中国科学院大学
University of Chinese Academy of Sciences

Product Chain of SoC Design

Integrated Device Manufacturer (IDM)

Chun-Zhang Chen, Ph.D.

June 25-29, 2018

Product Chain of SoC Design

- **What is an IDM?**
- Foundry/Fab Technology
- System & Fabless Design Houses
- IP Providers & Design Services
- Discussion

2018 Semiconductor Sales Leaders

- TOP 15

1Q18 Top 15 Semiconductor Sales Leaders ($M, Including Foundries)

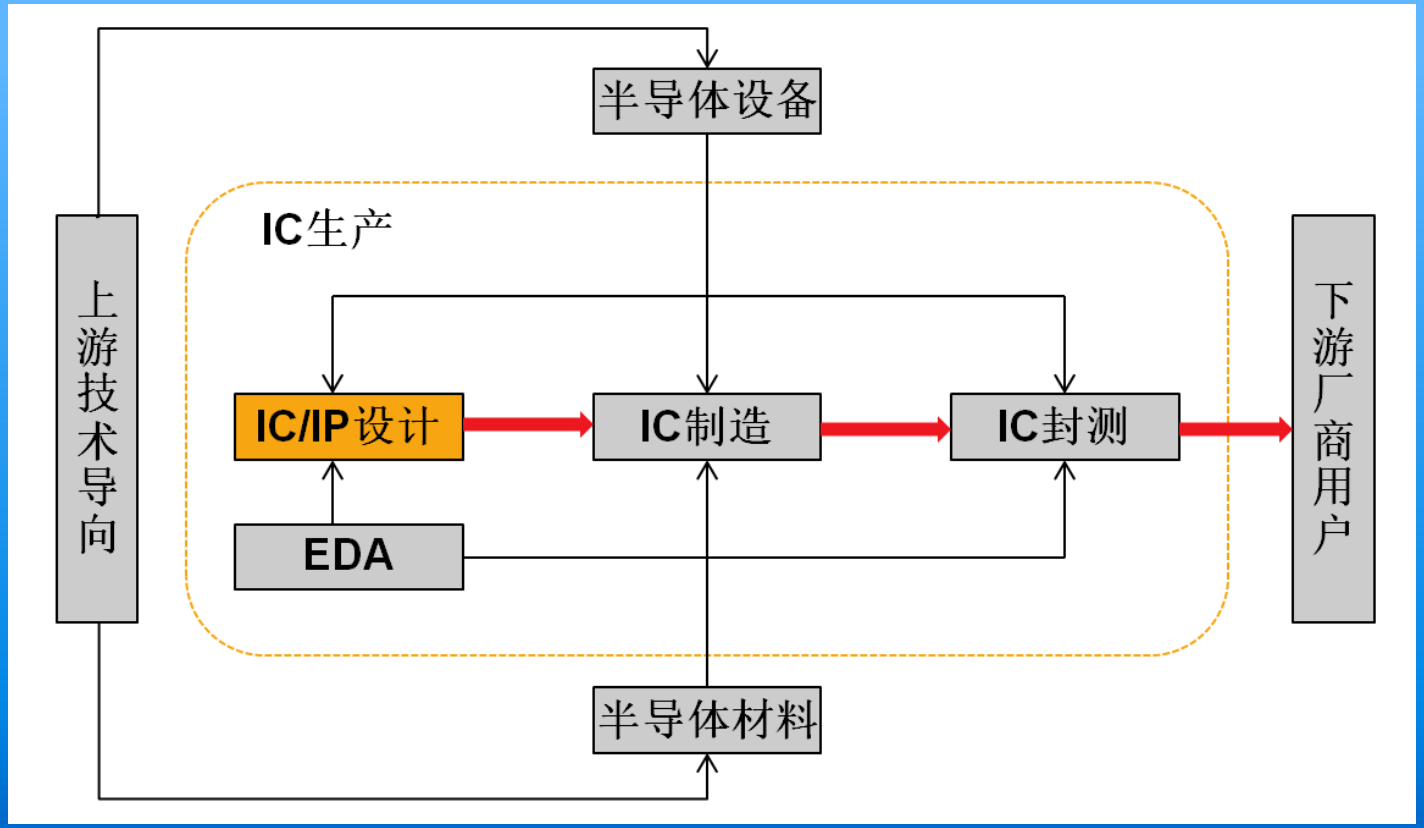
1Q18 Rank	1Q17 Rank	Company	Headquarters	1Q17 Tot IC	1Q17 Tot O-S-D	1Q17 Tot Semi	1Q18 Tot IC	1Q18 Tot O-S-D	1Q18 Tot Semi	1Q18/1Q17 % Change
1	2	Samsung	South Korea	12,811	770	13,581	18,581	820	19,401	43%
2	1	Intel	U.S.	14,220	0	14,220	15,832	0	15,832	11%
3	3	TSMC (1)	Taiwan	7,524	0	7,524	8,473	0	8,473	13%
4	4	SK Hynix	South Korea	5,346	109	5,455	8,016	125	8,141	49%
5	5	Micron	U.S.	4,931	0	4,931	7,360	0	7,360	49%
6	6	Broadcom Ltd. (2)	U.S.	3,740	368	4,108	4,160	430	4,590	12%
7	7	Qualcomm (2)	U.S.	3,676	0	3,676	3,897	0	3,897	6%
8	9	Toshiba	Japan	2,747	265	3,012	3,517	310	3,827	27%
9	8	TI	U.S.	2,960	204	3,164	3,339	227	3,566	13%
10	11	Nvidia (2)	U.S.	1,965	0	1,965	3,110	0	3,110	58%
11	15	WD/SanDisk	U.S.	1,795	0	1,795	2,350	0	2,350	31%
12	10	NXP	Europe	1,965	246	2,211	2,017	252	2,269	3%
13	12	Infineon	Europe	1,130	754	1,884	1,360	907	2,267	20%
14	13	ST	Europe	1,378	440	1,818	1,696	518	2,214	22%
15	17	Apple* (2)	U.S.	1,600	0	1,600	1,830	0	1,830	14%
—	—	Top 10 Total		59,920	1,716	61,636	76,285	1,912	78,197	26.9%
—	—	Top 15 Total		67,788	3,156	70,944	85,538	3,[illegible]	[illegible]	[illegible]

(1) Foundry (2) Fabless *Custom devices for internal use.

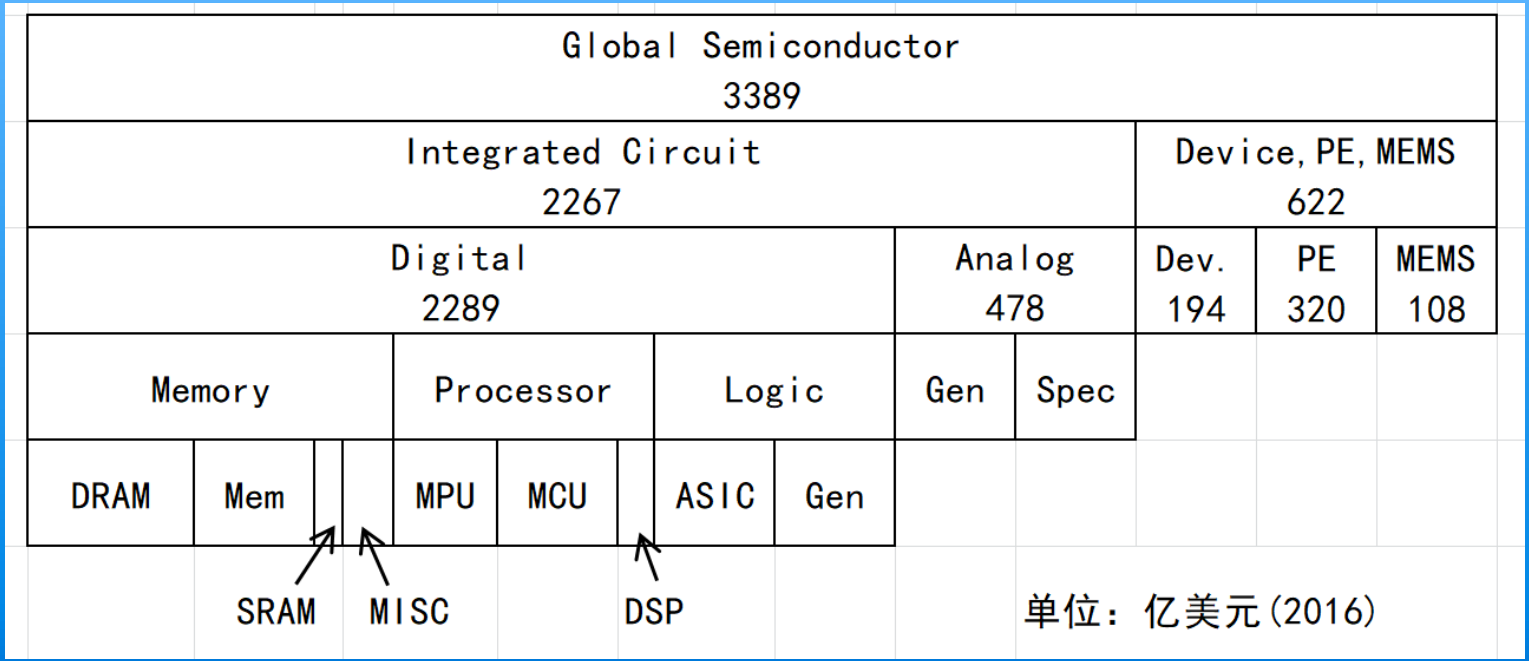
Source: Company reports, IC Insights' *Strategic Reviews* database

