University of Chinese Academy of Sciences

Semiconductor Industry Chain

IDM, Foundry and OSAT

Chun-Zhang Chen, Ph.D.

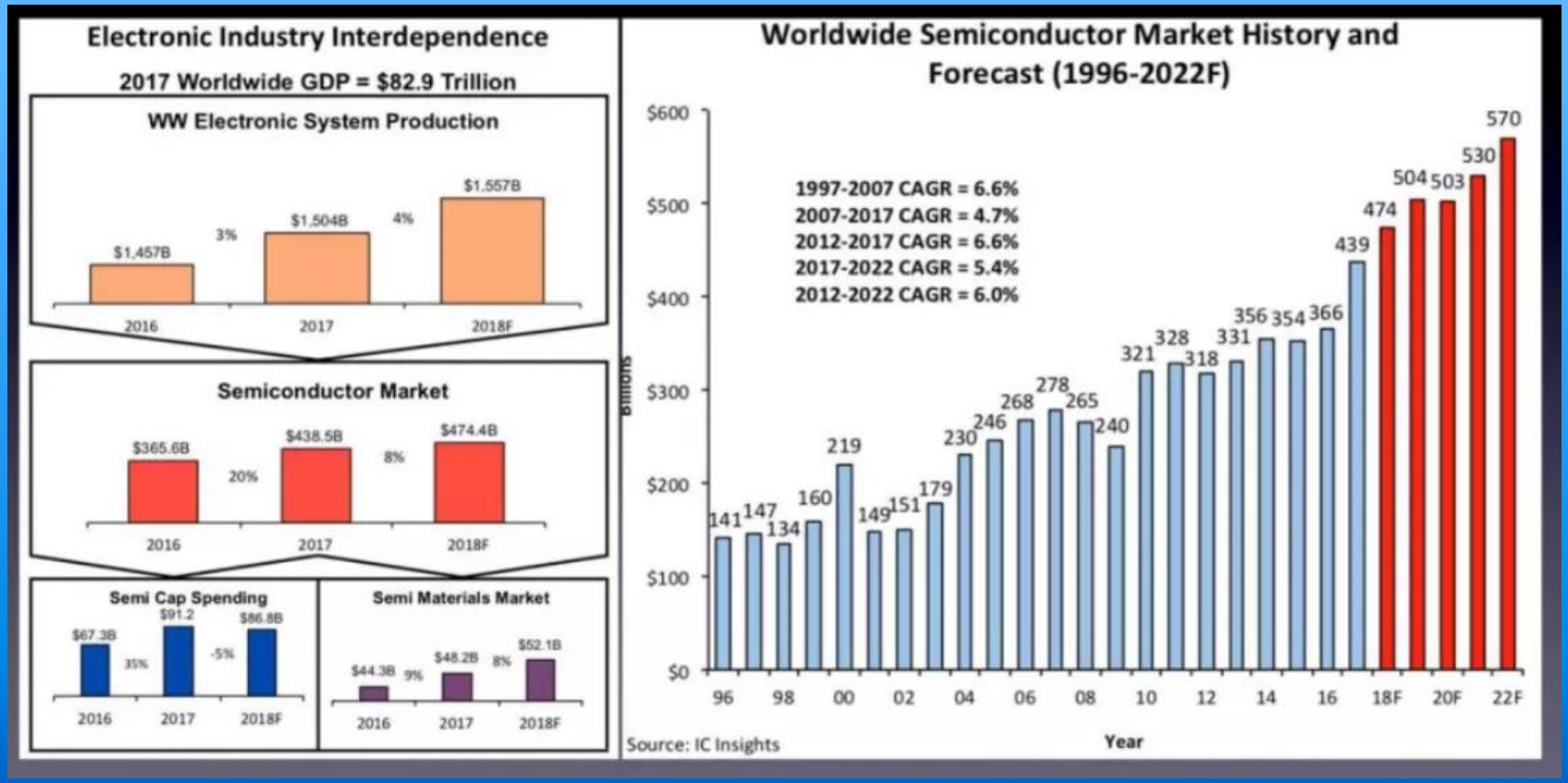
June 28 - July 2, 2021

Semiconductor Industry Chain

University of Chinese Academy of Sciences

- IDM and Fabless Model
- Foundry and Fab Technology
- Packaging and Testing
- Equipment and Materials
- Discussion

Semi Industry shares 3.4% of Global GDP (2020)

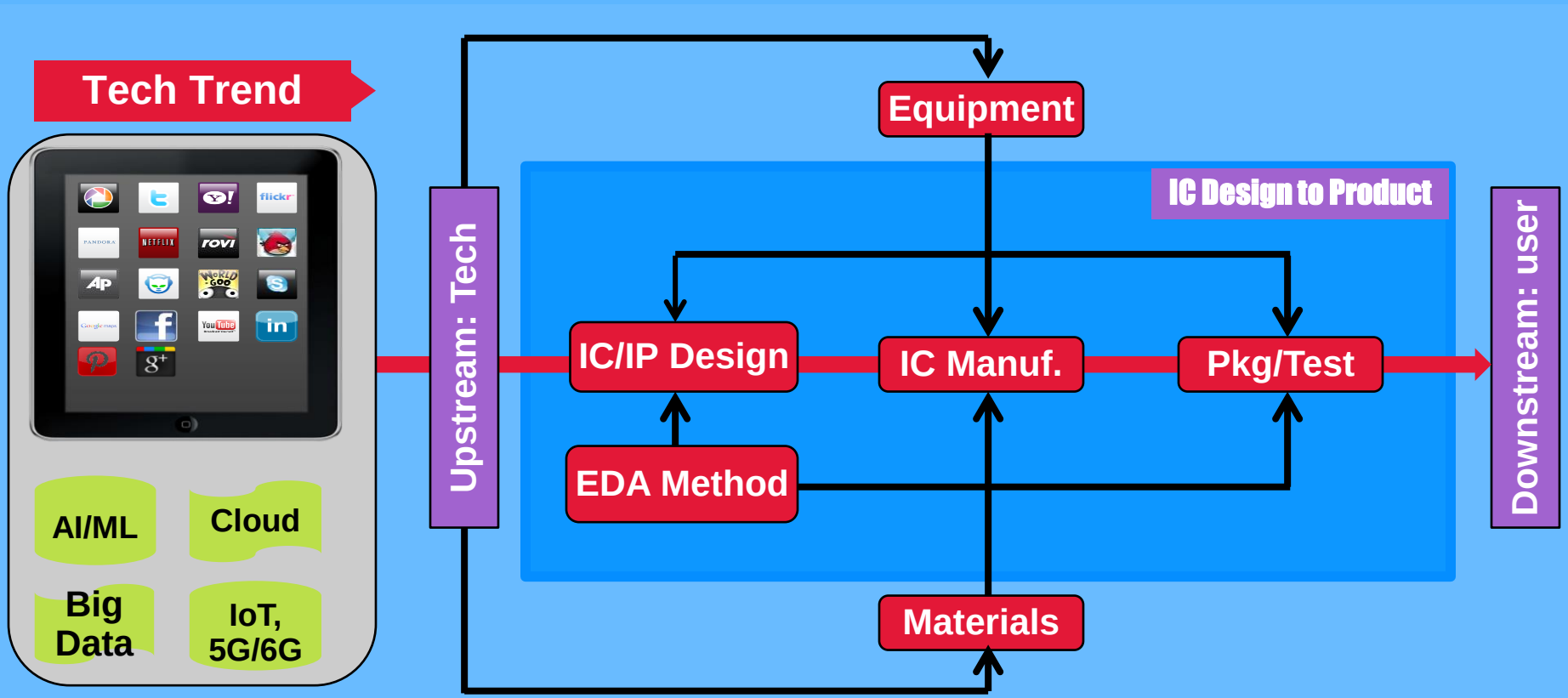


Demand by End-user

2019 DEMAND BY END-USE

End-Use Category	 Communication	 Computer	 Consumer	 Automotive	 Industrial	 Government
Annual Growth	-10.5	-18.7	-5.2	-6.9	-13.0	13.0
Total Value ($B)	**136.0**	**117.3**	**54.7**	**50.2**	**48.9**	**5.2**

