

SEMICONDUCTOR MARKET UPDATE

SESHA Symposium

Scottsdale, Arizona

April 18, 2017



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About IC Insights

IC Insights, Inc., based in Scottsdale, Arizona, is dedicated to providing high-quality, cost-effective market research for the semiconductor industry. Founded in 1997, IC Insights offers coverage of global economic trends, the semiconductor market forecast, capital spending and fab capacity trends, product market details, and technology trends, as well as complete IC company profiles and evaluations of end-use applications driving demand for ICs.

IC Insights Products & Services

The McCLEAN REPORT

A Complete Analysis and Forecast of the Integrated Circuit Industry

IC MARKET DRIVERS

A Study of Emerging and Major End-Use Applications Fueling Demand for ICs

O-S-D REPORT

A Market Analysis and Forecast for Optoelectronics, Sensors, and Discretes

STRATEGIC REVIEWS

Extensive Profiles of the World's IC Manufacturers and Fabless Suppliers

GLOBAL WAFER CAPACITY

A Thorough Examination of the IC Industry's Wafer Fab Capacity

Additional Information

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Your Trusted Source for Semiconductor Market Research Analysis





Presentation Outline

- **IC Market Status and Forecast**
- **Applications Driving IC Market Growth**
- **Technology Trends**

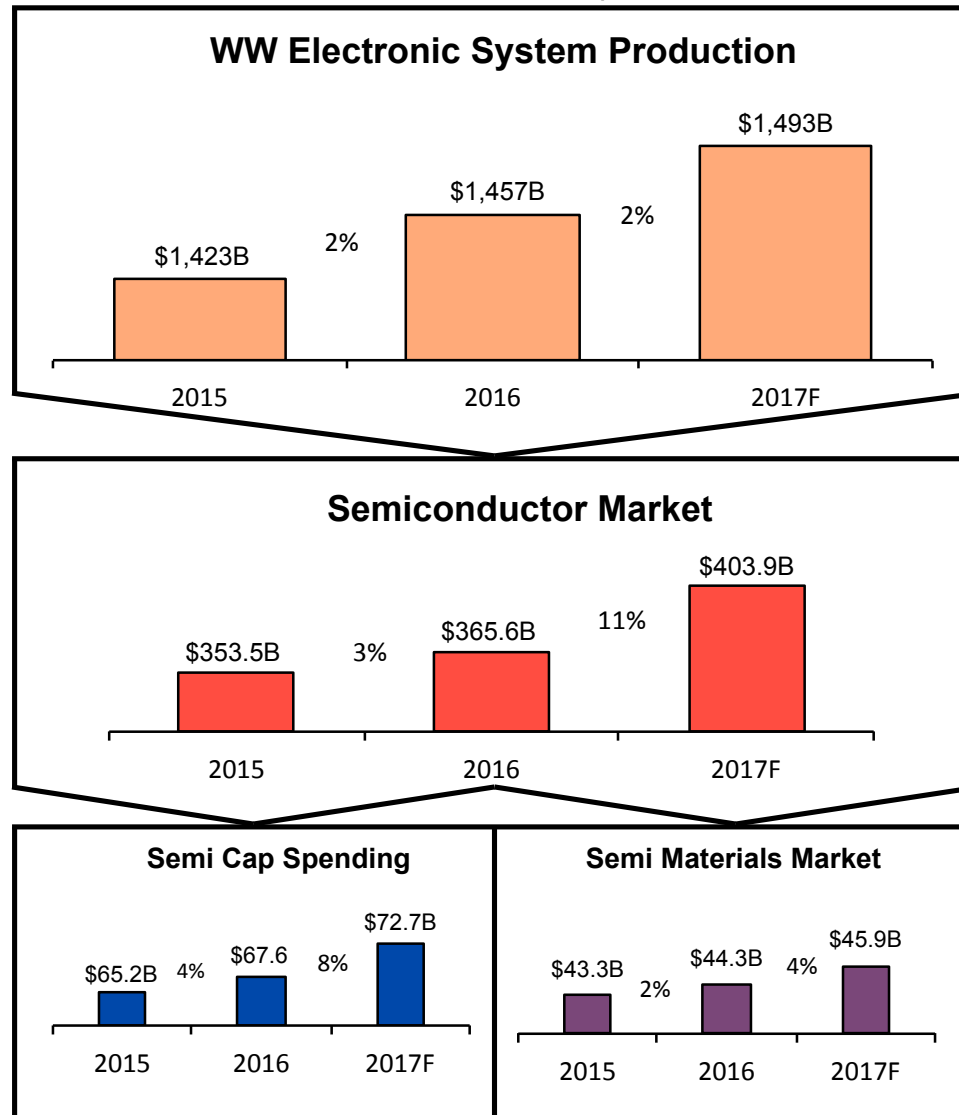


IC Market Status and Forecast



Electronic Industry Interdependence

2016 Worldwide GDP = \$80.4 Trillion



Source: IC Insights



Worldwide GDP Breakdown (2015-2017F)