半导体行业观察

Semiconductor Manuf. & IC Design Chain



World Semiconductor Growth



IC Talent Needs

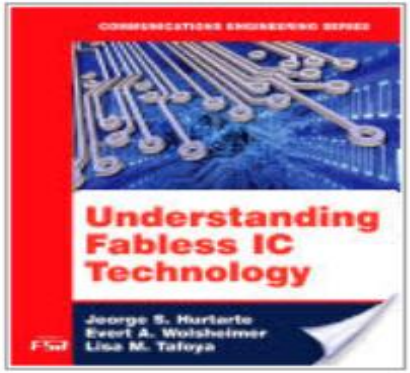
- By IC Job Types (2017)
  - R&D, 58%
  - MarCom
  - Manufacturing
  - Packaging & Test
  - Others
- By Education (2017)
  - PhD, 24%
  - MS
  - BS
  - Prof

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 needs on IC/Semicon - White Paper (2017-2018)
  - Special Program(s)

What is an IDM?

Understanding Fabless IC Technology



Jeorge S. Hurtarte, Evert A. Wolsheimer, Lisa M. Tafoya

Newnes, Apr 1, 2011 - Technology & Engineering - 296 pages

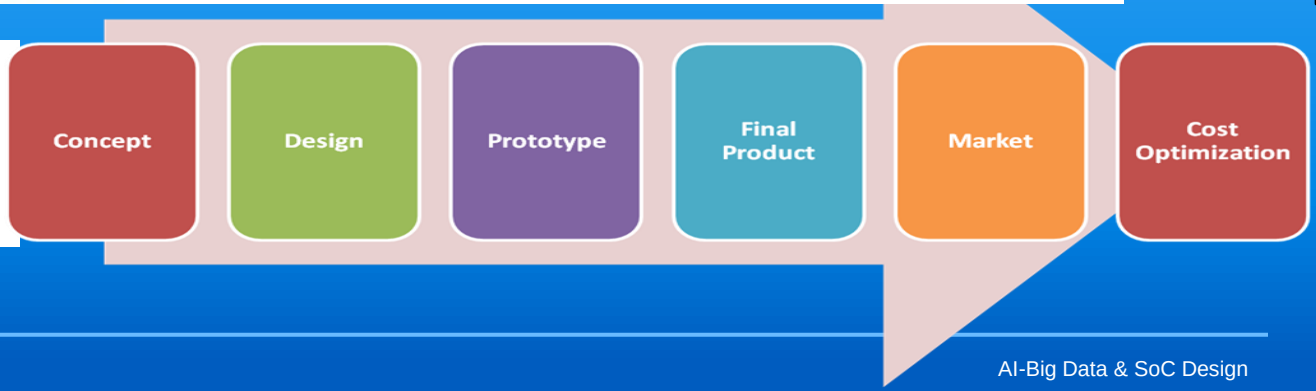
★★★★★

0 Reviews

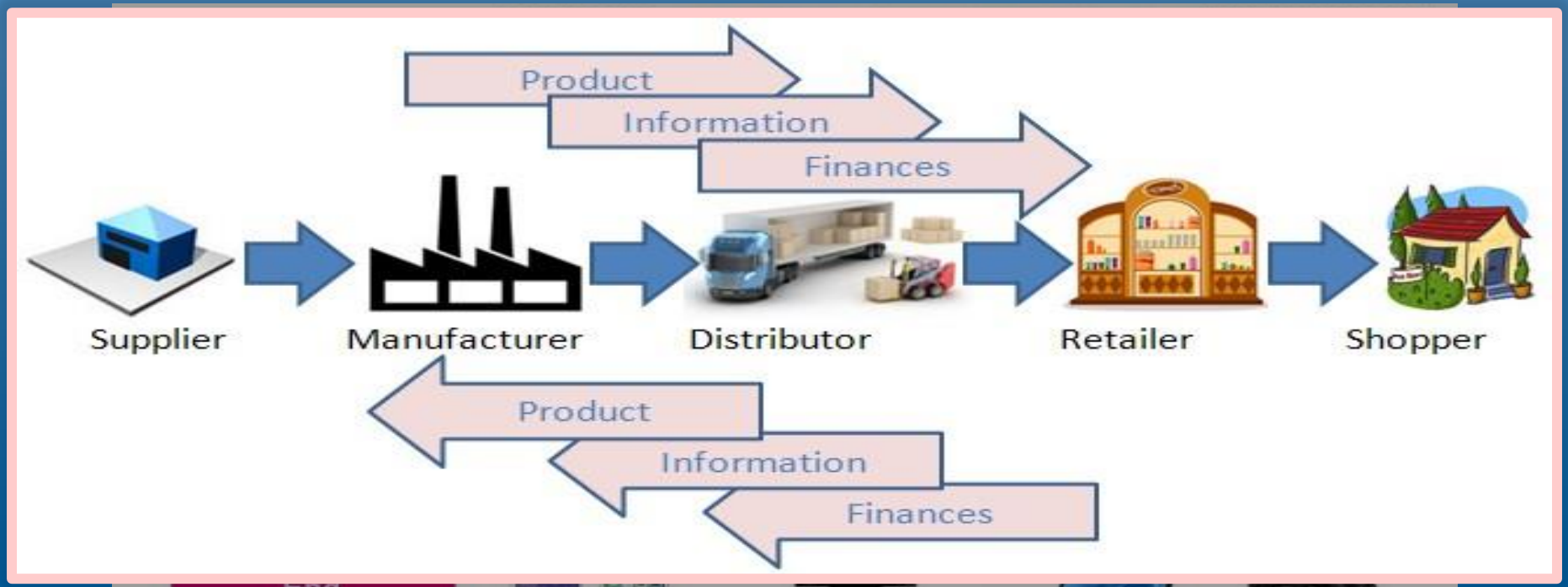
G+1 0

Fabless (no fabrication) IC (integrated circuit) techniques are gr
what will soon be required knowledge of the subject. Other book
control of the IC designing company. By contrast, this title reco
are those designed and marketed by one company but actually

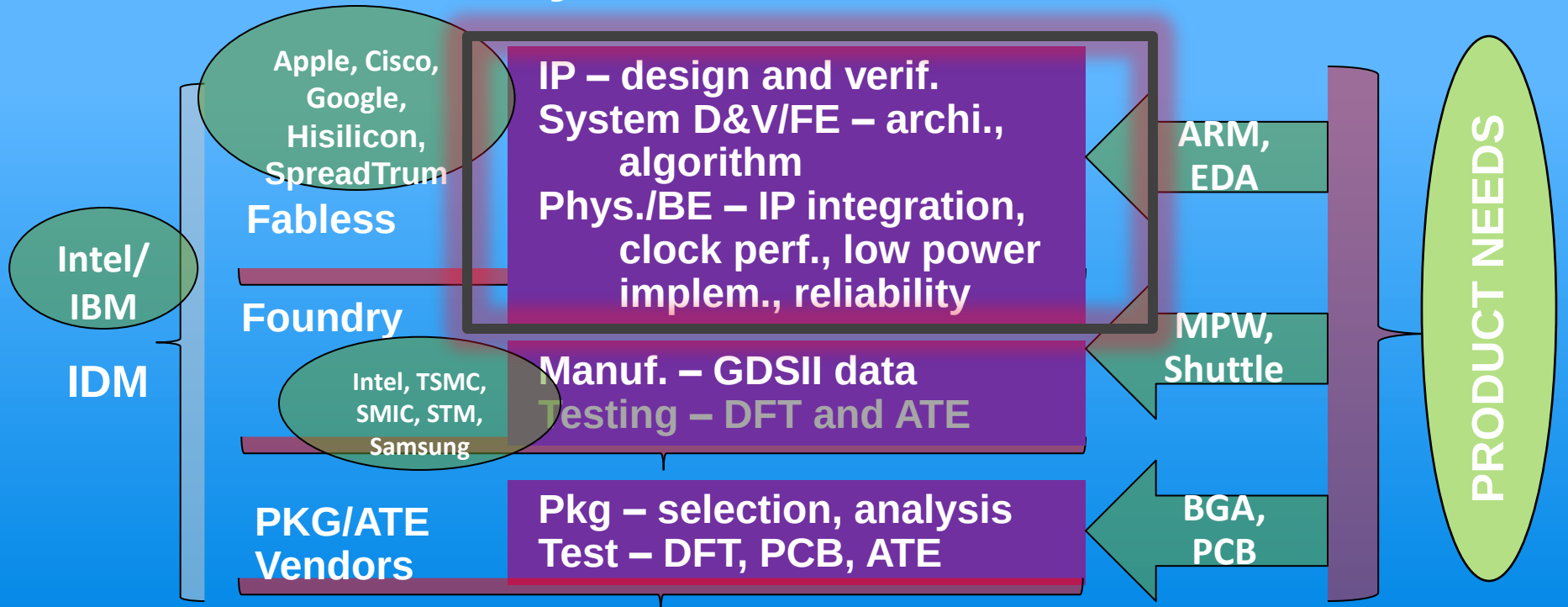
More »