Semiconductor Manuf. & IC Design Chain

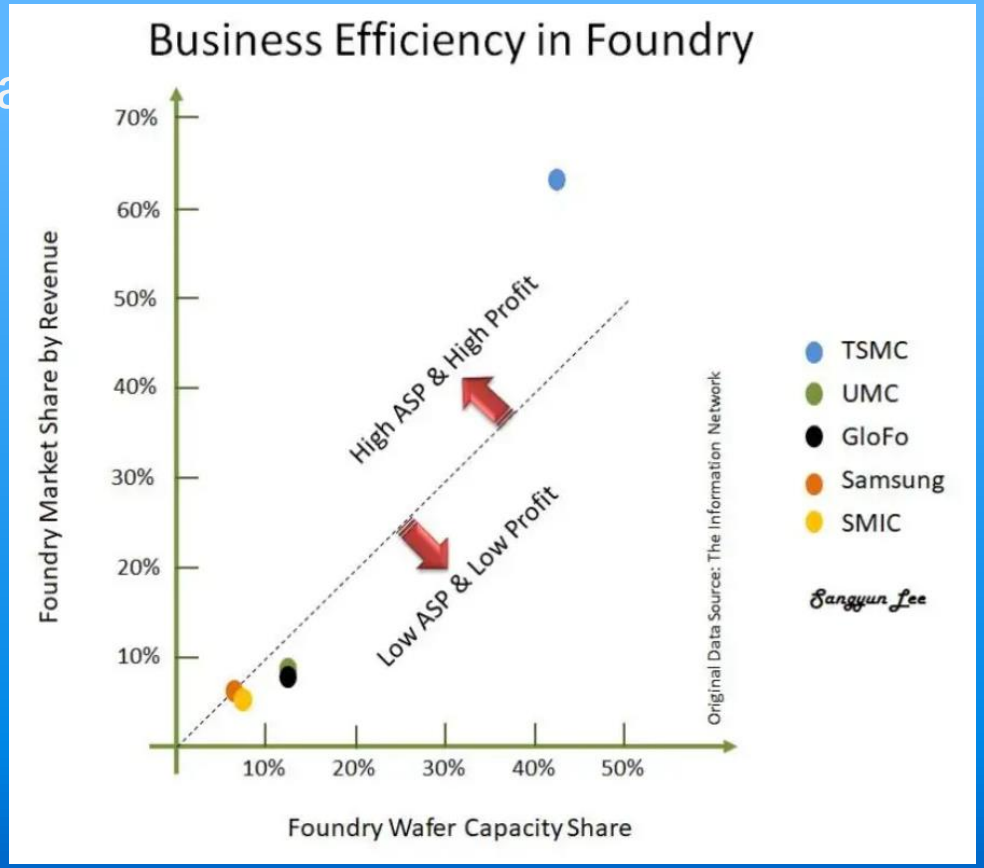


IDM: Fabless, Foundry and OSAT

- **OEM**
  - Original Equipment Manufacturer
- **EMS**
  - Electronic Manufacturing Services, or
  - **ECM** (Electronic Contract Manufacturing)
- **ODM**
  - Original Design Manufacturer
- **IDM**
  - Integrated Device Manufacturing

Déjà vu or Intel IDM 2.0

- Foundry ma



Have Fabs or Fabless?

- 1992, Jerry Sanders
  - ***"Now hear me and hear me well.*** **Real Men Have Fabs!!!!"**
    - 1982, TJ Rodgers in AMD, shortly found Cypress …
      - A Book Title: *Real Men Don't Eat Quiche…*
    - 1992, Valerie Rice, a writer for the San Jose Mercury News,

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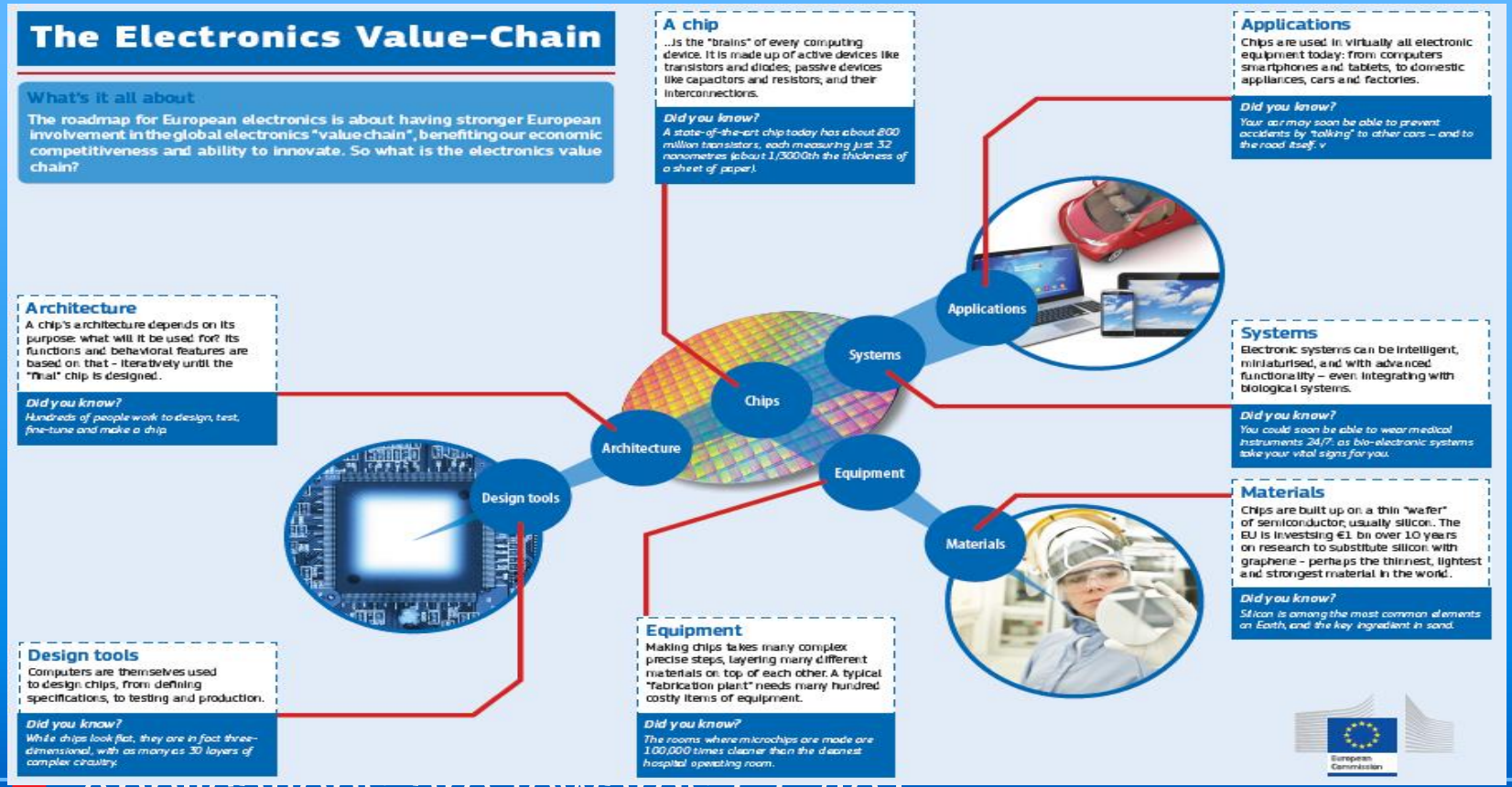
Foundry and Process Technology

Competition at 22/14/10/7 nm



- Applications are towards CC/IoT

2020 Global Fabs

2020年专属晶圆代工排名

2020排名	2019排名	公司	总部	2019年	2019市占率	2020年	2020市占率	年增长率
1	1	台积电TSMC	中国台湾	2225	60.51%	2924	63.22%	31.40%
2	3	联电UMC	中国台湾	310	8.43%	387	8.37%	24.91%
3	2	格芯GlobalFoundries	美国	373	10.13%	360	7.78%	-3.45%
4	4	中芯国际SMIC	中国大陆	200	5.44%	251	5.43%	25.39%
5	5	华虹集团HuaHong Group*	中国大陆	113	3.07%	135	2.92%	19.47%
6	7	力积电Powerchip	中国台湾	75	2.04%	102	2.20%	35.71%
7	6	高塔TowerJazz	以色列	79	2.15%	79	1.71%	0.08%
8	8	世界先进VIS	中国台湾	59	1.60%	71	1.53%	20.39%
9	10	东部高科DB HiTek	韩国	44	1.21%	61	1.32%	36.99%
10	9	稳懋WIN	中国台湾	45	1.21%	57	1.22%	26.98%
		前十大营收		3523	95.81%	4425	95.68%	25.60%
		其他营收		154	4.19%	200	4.32%	29.87%
		合计营收		3677	100.00%	4625	100.00%	25.78%

数据来源：芯思想研究院（ChipInsights），公司财报　2021年1月　单位：亿元人民币

*包括华虹宏力和上海华力

Top 10 Foundries

Foundry: a workshop or factory for casting metal.