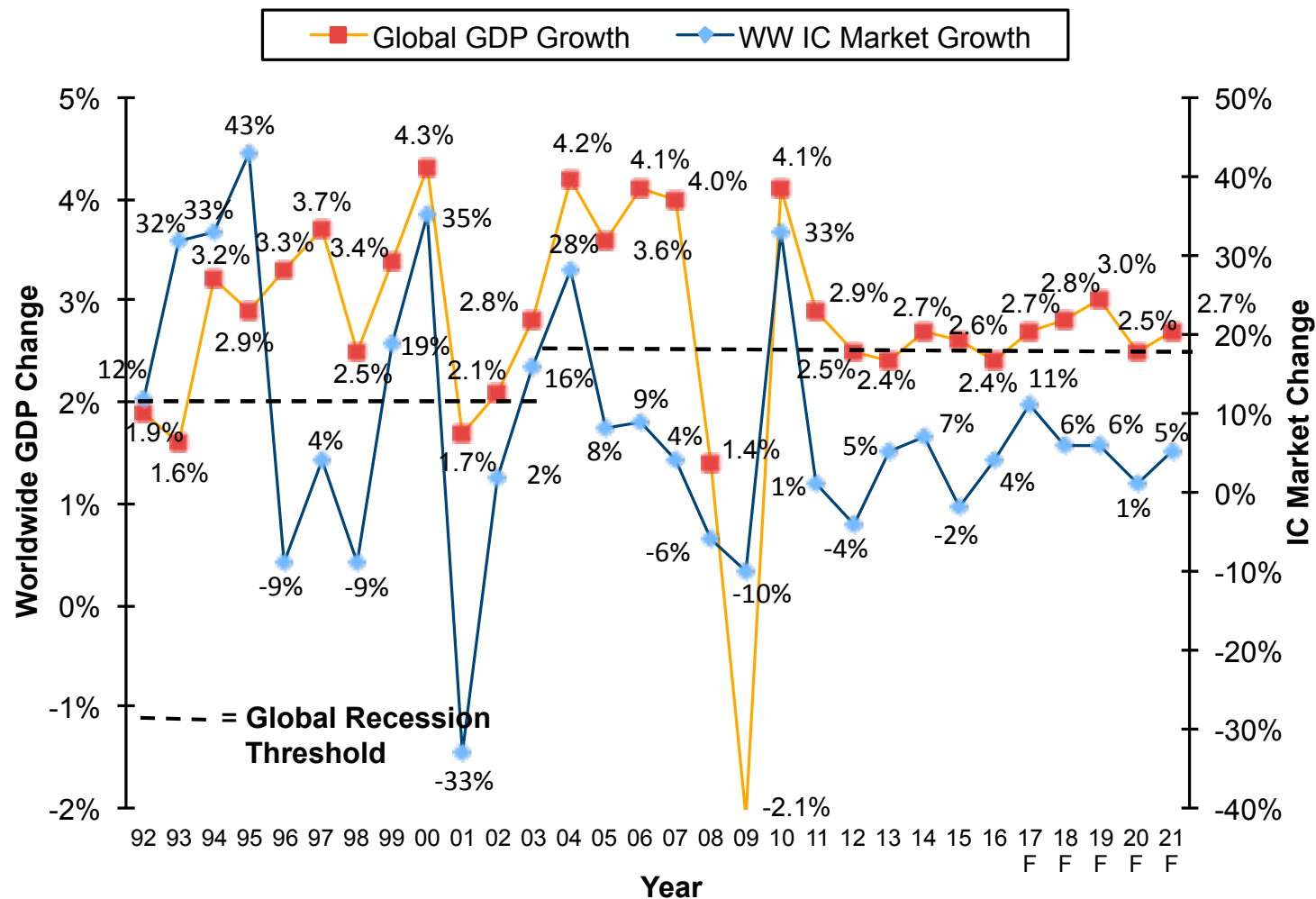
Country/Region	2015 GDP Growth %	2015 GDP (\$ Trillions)	2015 (% of Total)	2016 GDP Growth %	2016 GDP (\$ Trillions)	2016 (% of Total)	2017F GDP Growth %	2017F GDP (\$ Trillions)	2017F (% of Total)
High Income Countries/Region									
U.S.	2.6%	17.39	22.1%	1.6%	17.67	22.0%	2.2%	18.06	21.9%
Eurozone	2.0%	12.51	15.9%	1.7%	12.72	15.8%	1.5%	12.91	15.6%
Japan	1.2%	6.11	7.8%	1.0%	6.17	7.7%	0.9%	6.23	7.5%
U.K.	2.2%	2.65	3.4%	2.0%	2.70	3.4%	1.5%	2.74	3.3%
Canada	0.9%	1.88	2.4%	1.3%	1.90	2.4%	1.9%	1.94	2.4%
Other	2.0%	11.86	15.1%	1.9%	12.09	15.0%	2.2%	12.35	15.0%
Total High Income	2.1%	52.40	66.7%	1.6%	53.25	66.2%	1.8%	54.23	65.7%
Developing Countries	4.0%	26.12	33.3%	4.0%	27.16	33.8%	4.3%	28.33	34.3%
Worldwide Total	2.6%	78.52	100.0%	2.4%	80.42	100.0%	2.7%	82.57	100.0%
China*	6.9%	10.18	13.0%	6.7%	10.86	13.5%	6.5%	11.57	14.0%
India*	7.6%	2.25	2.9%	7.3%	2.41	3.0%	7.0%	2.58	3.1%
Brazil*	-3.8%	2.26	2.9%	-3.4%	2.18	2.7%	0.4%	2.19	2.7%

