, even if it is not described in the other embodiments, unless it is described contrary to or inconsistent with the context in the other embodiments.

The terms used herein describe particular embodiments only, and the present disclosure is not limited thereby. As used herein, the singular forms “a,” “an,” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise.

As set forth above, as one of the various effects of the present disclosure, a printed circuit board capable of improving process capability by securing flatness of a bump region may be provided.

While exemplary embodiments have been shown and described above, it will be apparent to those skilled in the art that modifications and variations could be made without departing from the scope of the present invention as defined by the appended claims.

What is claimed is:

1. A printed circuit board, comprising:
 - an insulating layer;
 - an interconnection layer disposed on the insulating layer, and including a plurality of metal pads for mounting a semiconductor chip thereon; and
 - a solder resist layer disposed on the insulating layer and covering the interconnection layer, the solder resist layer having a plurality of openings respectively exposing at least a portion of at least one of the plurality of metal pads,
 wherein a rectangular region created by substantially connecting outer edges of outermost openings among the plurality of openings in a straight line is substantially equally divided into a plurality of cells, and a ratio of areas of the metal pads disposed in each cell to an area of each cell is calculated, and when a maximum value thereof is P_{Max} and a minimum value thereof is P_{Min} , $(P_{Max} - P_{Min}) * 100 \leq 20$.
2. The printed circuit board of claim 1, wherein the plurality of cells are equally divided within a range having a horizontal length of 1.7 mm to 2.0 mm and a vertical length of 1.7 mm to 2.0 mm.
3. The printed circuit board of claim 1, wherein when an average depth of the openings in each of the plurality of cells is t_1, t_2, \dots, t_n , respectively, and a ratio of an area in each of the plurality of cells is P_1, P_2, \dots, P_n , respectively, where n is an integer equal to or greater than 3, t_1, t_2, \dots, t_n substantially satisfy a relationship of $0.22 * \{(P_1, P_2, \dots, P_n) * 100\} * (\mu m) + m * (\mu m)$, respectively, where, m is a rational number equal to or greater than 0.
4. The printed circuit board of claim 1, wherein an average thickness of the interconnection layer is 10 μm to 18 μm , and

a difference between a maximum thickness and a minimum thickness in the interconnection layer is within 5 μm .

5. The printed circuit board of claim 1, wherein an average thickness of the solder resist layer is 15 μm to 23 μm , and

a difference between a maximum thickness and a minimum thickness in the solder resist layer is within 7 μm .

6. The printed circuit board of claim 1, wherein an average diameter of the plurality of openings is 50 μm to 100 μm , and

a difference in diameters between an opening having a maximum diameter and an opening having a minimum diameter among the plurality of openings is within 10 μm .

7. The printed circuit board of claim 1, wherein each of the plurality of metal pads comprises copper (Cu).

8. The printed circuit board of claim 1, wherein the solder resist layer comprises a solder resist made of a photosensitive material.

9. The printed circuit board of claim 1, wherein the plurality of openings respectively expose at least the portion of the at least one of the plurality of pads in a solder mask defined (SMD) type.

10. The printed circuit board of claim 1, wherein the printed circuit board comprises a plurality of insulating layers, a plurality of interconnection layers respectively disposed on or within the plurality of insulating layers, and a plurality of via layers respectively penetrating at least one of the plurality of insulating layers and respectively connected to at least one of the plurality of interconnection layers,

the solder resist layer is disposed on the plurality of insulating layers,

the insulating layer, on which the interconnection layer including the plurality of metal pads is disposed, is an outermost layer among the plurality of insulating layers, and

the interconnection layer including the plurality of metal pads is an outermost layer among the plurality of interconnection layers.

11. The printed circuit board of claim 1, further comprising a first substrate portion and a second substrate portion disposed on the first substrate portion,

wherein the second substrate portion has higher interconnection density than the first substrate portion,

the solder resist layer is disposed on the second substrate portion, and

the insulating layer and the interconnection layer are disposed as an outermost layer of the second substrate portion, respectively.