Figure: Top Ten Foundries in 1Q19, Ranked

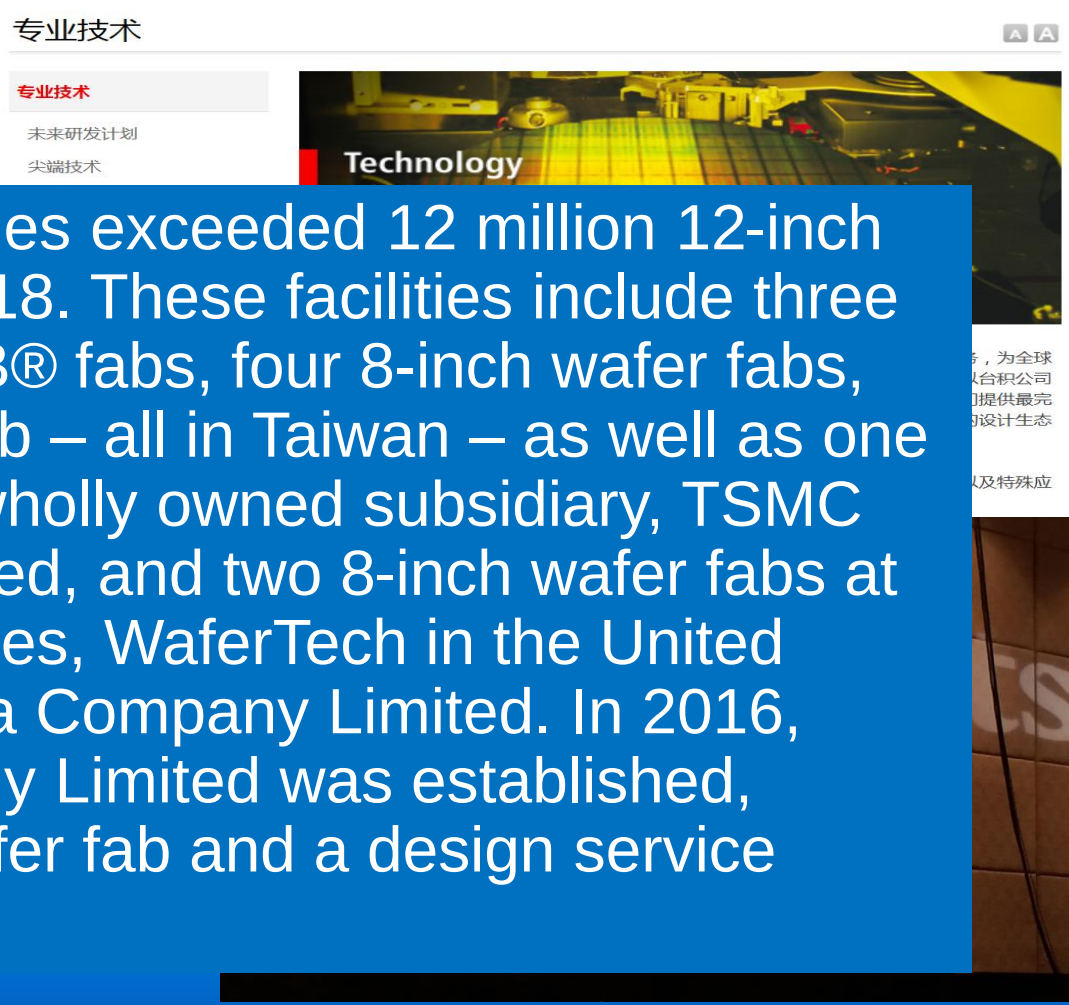
Million USD)

Rank	Company Name	1Q18 Revenue	1Q19 Revenue (E)	1Q19 Market Share (E)	1Q19 Revenue Growth YoY (E)
1	TSMC	8,547	7,028	48.1%	-17.8%
2	Samsung	3,253	2,785	19.1%	-14.4%
3	GlobalFoundries	1,513	1,234	8.4%	-18.4%
4	UMC	1,292	1,058	7.2%	-18.1%
5	SMIC	831	654	4.5%	-21.3%
6	Tower Semiconductor	313	310	2.1%	-0.9%
7	Powerchip Semiconductor	341	251	1.7%	-26.4%
8	VIS	221	225	1.5%	1.6%
9	Hua Hong Semiconductor	210	220	1.5%	4.7%
10	Dongbu HiTek	131	132	0.9%	1.1%

Note:
1. Samsung's revenue include those from its System LSI and Foundry Business
2. GlobalFoundries' revenue include that of its IBM Business
3. Only foundry revenue was included for Powerchip Semiconductor

Source: TrendForce, Mar. 2019

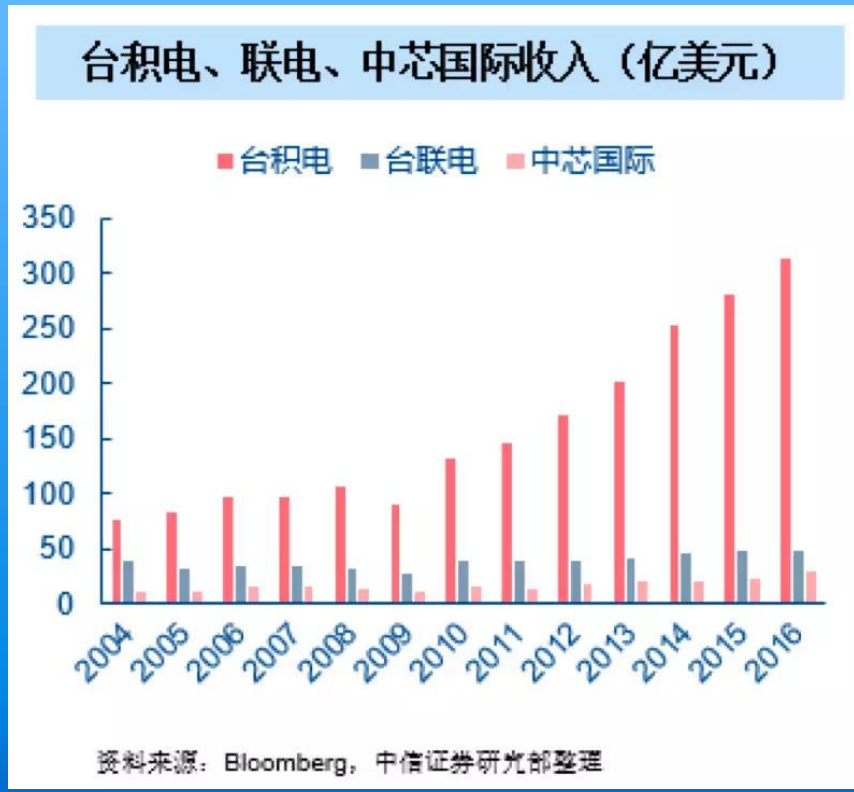
TSMC (since 1987)
Fabless/FSA-GSA

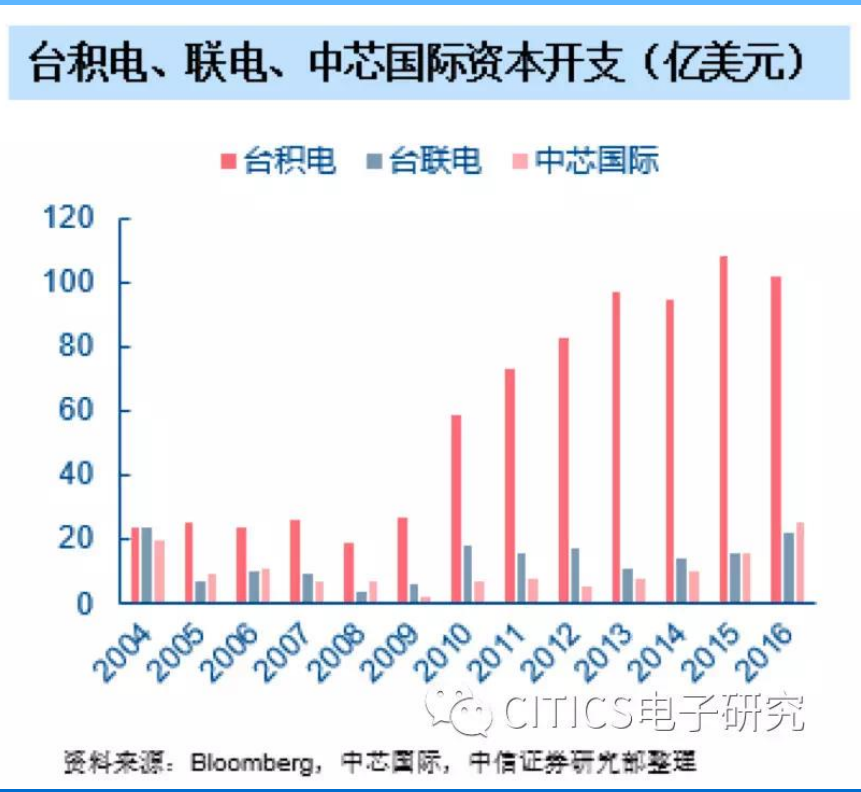


TSMC and its subsidiaries exceeded 12 million 12-inch equivalent wafers in 2018. These facilities include three 12-inch wafer GIGAFAB® fabs, four 8-inch wafer fabs, and one 6-inch wafer fab – all in Taiwan – as well as one 12-inch wafer fab at a wholly owned subsidiary, TSMC Nanjing Company Limited, and two 8-inch wafer fabs at wholly owned subsidiaries, WaferTech in the United States and TSMC China Company Limited. In 2016, TSMC Nanjing Company Limited was established, managing a 12-inch wafer fab and a design service center.