Product Chain of Electronics



Fabless, Foundry and IDM



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

GSA/FSA (1994-, FSA→GSA 2007-)

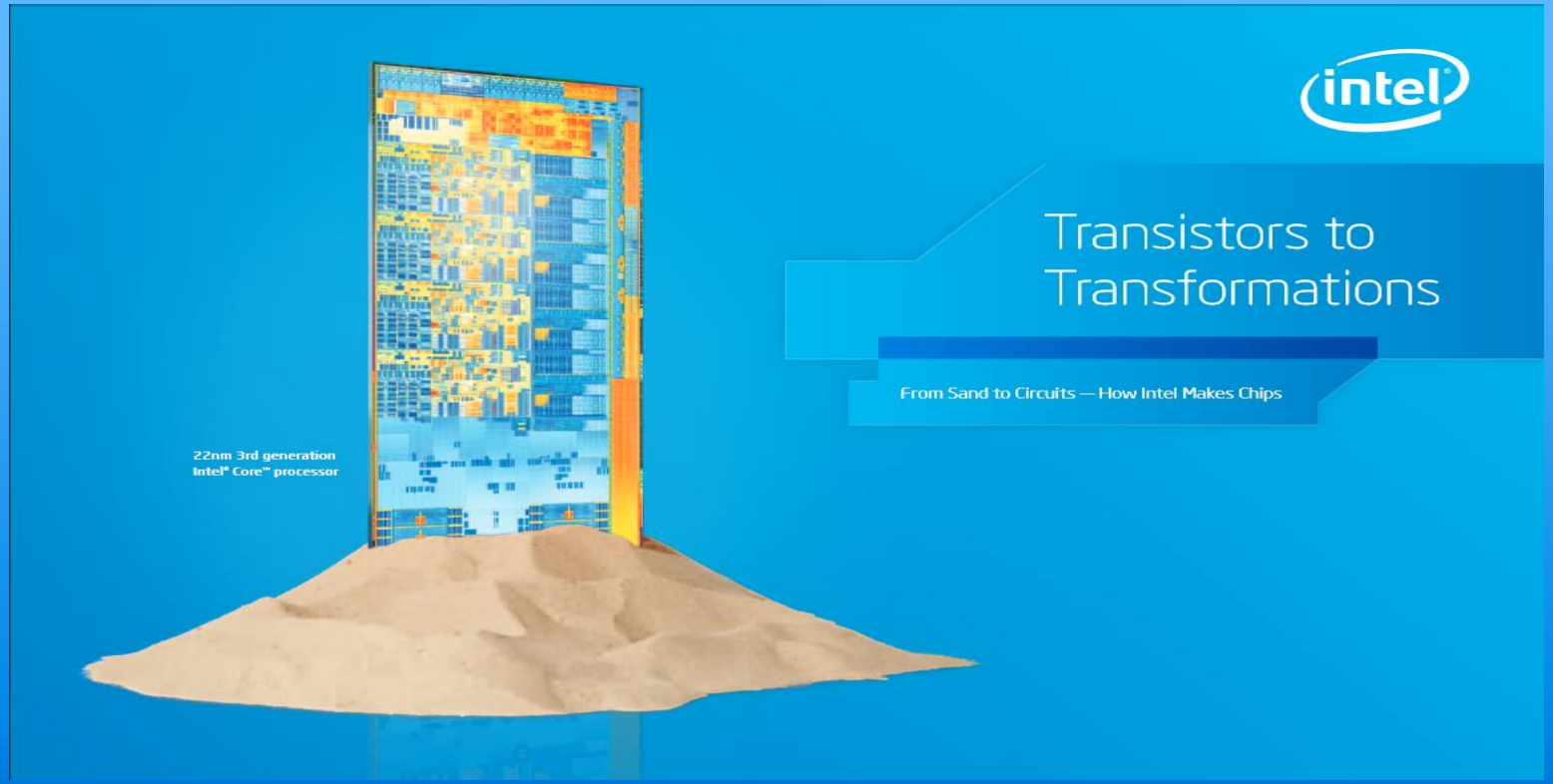
8 CEO at the 20th Anniversaries

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

IDM & IC Chain

- What is an IDM? Integrated Device Manufacturer, Fab/IC Manufacturer
- **Foundry/Fab Technology: Intel, TSMC, Samsung, STM**
- System & Fabless House: Intel, IBM, AMD, Qcom, HiSilicon
- IP Providers & Design Services: Arm, MIPS, Ceva
- Discussion: IC Product Chain

From Sand to Circuits



Sand to Circuit.PDF

How is the IC Chip made at the foundry

Six firms dominate 300-mm wafer fab capacity

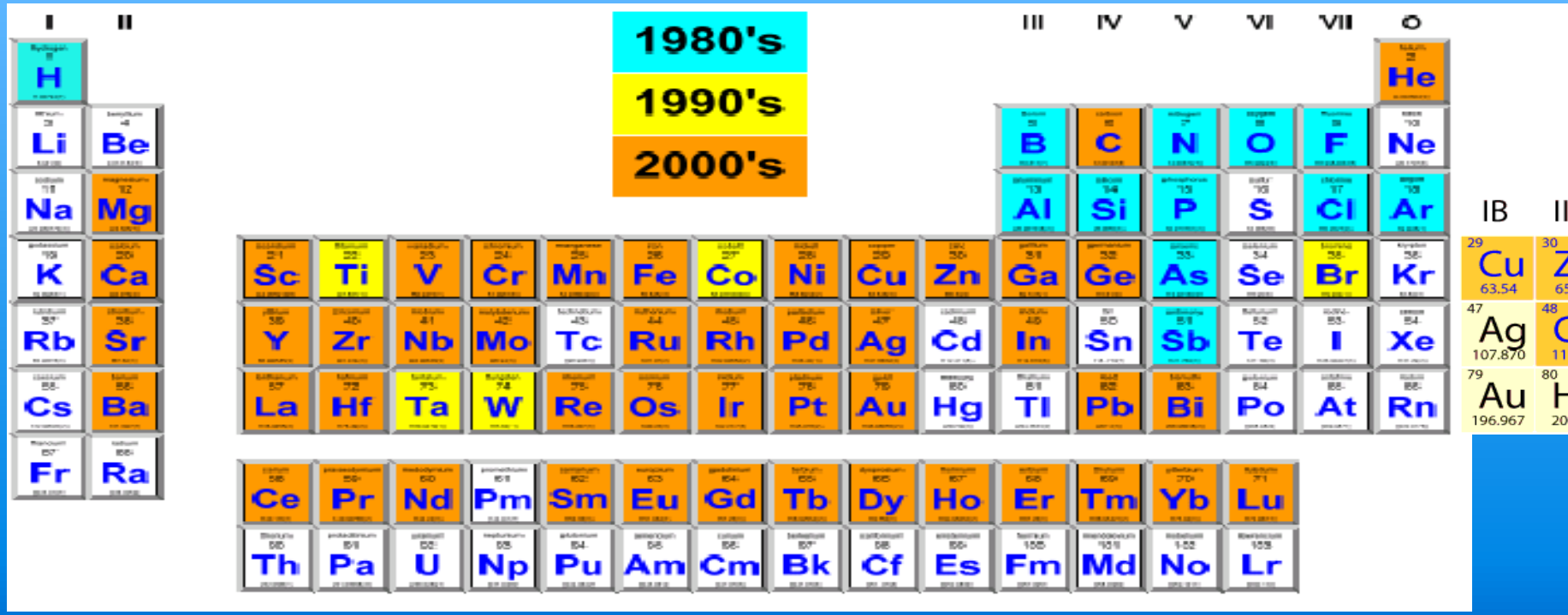
300mm Wafer Capacity Leaders Forecast
(Installed Monthly Capacity in 300mm Wafers x1000)