12. The printed circuit board of claim 11, wherein the first substrate portion comprises a core insulating layer, first and second core interconnection layers respectively disposed on both surfaces of the core insulating layer, a core via layer penetrating the core insulating layer and connecting the first and second core interconnection layers, a plurality of first and second build-up insulating layers respectively disposed on the both surfaces of the core insulating layer, a plurality of first build-up interconnection layers respectively disposed on or within the plurality of first build-up insulating layers, a plurality of first build-up via layers respectively penetrating at least one of the plurality of first build-up insulating layers and respectively connected to at least one of the plurality of first build-up interconnection layers, a plurality of second build-up interconnection layers respectively disposed on or within the plurality of second build-up insulating

21

ing layers, and a plurality of second build-up via layers respectively penetrating at least one of the plurality of second build-up insulating layers and respectively connected to at least one of the plurality of second build-up interconnection layers,

wherein the second substrate portion comprises a plurality of third build-up insulating layers, a plurality of third build-up interconnection layers respectively disposed on or within the plurality of third build-up insulating layers, and a plurality of third build via layers respectively penetrating at least one of the plurality of third build-up insulating layers and respectively connected to at least one of the plurality of third build-up interconnection layers,

wherein the solder resist layer is disposed on the plurality of third build-up insulating layers,

wherein the insulating layer is an outermost layer among the plurality of third build-up insulating layers,

wherein the interconnection layer is an outermost layer among the plurality of third build-up interconnection layers.

13. A printed circuit board, comprising:
an insulating portion;

a plurality of metal pads disposed on the insulating portion, and for mounting a semiconductor chip thereon; and

a first solder resist layer disposed on the insulating portion and covering the plurality of metal pads, the first solder resist layer having a plurality of first openings respectively exposing at least a portion of at least one of the plurality of metal pads,

wherein a rectangular region created by substantially connecting outer edges of outermost first openings among the plurality of first openings in a straight line is substantially equally divided into n cells within a range having a horizontal length of 1.7 mm to 2.0 mm and a vertical length of 1.7 mm to 2.0 mm, and a ratio of areas of the metal pads disposed in each cell to a total area of the rectangular region is calculated, and when a maximum value thereof is Q_{Max} and a minimum value thereof is Q_{Min} , $n*(Q_{Max}-Q_{Min})*100 \leq 20$, where n is a positive integer.

14. The printed circuit board of claim 13, wherein when an average depth of the first openings in each of the plurality of cells is t_1, t_2, \dots, t_n , respectively, and a ratio of an area of the metal pads disposed in each cell to the total area of the rectangular region is Q_1, Q_2, \dots, Q_n , respectively, where n is an integer equal to or greater than 3, t_1, t_2, \dots, t_n substantially satisfies a relationship of $0.22*n*\{(Q_1, Q_2, \dots, Q_n)*100\}*(\mu m)+k*(\mu m)$, respectively, where k is a rational number equal to or greater than 0.

15. The printed circuit board of claim 13, wherein an average thickness of the plurality of metal pads is 10 μm to 18 μm , and

a difference in thicknesses between a metal pad having a maximum thickness and a metal pad having a minimum thickness among the plurality of metal pads is within 5 μm .

16. The printed circuit board of claim 13, wherein an average thickness of the first solder resist layer is 15 μm to 23 μm , and

a difference between a maximum thickness and a minimum thickness in the first solder resist layer is within 7 μm .

17. The printed circuit board of claim 13, wherein an average diameter of the plurality of first openings is 50 μm to 100 μm , and

22

a difference in diameters between a first opening having a maximum diameter and a first opening having a minimum diameter among the plurality of first openings is within 10 μm .

18. The printed circuit board of claim 13, further comprising:

a plurality of interconnection layers respectively disposed on or within the insulating portion,

wherein an interconnection layer disposed on an uppermost layer among the plurality of interconnection layers includes the plurality of metal pads.

19. The printed circuit board of claim 18, further comprising:

a plurality of solder bumps respectively disposed on the plurality of first openings, and respectively connected to at least the portion of the at least one of the plurality of metal pads; and

a semiconductor chip disposed on the first solder resist layer, and connected to the plurality of metal pads through the plurality of solder bumps.

20. The printed circuit board of claim 19, further comprising:

a second solder resist layer disposed on a side opposite to a side of the insulating portion on which the first solder resist layer is disposed, the second solder resist layer having a plurality of second openings respectively exposing at least a portion of an interconnection layer disposed on a lowermost layer among the plurality of interconnection layers; and

a plurality of electrical connection metal members respectively disposed on the plurality of second openings, and respectively connected to at least the portion of the interconnection layer disposed on the lowermost layer thereof.