- Morris Zhang

TSMC, UMC, SMIC: Income & Expense





SAMSUNG

300MM

Logic	RF	eFlash	eMRAM	HV(Display)
7/5nm	○			
10/8nm	Planning			
14/11nm	○			
18nm (FD-SOI)	○		○	
28nm (FD-SOI)	○		○	
28nm	○	○		
45nm		○		

14/11nm, Vnorm 0.8V:
- 14LPE, 14LPP, 14LPC, 14LPU, 11LPP

10/8nm, Vnorm 0.75V
- 10LPE, 10LPP, 8LPP, 8LPU

EUV 7/5nm, Vdd 0.75V
- 7LPP
- 5LPE

HKMG (High-K Metal Gate)
: Foundry 1st HKMG in Samsung Foundry

32LP	Low Power	Vnom 1.0V
28LP	Scaling	Vnom 1.0V
28LPP	High Performance	Vnom 1.0V

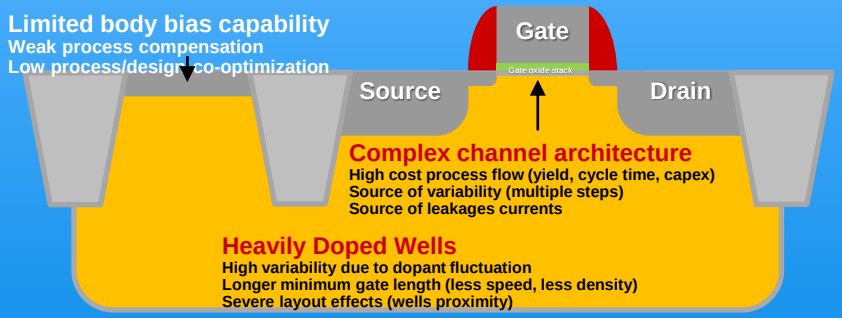
FD-SOI (Fully Depleted-Silicon on Insulator)
: One of Differentiated Platform for MCU, IoT, Consumer and Automotive

28FDS	Low Power	Vnom 1.0V (~ 0.7V)
18FDS	Cost effective	Vnom0.8V

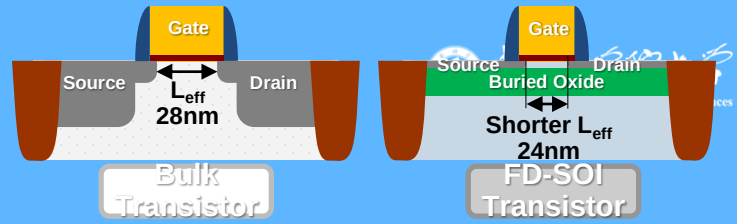
ST Micro (since 1998 ←1987)

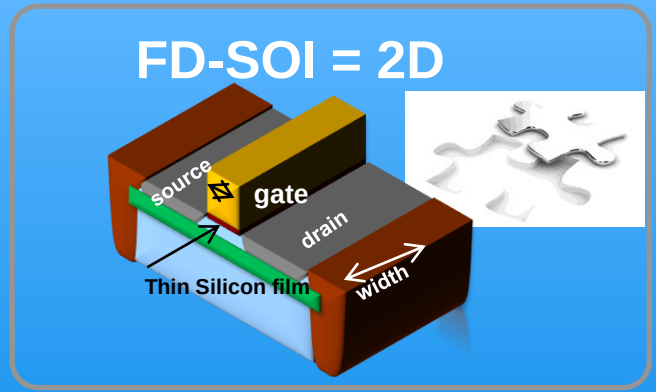
1987: Società Generale Semiconduttori, Italy + Thomson Semiconducteurs, France

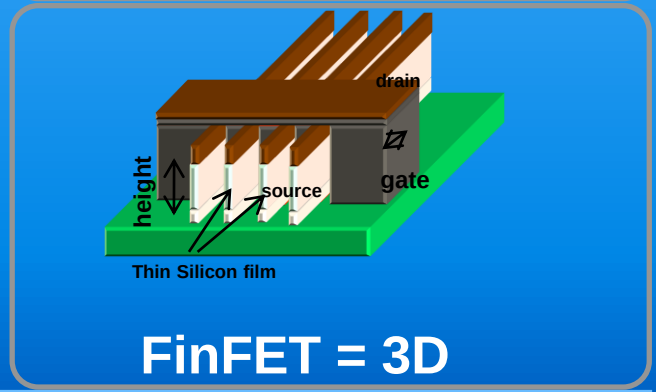
- FD-SOI vs Bulk CMOS (planar)
- FD-SOI vs FinFET



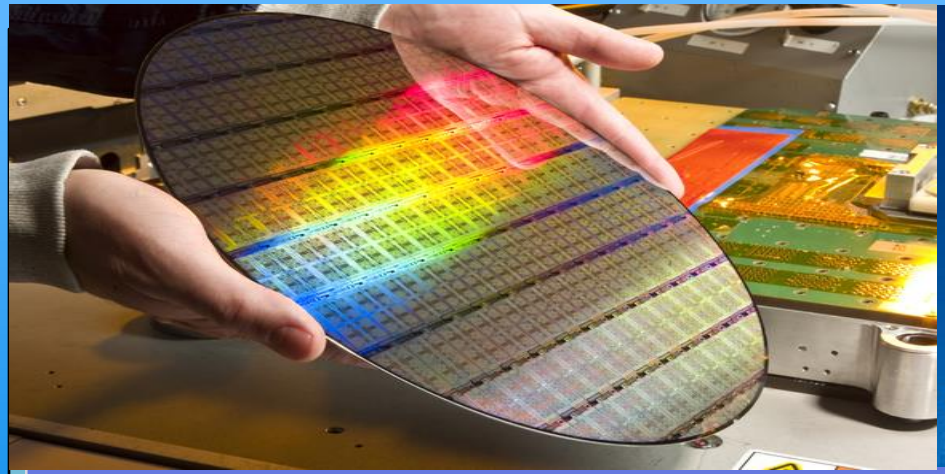
Depleted devices deliver improved electrostatic control and device scalability