2013F Rank	Company	2012 Installed Capacity (K w/m)	2012 % of WW Total	2013F Installed Capacity (K w/m)	2013F % of WW Total
1	Samsung	675	18.8%	717	18.4%
2	Micron-Elpida*	512	14.3%	536	13.8%
3	SK Hynix	420	11.7%	450	11.6%
4	Intel	388	10.8%	441	11.3%
5	TSMC	356	9.9%	414	10.7%
6	Toshiba/SanDisk	320	8.9%	320	8.2%
7	GlobalFoundries	125	3.5%	150	3.9%
8	Nanya	125	3.5%	127	3.3%
9	UMC	97	2.7%	115	3.0%
10	Powerchip**	125	3.5%	90	2.3%
11	TI	51	1.4%	60	1.5%
12	SMIC	51	1.4%	57	1.5%
—	Top 12	3,245	90.4%	3,477	89.5%
—	Others	346	9.6%	410	10.5%
—	TOTAL	3,591	100%	3,887	100%

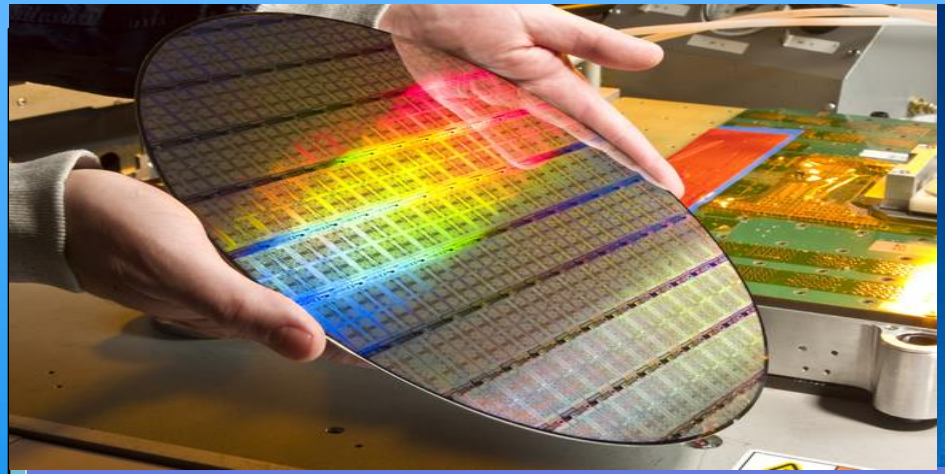
*Assumes Micron completes acquisition of Elpida in 1H13.
**Assumes Powerchip either sells or tears down its P3 fab as it plans to do.