21. A printed circuit board, comprising:

an insulating layer;

an interconnection layer disposed on the insulating layer, and including a plurality of metal pads for mounting a semiconductor chip thereon; and

a solder resist layer disposed on the insulating layer and covering the interconnection layer, the solder resist layer having a plurality of openings respectively exposing at least a portion of at least one of the plurality of metal pads,

wherein a rectangular region created by substantially connecting outer edges of outermost openings among the plurality of openings in a straight line is substantially equally divided into a plurality of cells, an average depth of the openings in each of the plurality of cells is t_1, t_2, \dots, t_n , respectively, and a ratio of an area of the metal pads disposed in each cell to an area of each cell are P_1, P_2, \dots, P_n , respectively, where n is an integer equal to or greater than 3, t_1, t_2, \dots, t_n substantially satisfy a relationship of $0.22*\{(P_1, P_2, \dots, P_n)*100\}*(\mu m)+m*(\mu m)$, respectively, where, m is a rational number equal to or greater than 0.

22. The printed circuit board of claim 21, wherein the plurality of cells are equally divided within a range having a horizontal length of 1.7 mm to 2.0 mm and a vertical length of 1.7 mm to 2.0 mm.

23. The printed circuit board of claim 21, wherein an average thickness of the interconnection layer is 10 μm to 18 μm , and

a difference between a maximum thickness and a minimum thickness in the interconnection layer is within 5 μm .

23

24. The printed circuit board of claim 21, wherein an average thickness of the solder resist layer is 15 μm to 23 μm , and

a difference between a maximum thickness and a minimum thickness in the solder resist layer is within 7 μm .

25. The printed circuit board of claim 21, wherein an average diameter of the plurality of openings is 50 μm to 100 μm , and

a difference in diameters between an opening having a maximum diameter and an opening having a minimum diameter among the plurality of openings is within 10 μm .

26. The printed circuit board of claim 21, wherein the plurality of openings respectively expose at least the portion of the at least one of the plurality of pads in a solder mask defined (SMD) type.

27. A printed circuit board, comprising:

an insulating portion;

a plurality of metal pads disposed on the insulating portion, and for mounting a semiconductor chip thereon; and

a solder resist layer disposed on the insulating portion and covering the plurality of metal pads, the solder resist layer having a plurality of openings respectively exposing at least a portion of at least one of the plurality of metal pads,

wherein a rectangular region created by substantially connecting outer edges of outermost openings among the plurality of openings in a straight line is substantially equally divided into n cells within a range having a horizontal length of 1.7 mm to 2.0 mm and a vertical length of 1.7 mm to 2.0 mm, an average depth of the openings in each of the plurality of cells is t_1, t_2, \dots, t_n , respectively, and a ratio of an area of the metal pads disposed in each cell to the total area of the rectangular region is Q_1, Q_2, \dots, Q_n , respectively, where n is an integer equal to or greater than 3, t_1, t_2, \dots, t_n substantially satisfies a relationship of $0.22 \cdot n \cdot \{(Q_1, Q_2, \dots, Q_n) \cdot 100\} \cdot (\mu\text{m}) + k \cdot (\mu\text{m})$, respectively, where k is a rational number equal to or greater than 0.

28. The printed circuit board of claim 27, wherein an average thickness of the plurality of metal pads is 10 μm to 18 μm , and

24

a difference in thicknesses between a metal pad having a maximum thickness and a metal pad having a minimum thickness among the plurality of metal pads is within 5 μm .

29. The printed circuit board of claim 27, wherein an average thickness of the solder resist layer is 15 μm to 23 μm , and

a difference between a maximum thickness and a minimum thickness in the solder resist layer is within 7 μm .

30. The printed circuit board of claim 27, wherein an average diameter of the plurality of openings is 50 μm to 100 μm , and

a difference in diameters between a opening having a maximum diameter and a opening having a minimum diameter among the plurality of openings is within 10 μm .

31. A method to determine whether a printed circuit board is suitable for a semiconductor chip mounted thereon, wherein the printed circuit board includes an insulating layer, a plurality of metal pads disposed on the insulating layer, and a solder resist layer disposed on the insulating layer and having a plurality of openings respectively exposing at least a portion of at least one of the plurality of metal pads, the method comprising:

substantially equally dividing a rectangular region created by substantially connecting outer edges of outermost openings among the plurality of openings in a straight line into a plurality of cells;

calculating a ratio of areas of the metal pads disposed in each cell to an area of each cell; and

determining that the printed circuit board is suitable for the semiconductor chip mounted thereon based on a result that $(P_{Max} - P_{Min}) \cdot 100$ is equal to or less than a predetermined value, where P_{Max} is a maximum value among the ratios for the plurality of cells and P_{Min} is a minimum value among the ratios for the plurality of cells.

32. The method of claim 31, wherein the predetermined value is 20.

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