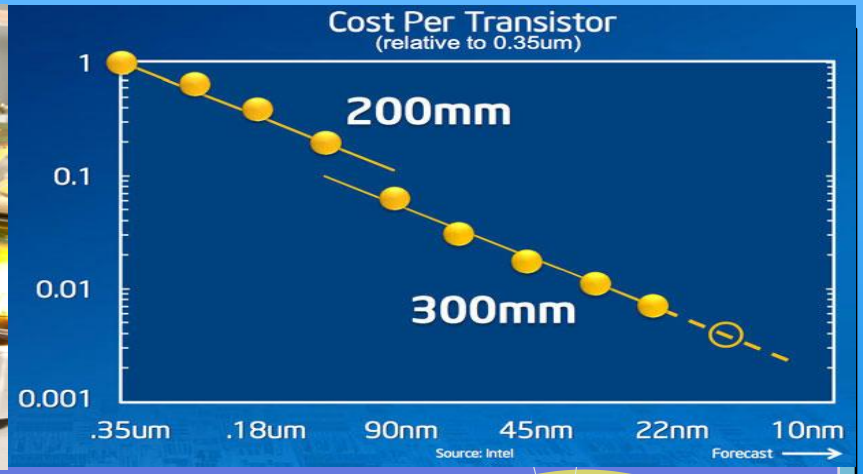


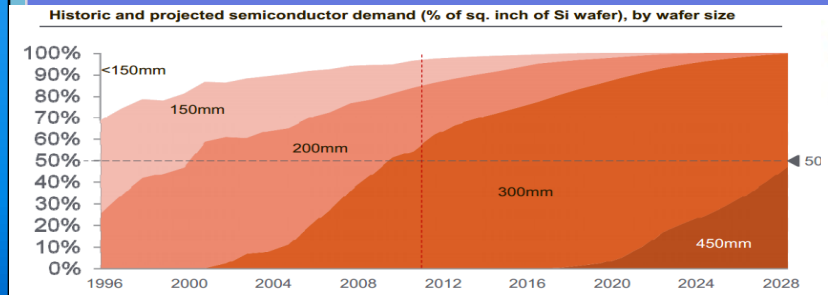


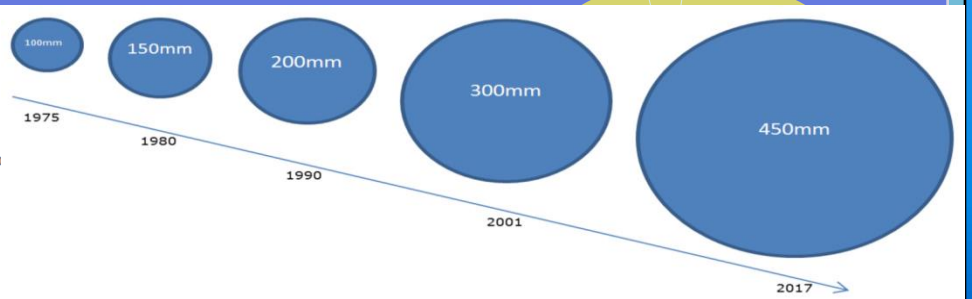


Feature Size and Wafer Size



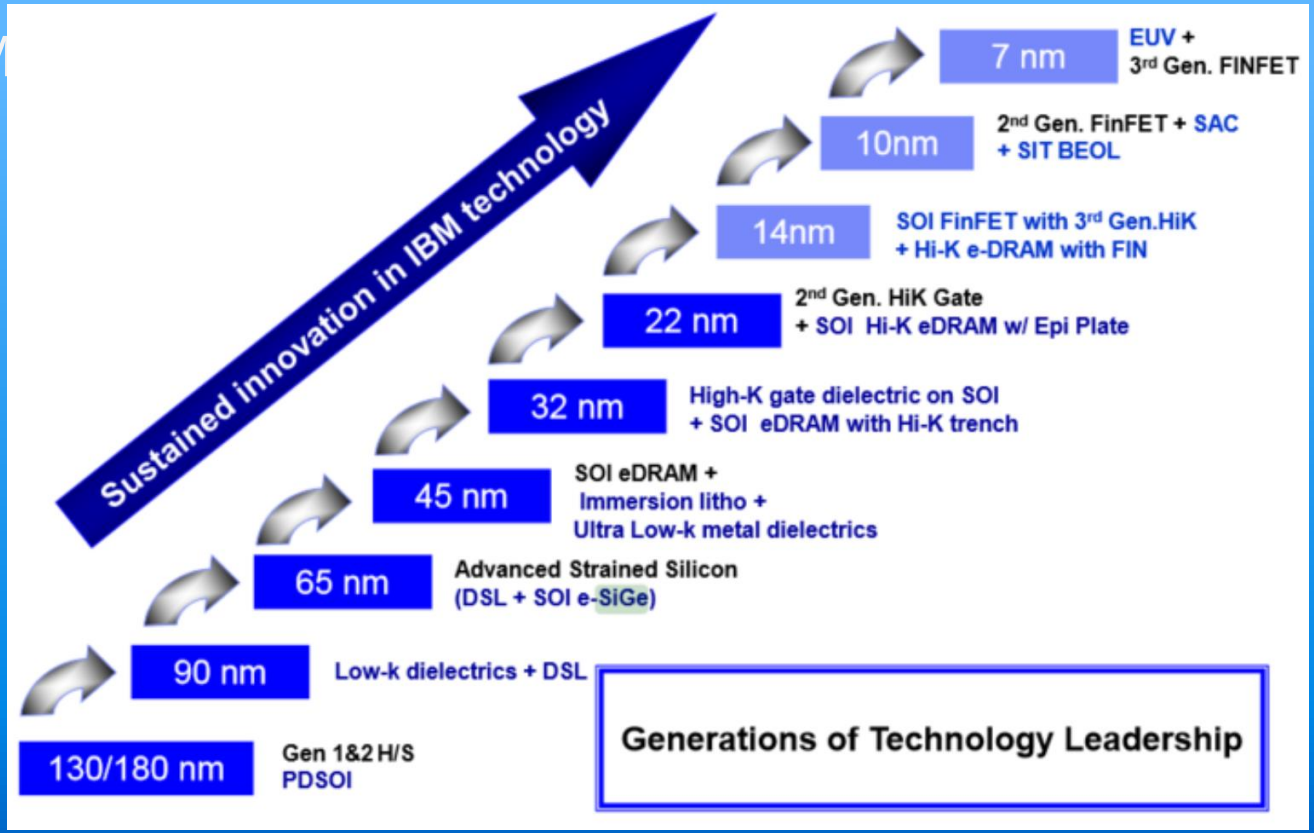






IBM SOI Technology (10 Generations)

- IBM



GF

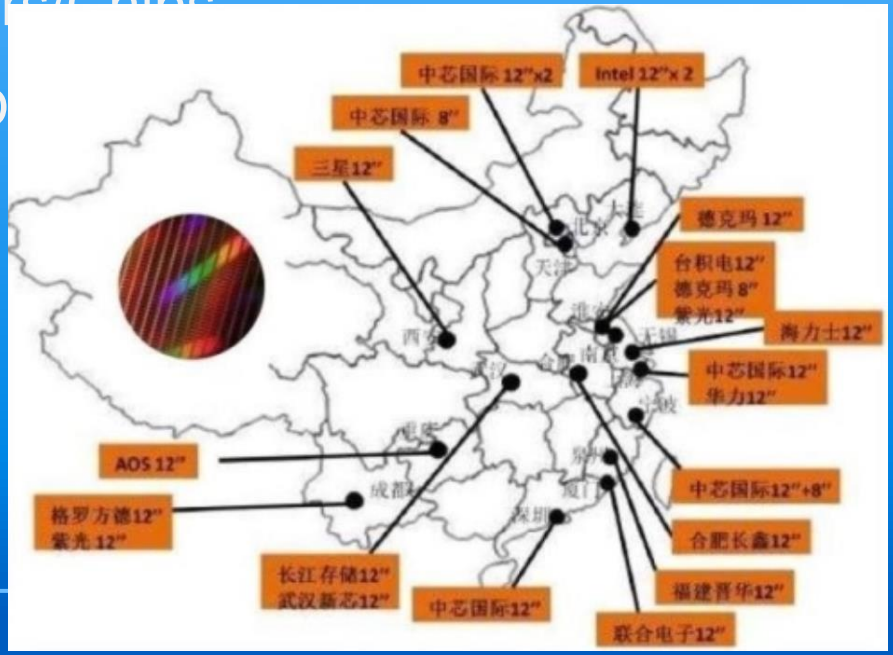
- 2009 span of AMD, ATIC of *Abu Dhabi* in UAE
- 2010, acquired Chartered Semiconductor, S'pore
- 2015: Microelectronics + $1.5B from IBM + 16,000 patents
- CMOS Main Stream: 40nm, 55/65nm, 130/180nm, Analog Power, RF CMOS
- FD-SOI: 12FDX, 22FDX, 28nm HKMG
- Embedded

GF eNVM (nm)	130	55	40	28	22	14	12	7
eMRAM					○			
eFLASH	●	●	○				Planned	
SIP Flash	IP	IP	IP	●	●			

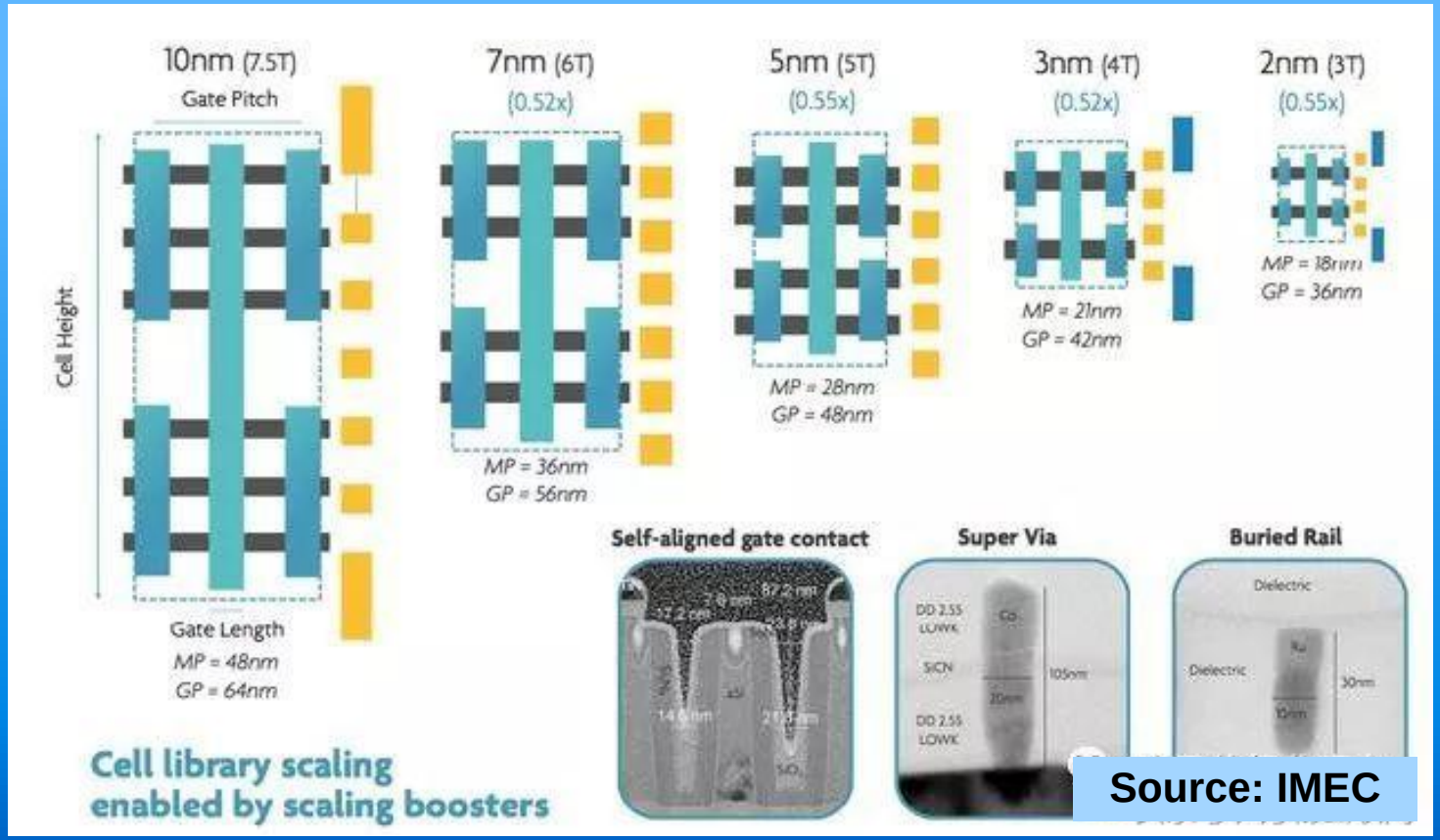
● *Available* ○ *Prototype available* IP *IP Available*