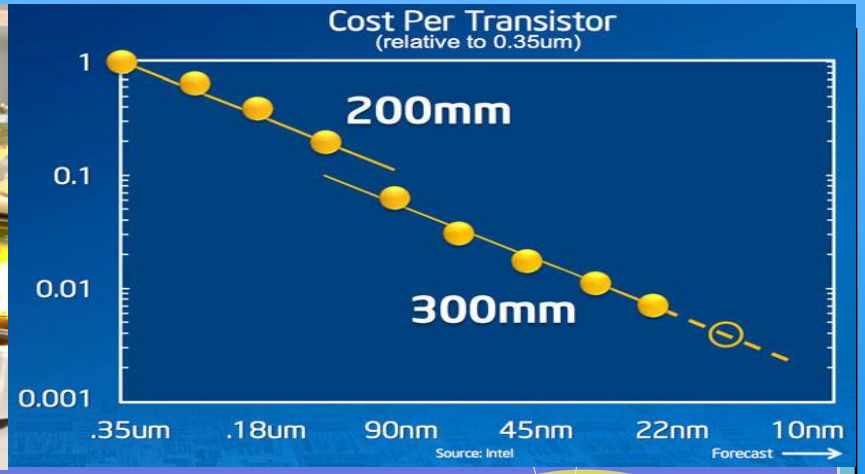
Source: Companies, IC Insights

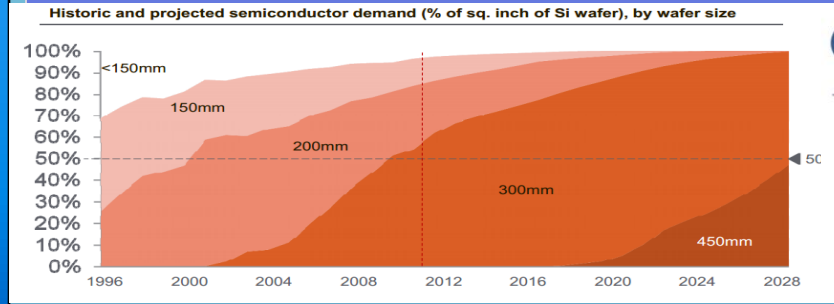
New Materials used in CMOS continuously

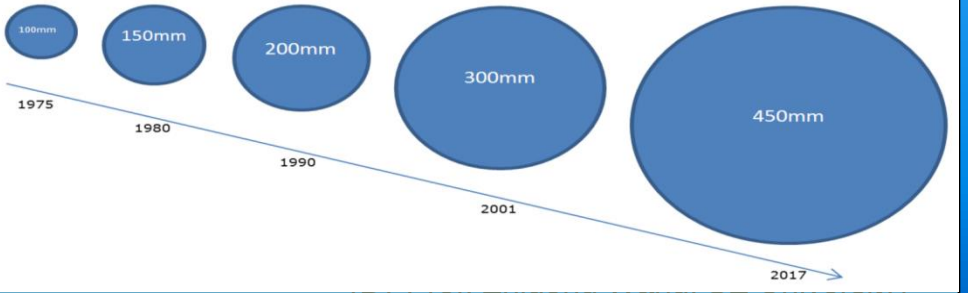


Feature Size and Wafer Size



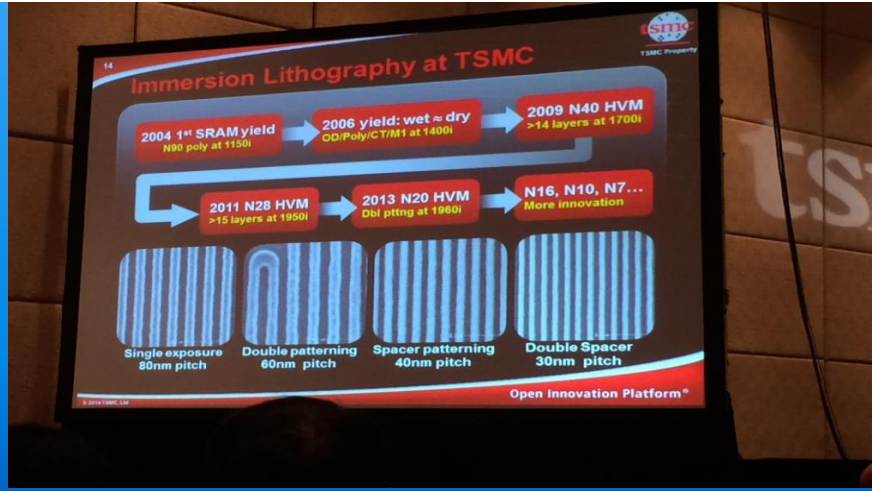




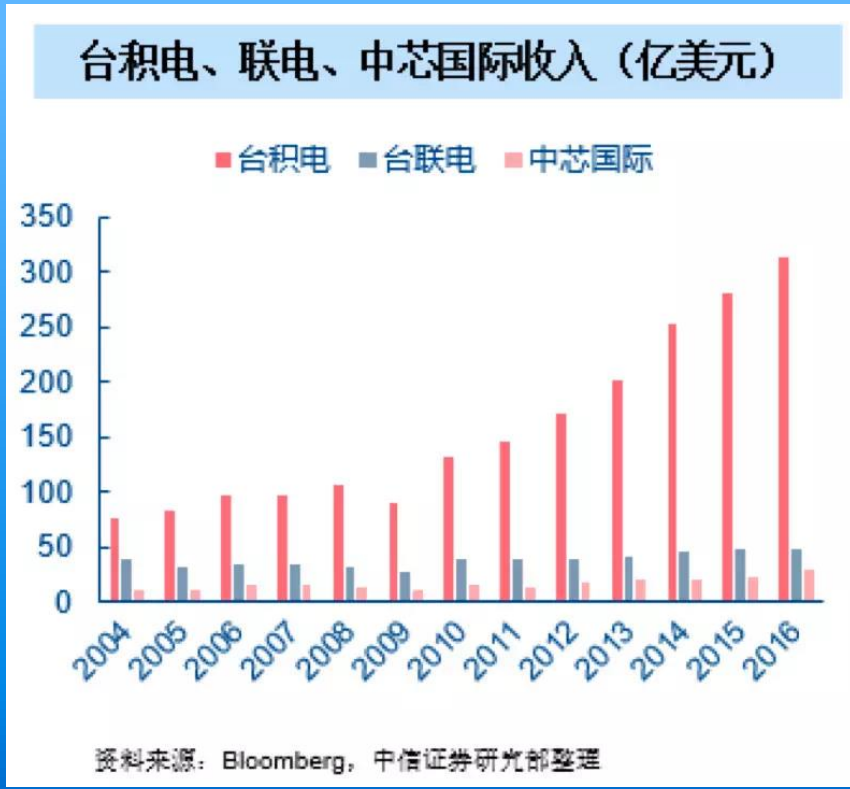


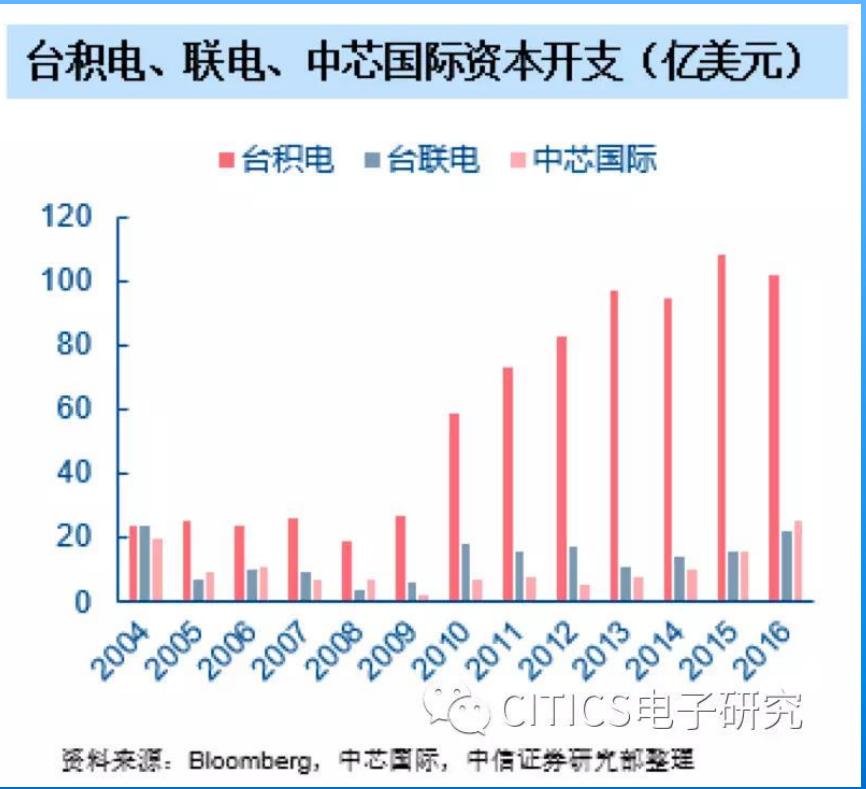
TSMC (1987-)
Fabless/FSA-GSA

- Immersion
- OIP: Open Innovation Platform
- CoWoS
  - Chip-On-Wafer-On-Substrate
- IP/EDA/Ref. Flow
- HKMG; Gate-last
- FinFET: 16FF→16FF+
- IoT
- Morris Zhang



TSMC, UMC, SMIC: Income & Expense



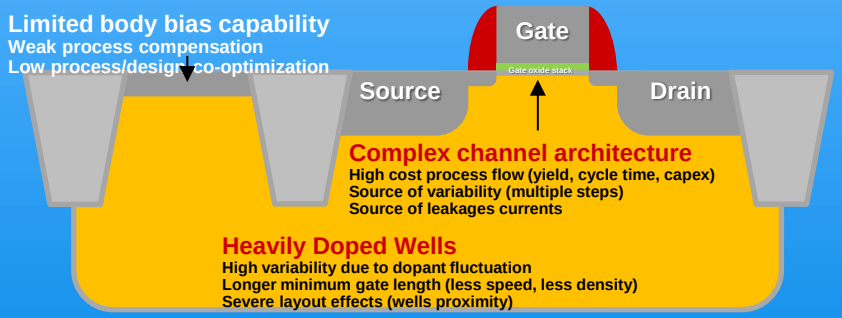


Samsung

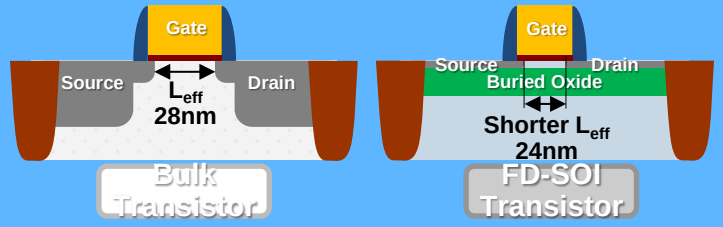
- 1974-1979: 1974, Samsung Electronics acquires Hankook Semiconductor
- 1980-1989: 1983, VLSI, 64Kb DRAM; 1988, 4Mb DRAM
- 1990-1999: 1992, Industry's first 64Mb DRAM; 1998, 128Mb Flash
- 2000-2009: 2005, DDR3; 2009, 40nm 2Gb DRAM
- 2010- : 2010, Industry's 32nm HKMG; 2016, 10nm FinFET SoC & 10nm DRAM

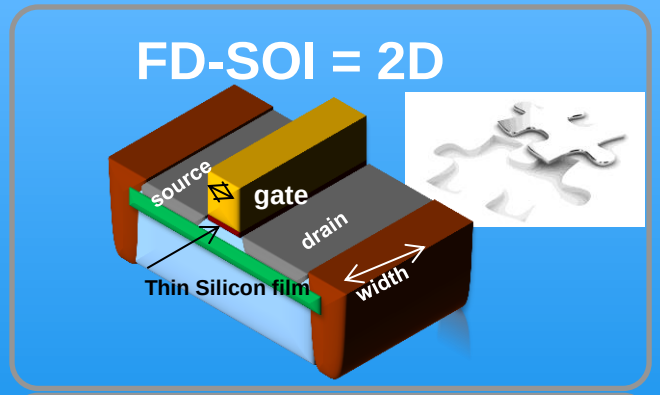
STM

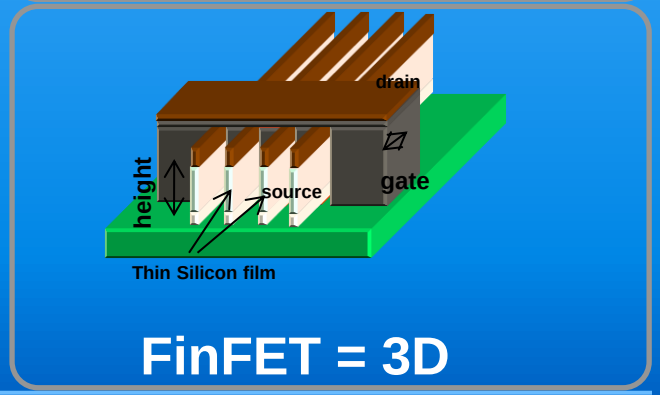
- FD-SOI vs Bulk CMOS (planar)
- FD-SOI vs FinFET