12” Foundries in China

- SMIC-Shanghai; SMIC-Beijing 28nm in 2015
- Wuhan XMC: Flash Memory
- Intel Dalian: Internal Processors/Chips
- SK Hynix Wuxi: DRAM, NAND
- Samsung Xi’an: 3D NAND
- UMC Xiamen: 2017
- Lijing (GF?) Hefei: 2017
- TSMC Nanajing: 28nm 2018



Chip Integration in 10nm and Below



GSA/FSA (1994-, FSA→GSA 2007-)

8 CEO at the 20th Anniversaries

- 40 founding members
- Semiconductor Members
- Supplier Partner Members
- Service Partner Members
- Industry Partner Members
- Organizations / Associations / Government & Educational Partner Members

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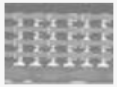
Packaging Types

- Traditional Packaging
  - SIP, DIP, SOP, SOT, TO, QFP, QFN, DFN, BGA
    - THP, SMP; QFP,
- Advanced Packaging
  - FC, WLP, SiP (2.5D, 3D)
  - MCM, Embedded, CoB,
- *Ref: Collection of IC Packaging Techniques*

Amkor and ChangDian



3D/3DIC - Through Silicon Via (TSV)

Through Silicon Via (TSV) interconnects have emerged to serve a wide range of 2.5D & 3D packaging applications & architectures that demand very high performance and functionality at the lowest energy/performance metric.

Fine Pitch Copper Pillar Flip Chip

Copper pillar bump is a next generation flip chip interconnect which offers advantages in many designs while meeting current and future ROHS requirements. It is an excellent interconnect choice for applications where some combination of fine pitch, ROHS / Green compliance, low cost and electromigration performance are required.

Flip Chip BGA (fcBGA)

Amkor Flip Chip BGA (fcBGA) packages are assembled around state-of-the-art, single unit laminate or ceramic substrates. Utilizing multiple high density routing layers, laser drilled blind, buried, and stacked vias, and ultra fine line/space metallization, fcBGA substrates have the highest routing density available.

Flip Chip Packaging Technology Solutions

Since being the first OSAT to provide FCiP solutions in 1999, Amkor has continued to introduce innovative packaging solutions utilizing Flip Chip interconnect, and offers the broadest range of FCiP solutions on the market. SuperFC®, FCBGA, FlipStack CSP, fcLBGA, fcLGA and fcCSP are qualified and are in production.

Flip Chip CSP (fcCSP) | Flip Chip LGA (fcLGA)

Amkor Technology is now offering the Flip Chip CSP (fcCSP) package -- a flip chip solution in a CSP package format. This package construction utilizes Pb-Free (or Eut. SnPb) flip chip interconnect technology, in either area array or peripheral bump layout, replacing standard wire-bond interconnect.

Silver Wire Bonding

Ag-Alloy offers properties similar to those of Gold while its cost is similar to that of Palladium Coated Copper (PCC).

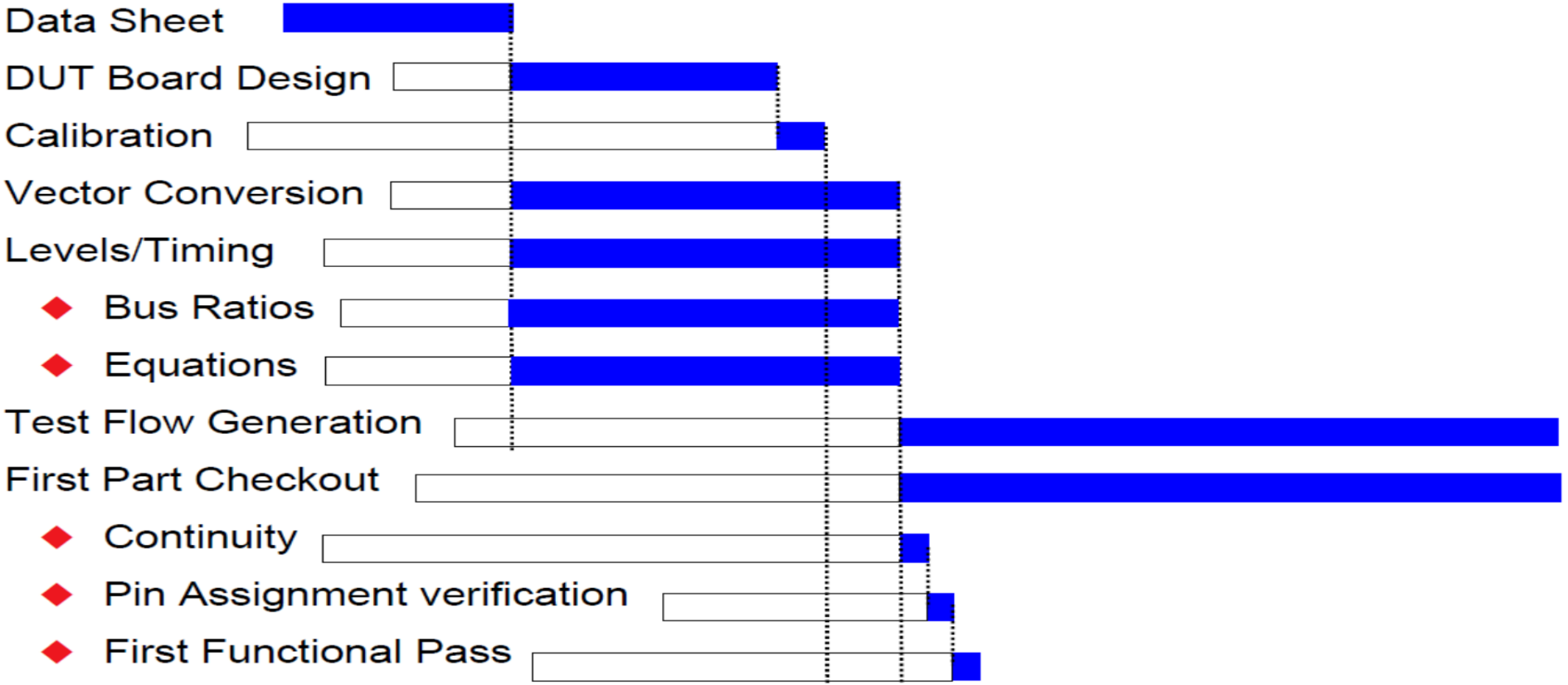
DFT and ATE

- DFT
  - BSD, Scan Chain, BIST, MBIST,
- ATE
  - Digital IC, Memory IC, Analog/RF IC, I/O (IBIS)
  - Advanced IP:
    - MIPI (D-PHY, M-PHY, C-PHY), UFS (high-speed memory I/O)
    - LPDDR3/4, TypeC/USB3.1, HDMI/MHL