Depleted devices deliver improved electrostatic control and device scalability







GLOBALFOUNDRIES

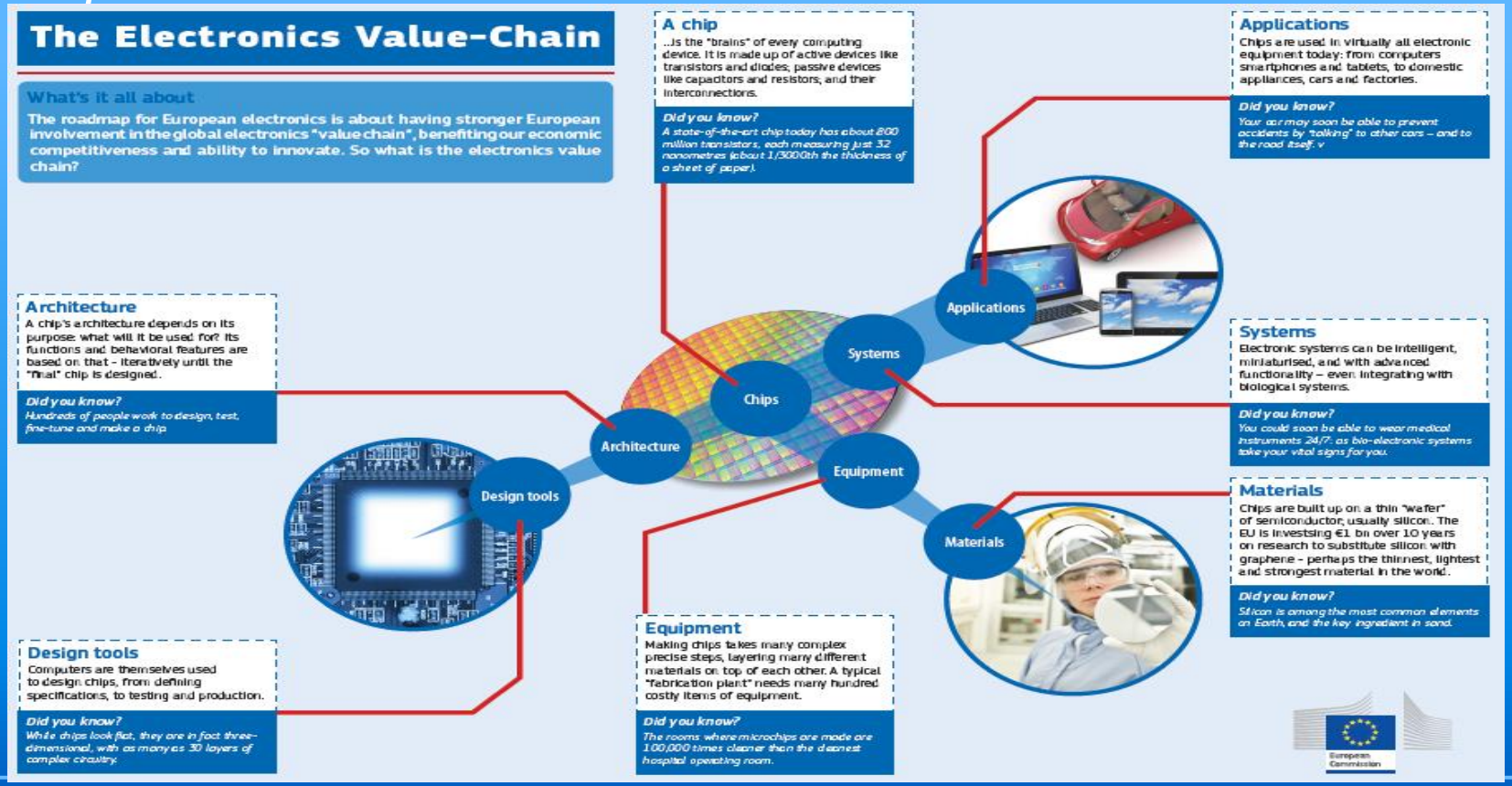
- 2009 span of AMD, ATIC of Abu Dhabi in UAE
- 2010, acquired Chartered Semiconductor, S'pore
- 22nm FD-SOI [w/ Samsung and STM]
- 14nm FinFET [Samsung]
- 2015: Microelectronics + $1.5B from IBM + 16,000 patents

12” Foundries in China

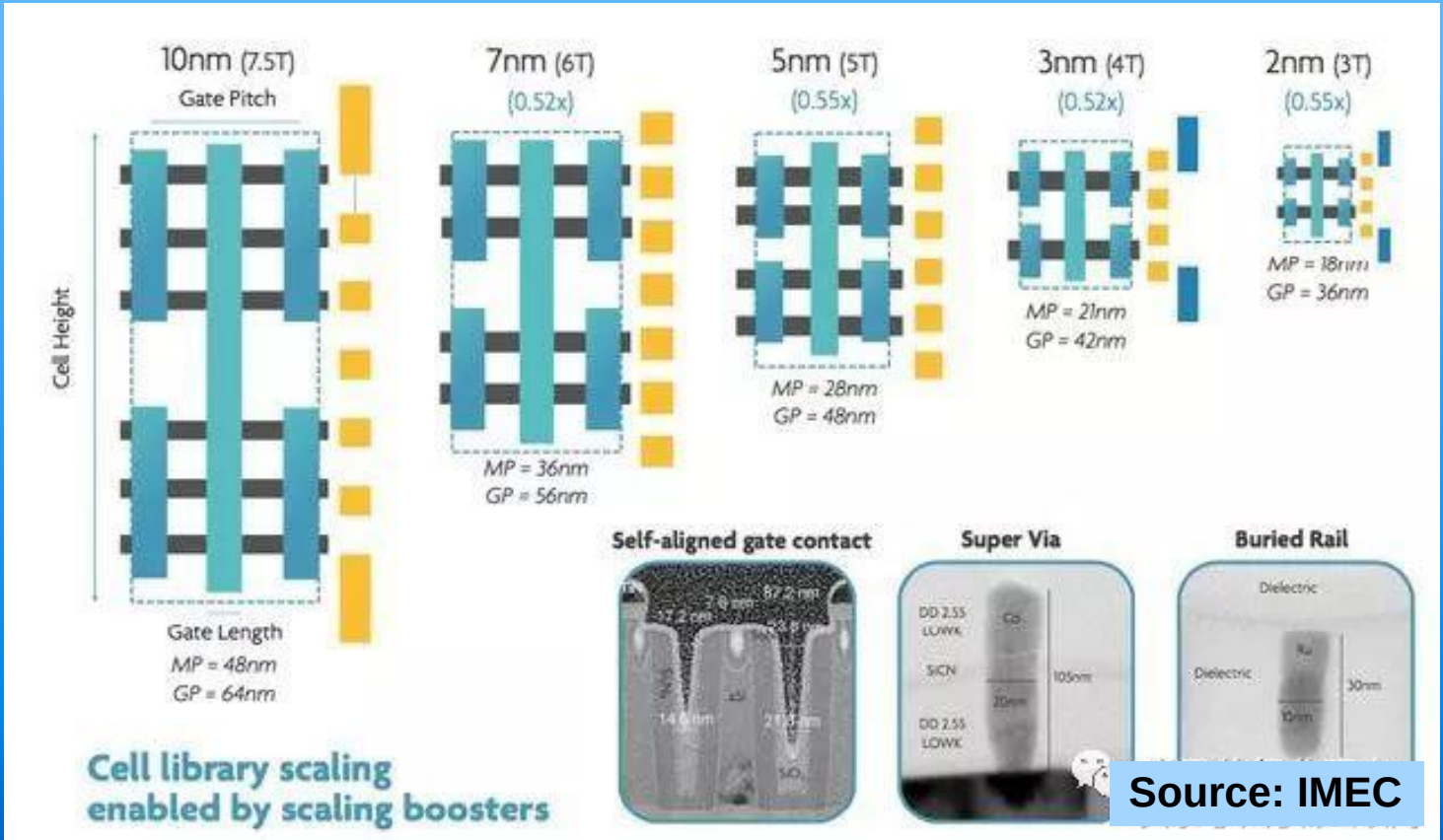
- SMIC-Shanghai; SMIC-Beijing 28nm in 2015
- Wuhan XMC: Flash Memory
- Intel Dalian: Internal Processors/Chips
- SK Hynix Wuxi: DRAM, NAND Flash
- Samsung Xi’an: 3D NAND
- UMC Xiamen: 2017
- Lijing (GF?) Hefei: 2017
- TSMC Nanajing: 28nm 2018

Foundry and Fabless

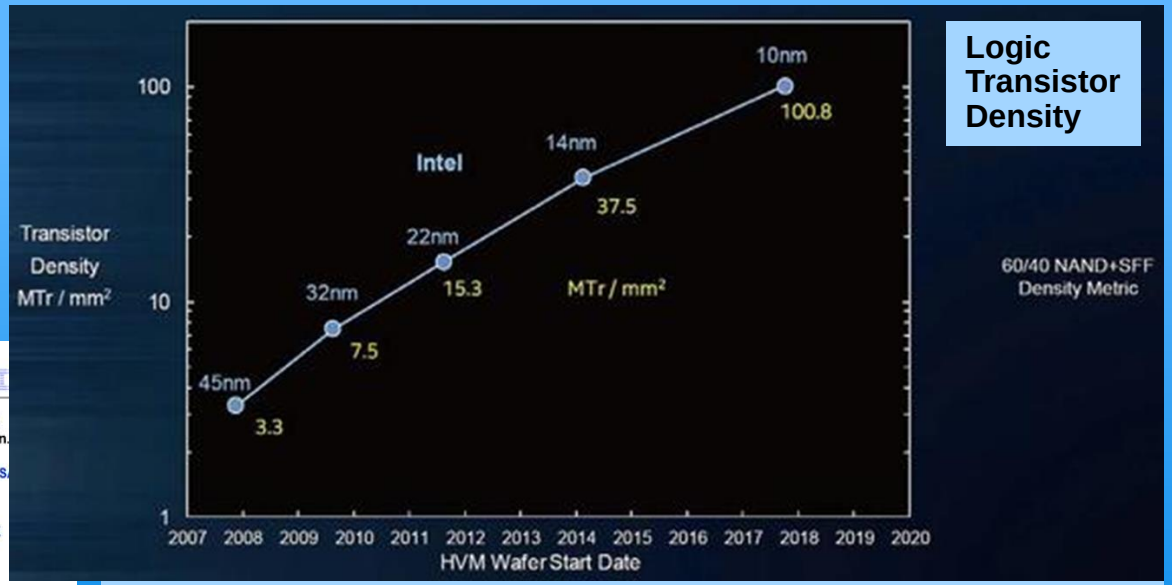
Competition at 22/14/10/7 nm



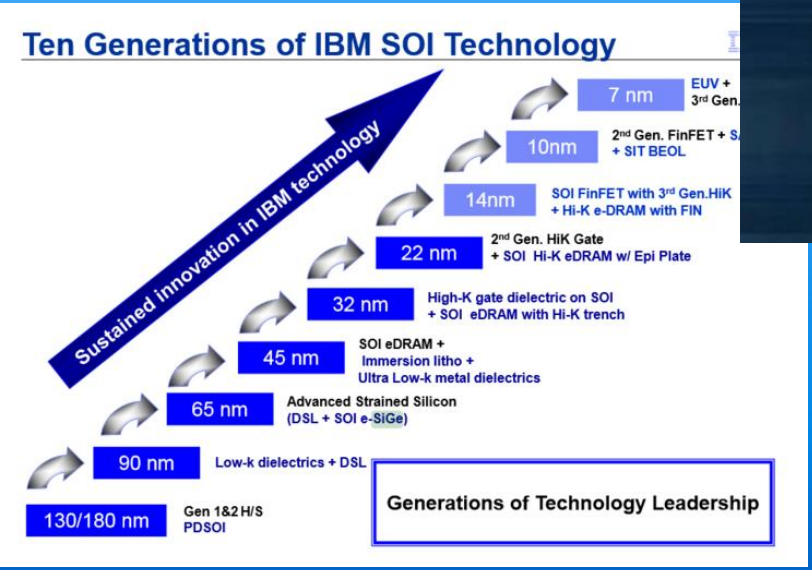
MP & GP in 10nm and Below



Transistor Density and Moore's Law



At 10nm, Transistor Density >100MTr/mm^2

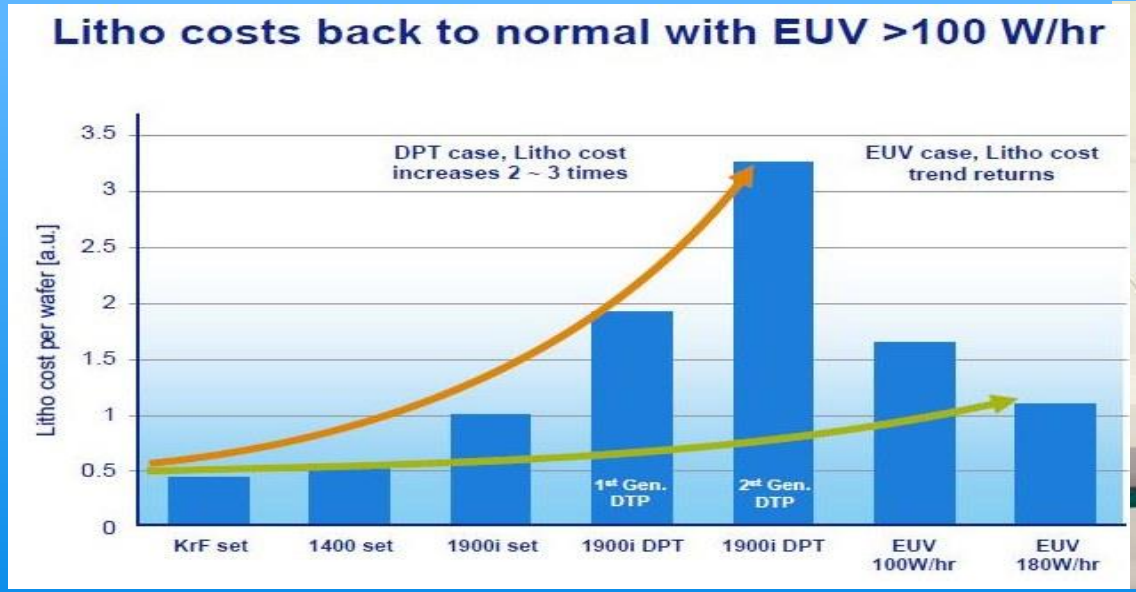


Shrinkage of Gate Length

Tech Node, nm	Intel	Samsung	TSMC	GF	UMC	ST	SMIC
Bulk 32/28	2010, 32nm, Core i7 980x	2011, 32nm, Exynos 4212	28nm Bulk CMOS	28nm	2010, 28nm HPC+	FD-SOI 28nm	28nm Bulk CMOS
22 G1 *Tri-Gate*	2011, Atom, First FinFET	N/A	N/A	22nm FD-SOI (22FDX)	N/A	FD-SOI 22nm (22FDX)	N/A
16 FinFET	N/A	N/A	201?, GTX 1000	N/A	N/A	?FD-SOI 16nm	N/A
14 G2 FinFET	37.3M/mm^2 XMM 7560	2016, Exynos8890, Snapdrogon820	N/A	2015, Apple A9	CPU/GPU		Planned
10 G3 FinFET	100.8 MTr/mm^2 Core i3	55.1 MTr/mm^2 Exynos 9810	?55 MTr/mm^2 Apple A11, 1H17	N/A			
7	Plan 2020	101.2 MTr/mm^2 2H18	<101.2 MTr/mm^2 2H18	<101.2 MTr/mm^2			
5	Planned 2017	2017, Test	Plan 1H19				

MTr: millian transistor

Can people still make 450mm wafer possible?



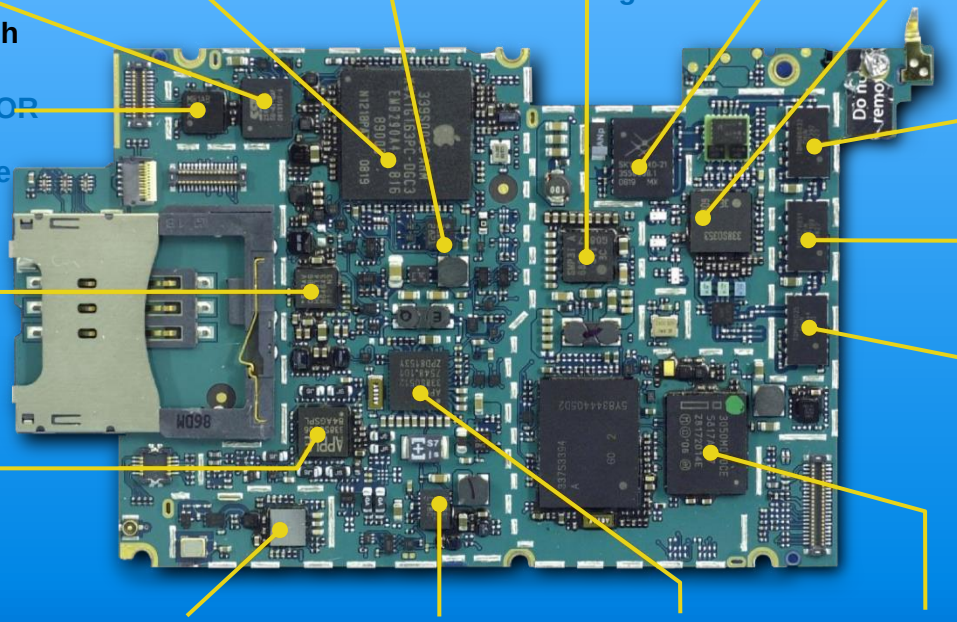
IDM & IC Chain

- What is an IDM? Integrated Device Manufacturer, Fab/IC Manufacturer
- Foundry/Fab Technology: Intel, TSMC, Samsung, STM
- **System & Fabless House: Intel, IBM, AMD, Qcom, HiSilicon**
- IP Providers & Design Services: Arm, MIPS, Ceva
- Discussion: IC Product Chain