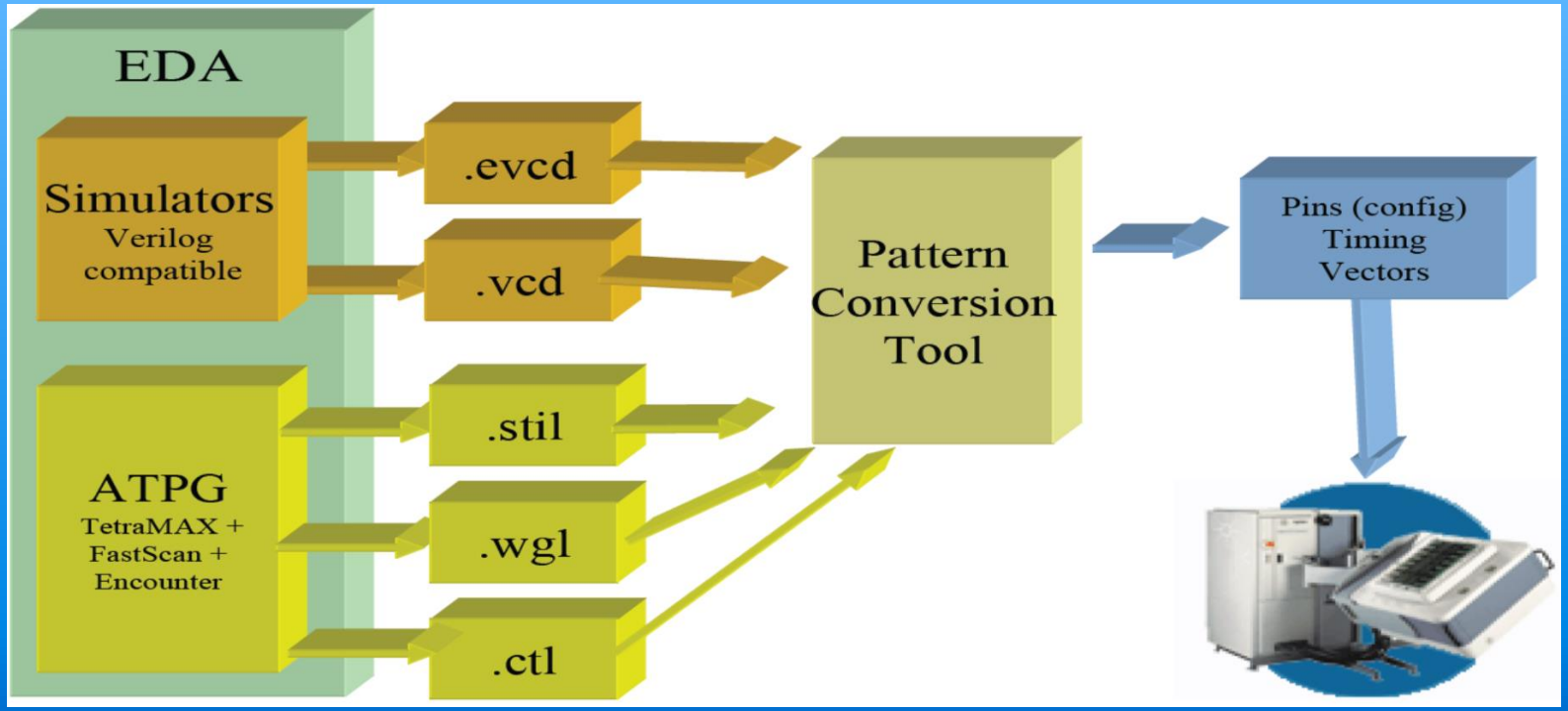
DUT Board Design

- Package type
- Pin names
- Tester configuration
- Types of tests
- Decoupling
- Power supplies
- Special tests: RF, Analog, Memory
- High speed

Test Program Generation



Vector Conversion



Installed ATE Example

Verigy 93000 PinScale test system

- Up to 3.6Gbps data rate
- 448 channels
- Mixed-Signal option
- Port Scale RF option

Advantest T2000 test system

- Up to 800Mbps data rate
- 512 channels
- Mixed-Signal option
- RF test option

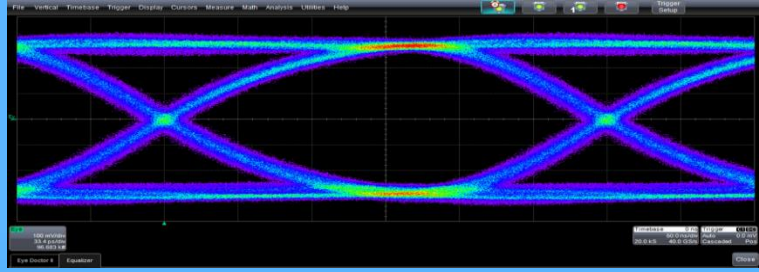
Teradyne J750HD test system

- Up to 800Mbps data rate
- 256 channels
- Wafer sort toolkit

Chroma 3360P test system

- 25/50 Mbps data rate
- 256 channels
- Wafer sort orientated configuration

ATE Sample



- Analyzing Equipment
  - Teledyne LeCroy WaveMaster
    - SDA 830Zi-B: bandwidth 30 GHz, sample rate 80GS/s

- Automatic Test Equipment
  - ADVANTEST (1954-, Tokyo)

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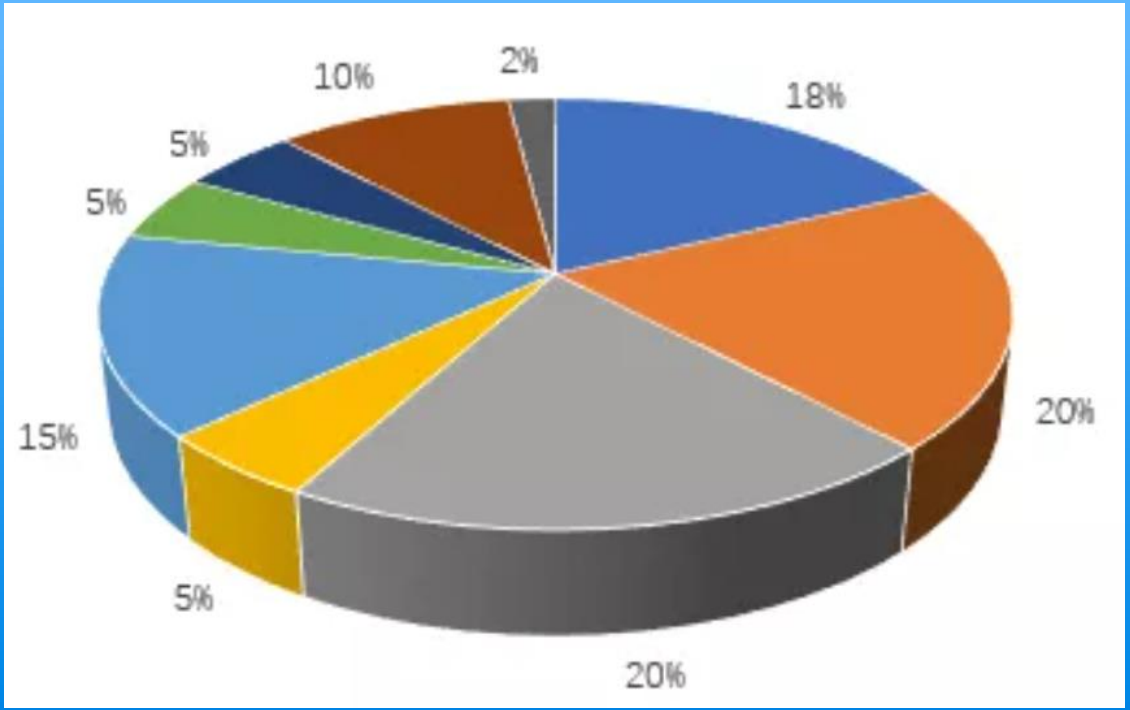
Types of Semiconductor Equipment

- Foundry/ Fabrication Equipment, 80%
- Test Equipment, 8%
- Assembly and Packaging, 7%
- Other Front-End Equipment etc., 5%

Application of Semiconductor Equipment

- Lithograph
- Etching
- Thin film
- Ion implantation
- Control/Monitoring
- Cleaning
- CMP
- Test
- Misc.