Apple iPhone

an Integration of Digital and Analog SOC

Analog
Mixed
Signal
RF
MEMS

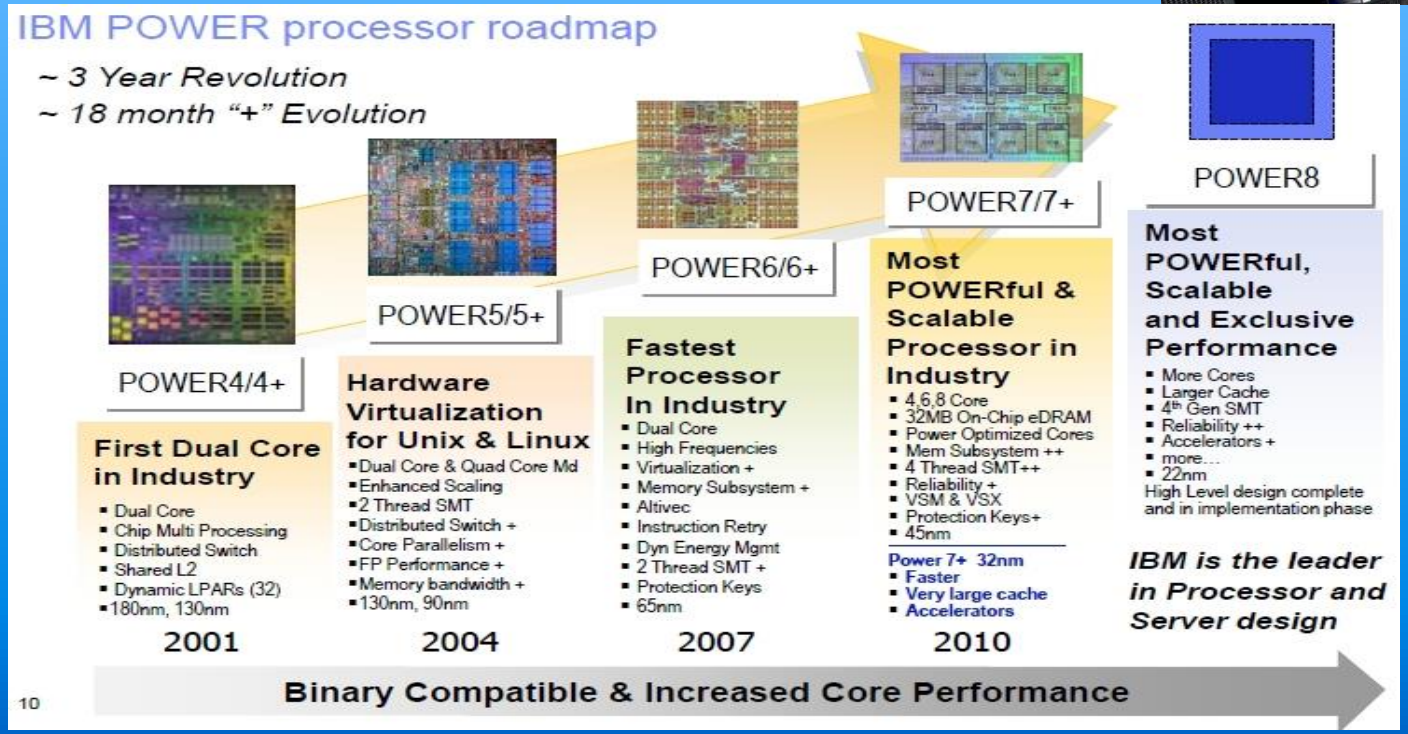


Source: Dr. Alberto Sangiovanni-Vincentelli

IBM/Lenovo

M= MACHINES

AIX Version 7.1



SoC vs. CPU

The battle for the future of computing

- **After more than 50 years at the top of the heap, the CPU finally has some competition from an upstart called the SoC. For decades, you could walk into a shop and confidently pick out a new computer based on its CPU — and now, everywhere you look, from smartphones to tablets and even some laptops, there are SoCs.**
- **Don’t worry, though, CPUs and SoCs are actually rather similar, and almost everything you know about CPUs can also be applied to SoCs.**
- **What is a CPU?**
- **What is an SoC?**

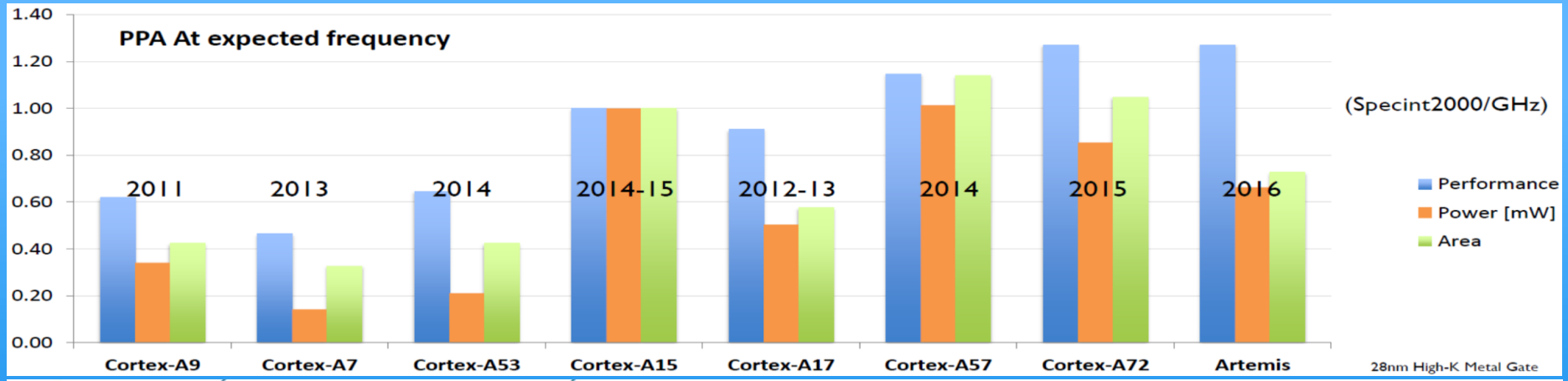
IDM & IC Chain

- What is an IDM? Integrated Device Manufacturer, Fab/IC Manufacturer
- Foundry/Fab Technology: Intel, TSMC, Samsung, STM
- System & Fabless House: Intel, IBM, AMD, Qcom, HiSilicon
- **IP Providers & Design Services: Arm, MIPS, Ceva**
- Discussion: IC Product Chain

Types of IP

- Design type
  - Digital, Analog, MS
  - PLL/DLL
- Function type
  - Library
  - Memory storage
  - Connectivity
  - MCU (IoT)
  - DSP (data)
  - CPU/GPU etc

ARM Holdings (1990-)



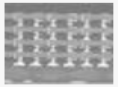
		Cortex-A53 MP4	Cortex-A17 MP4	Cortex-A57 MP4	Cortex-A72 MP4 mixed Vt	Artemis MP4 – uLVT
	L2 Cache Size [Area]	2MB	2MB	2MB	2MB	2MB
Perf	Frequency [GHz] SSG TT/V_{OD}	1.7 2.15	1.6~1.75 2.0~2.1	1.95 2.25	2.0 2.3	1.9~2.0 2.3
Power	Performance [SpecInt2k/GHz] [Specint2006/GHz]	500 3.8	640	780 6.0	816 6.7	820~840
	$P_{dynamic\ (1\ Core)}$ [mW/GHz]	73	~163	306	245	210~222
	P_{static} CPU / non-CPU L2 [mW]	29 / 22	51/ 37	89/ 77	65 / 45	65/ 47
Area	Core [mm²]	0.5	0.74	1.51	1.34	1.1~1.15
	Total Cluster [mm²]	4.8 (L2 ECC)	5.8 (no ECC) 6.4 (L2 ECC)	9.7 (L2 ECC)	7.6 (no ECC) 8.0 (L2 ECC)	7.0~7.2 (no L2 ECC)

16nm FF, Performance Tuned 9T uLVT20

IDM & IC Chain

- What is an IDM? Integrated Device Manufacturer, Fab/IC Manufacturer
- Foundry/Fab Technology: Intel, TSMC, Samsung, STM
- System & Fabless House: Intel, IBM, AMD, Qcom, HiSilicon
- IP Providers & Design Services: Arm, MIPS, Ceva
- **Discussion: IC Product Chain**

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.

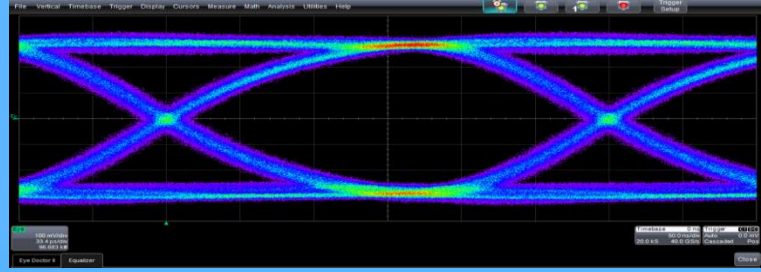
Flip Chip BGA (fcBGA)
Amkor Flip Chip BGA (fcBGA) packages are assembled around state-of-the-art, single unit laminate or ceramic substrates. Utilizing multiple high density routing layers, laser drilled blind, buried, and stacked vias, and ultra fine line/space metallization, fcBGA substrates have the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

ATE



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

- Automatic Test Equipment

EDA Vendors

EDA CONSORTIUM Where Electronics Begins™

- Cadence
- Mentor
- Synopsys

DESIGN AUTOMATION CONFERENCE 52
Sunday Jun 7th, 2015
to
Thursday Jun 11th, 2015

DATE 16
Monday Mar 14th, 2016
to
Friday Mar 18th, 2016

- Calypto
- SpyGlass
- ATopTech

DAC 2015
ATopTech CALYPTO SPYGLASS

Summary

- **Equipment Manufacturer:**
  - ASML
- **IC Manufacturer:**
  - TSMC, SMIC, ST
- **System Design House:**
  - Huawei,
- **IC Design House:**
  - SpreadTrum
- **Supply Partners:**
- **EDA Vendors:**

Summary

- Industrial Chain & Product Segments
- IDM, Foundry and GSA
- Sand to Silicon and 45/32 to 10/7 nm
- System & Fab, IP/DS and EDA