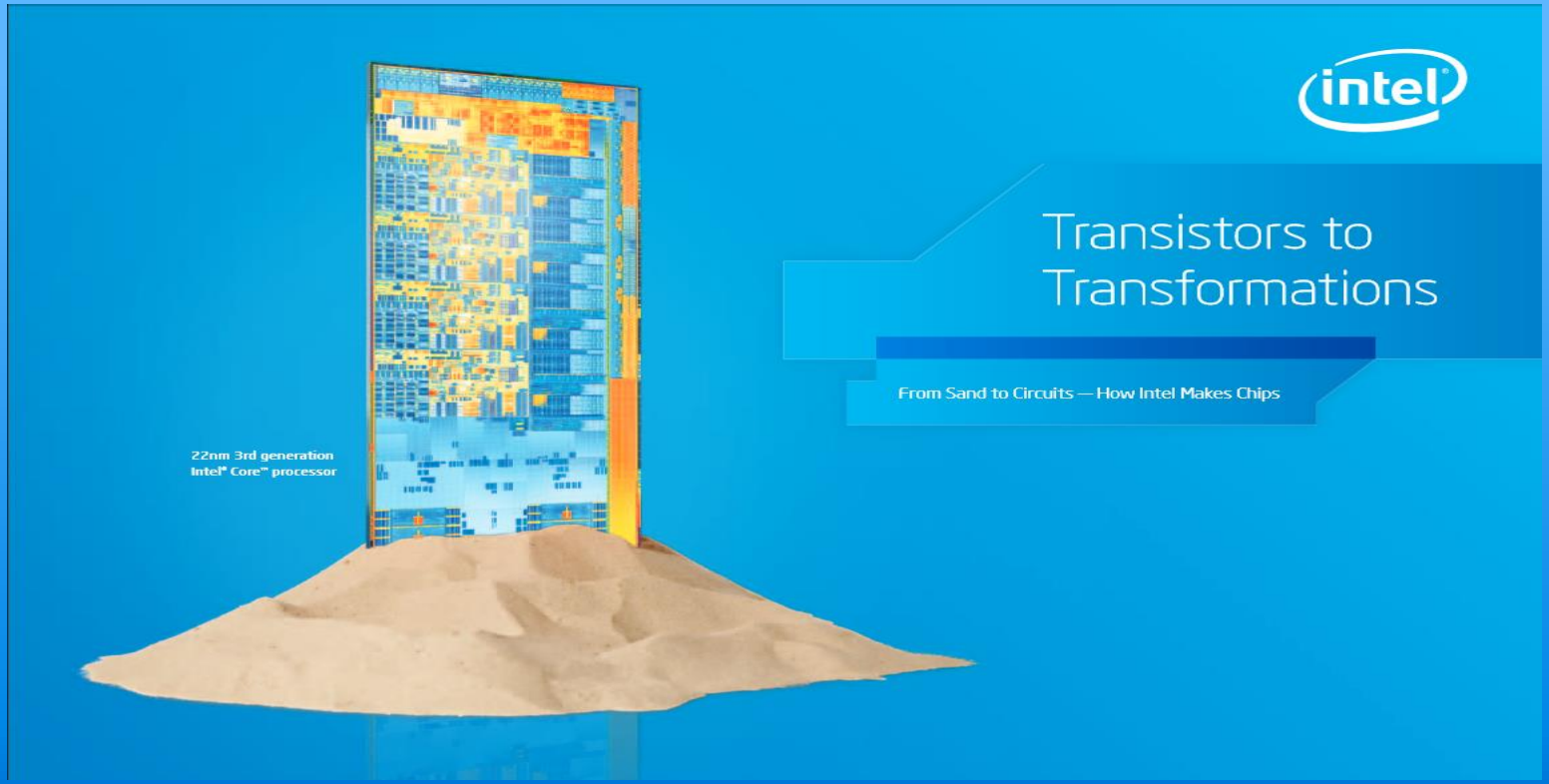


Global Semi-Equip Share (Source: Gartner 2017)

Equipment Market

Year	Revenue, B	Change
2015	36.5	
2016	41.2	
2017	55.9	
2018	64.5	
2019	59.8	-7%
2020	71.2	19%
2021 Q1	*23.5*	*51%*

From Sand to Circuits



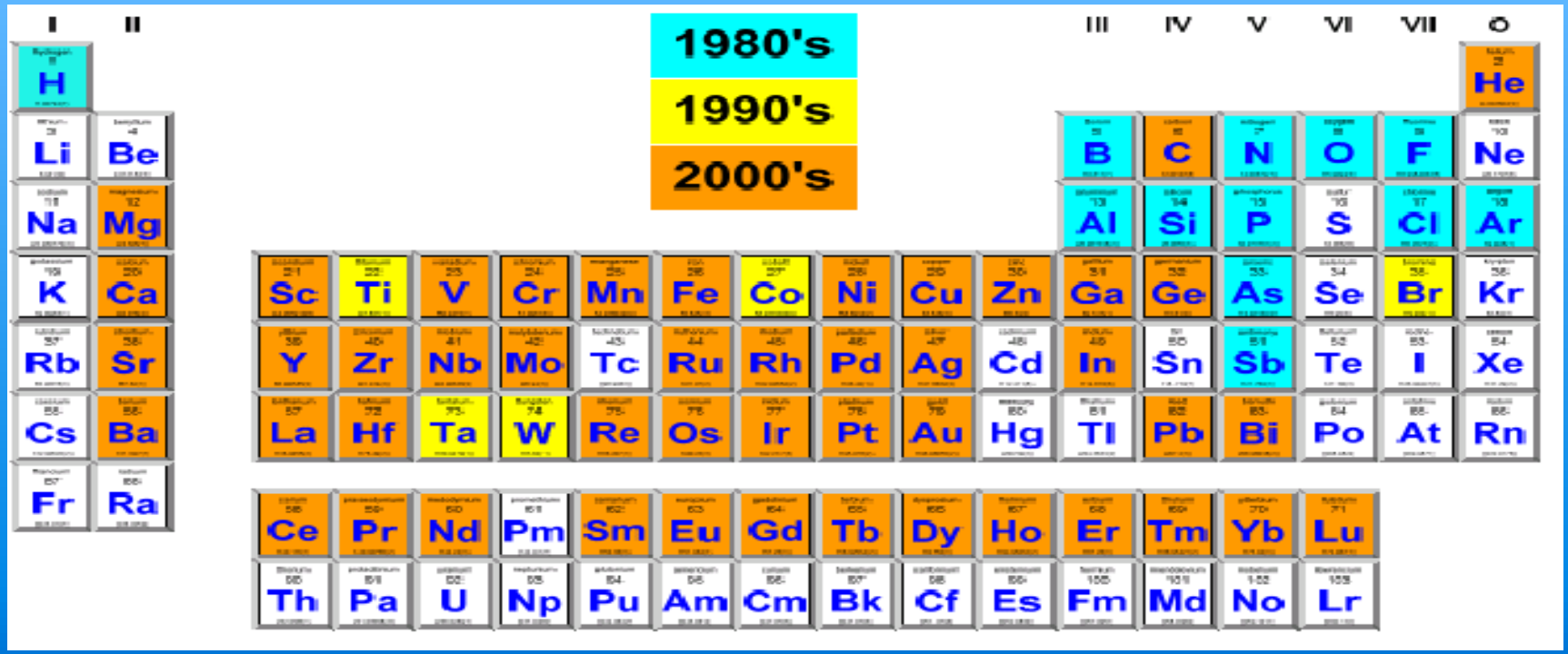
Sand to Circuit.PDF

R&D on System to New Materials

- R&D on IC System
  - SoC & AI-Chip, IIot & MCU/IP Chip, 5G & Comm.
- New Devices, New Processes and New Materials
  - Device: FinFET and …
    - Graphene, CNT, GAA; RRAM, MRAM
    - G1: Ge/Si; G2: GaAs, InP; G3: GaN, SiC
    - GTO, IGBT, ICBT, ETO, MCT
  - Process: 7/5/3/1.5nm, EUV (Smart Manuf.)
  - Graphene-CNT(L:D/1.32x10^8:1), III-V Elements
- Talents and Education
  - Talents for IC/Semicon - White Paper (2017-2018)
  - Special Program(s)

IIIA	IVA	VA
5 B 硼 10.811(7)	6 C 碳 12.0107(8)	7 N 氮 14.0067(2)
13 Al 铝 26.981538(2)	14 Si 硅 28.0855(3)	15 P 磷 30.973761(2)
31 Ga 镓 69.723(1)	32 Ge 锗 72.64(1)	33 As 砷 74.92160(2)
49 In 铟 114.818(3)	50 Sn 锡 118.710(7)	51 Sb 锑 121.760(1)
81 Tl 铊 204.3833(2)	82 Pb 铅 207.2(1)	83 Bi 铋 208.98038(2)
113 Uut * (278)	114 Uuq * (289)	115 Uup * (288)

New Materials used in CMOS continuously



IDM and IC Industry Chain

University of Chinese Academy of Sciences

- Fabless and Foundry Model
- Foundry and Fab Technology
- Packaging and Testing
- Equipment and Materials
- Discussion

Summary

- **Equipment Manufacturer [**Sand to Silicon 10/7 nm**]**
  - ASML
- **IC Manufacturer [**IDM, Foundry and GSA**]**
  - Intel, TSMC, Samsung
- **System Design House:**
  - Intel, Apple, Huawei,
- **IC/IP Design House:**
  - Arm, SpreadTrum
- **Supply Partners: Design & Reuse**
- **EDA Vendors: C, S, M**

Glossary and Terminology

Please take your notes