*Included in Developing Countries

Source: World Bank, IMF, IC Insights



1992-2021F IC Market Growth versus Worldwide GDP Growth



Source: IC Insights



Semiconductor Industry Supply Base Changes

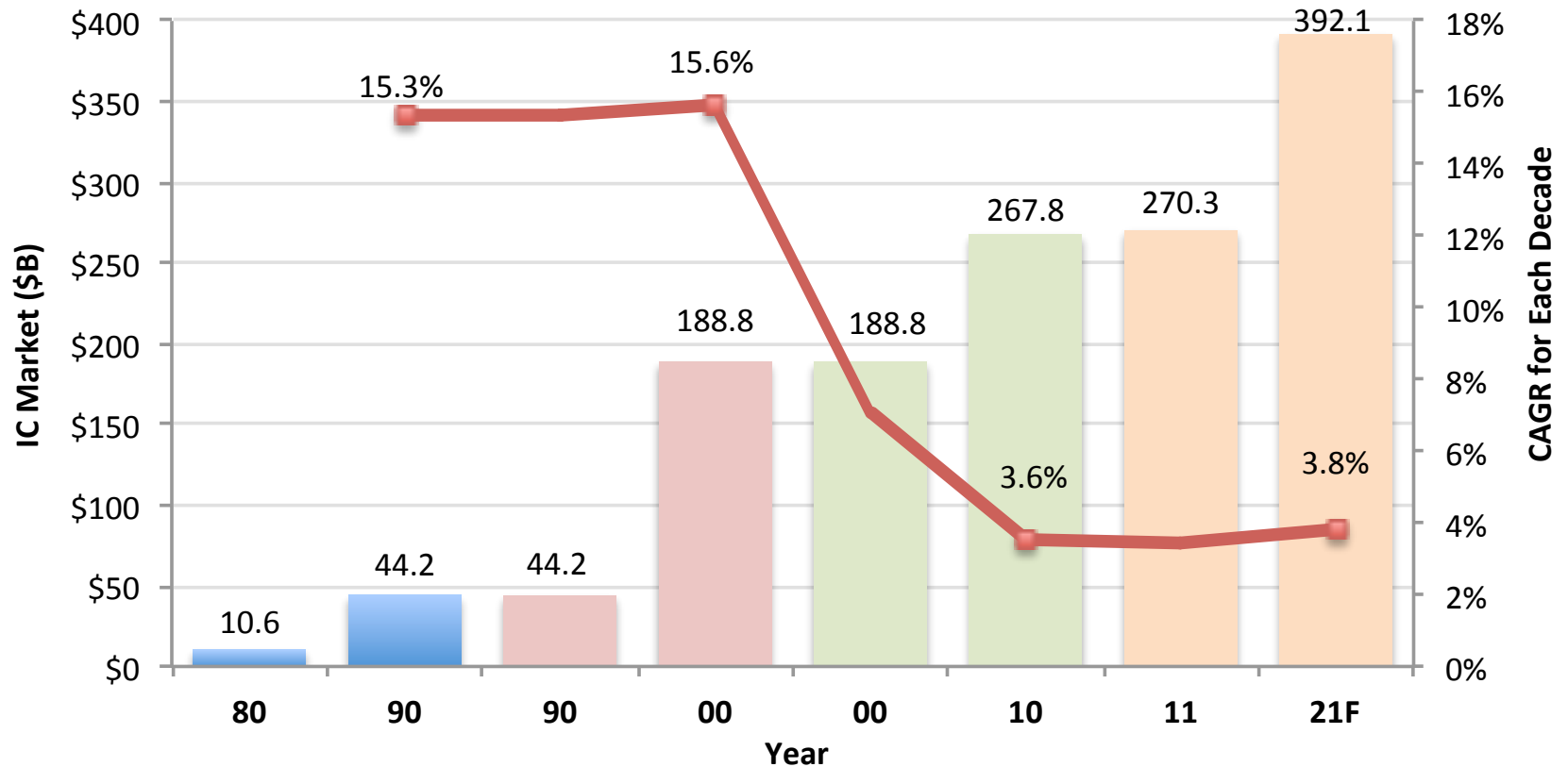
Changes spurring semiconductor market maturity:

- **With few entry-point opportunities (e.g., MPUs, foundry, flash memory, etc.), the IC industry has been closed to new major IC manufacturing startups since the early 2000s** — It remains to be seen if the new Chinese memory companies are able to gain traction in the future.
- **Fab-lite foundry movement** — Will lead to less overspending for fabrication capacity.
- **Capex as a percent of sales budgets** — After averaging 25% in the late 1990s, the ratio is forecast to decline to 17-20% in the 2010s.
- **Fewer manufacturers and suppliers helps lessen oversupply** — The IC industry is forecast to go from 58 manufacturers currently using 200mm wafers to about 23 using 300mm wafers to less than 10 using 450mm wafers (if they are adopted at all). Moreover, increased M&A activity will serve to lessen competitive pressures in the future.

Source: IC Insights

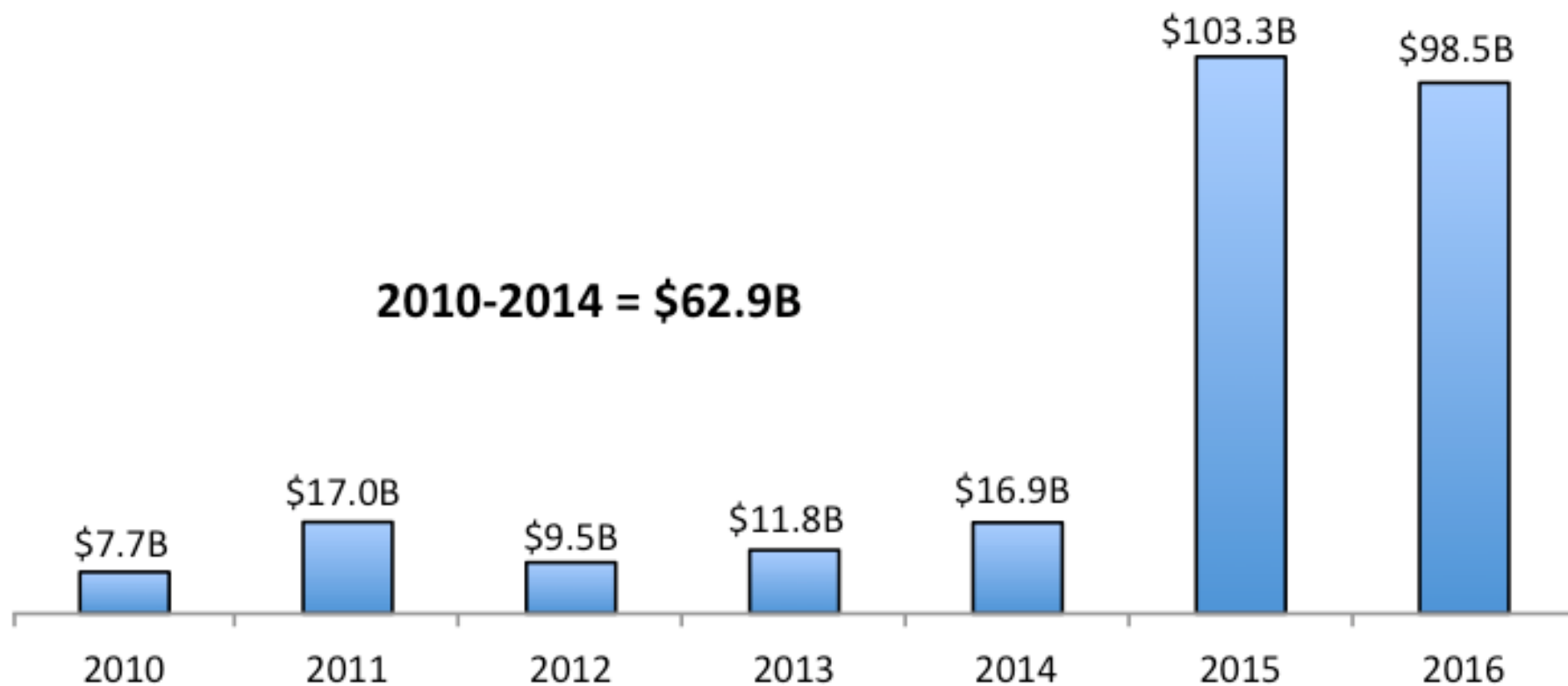


IC Market Growth Dramatically Slower (CAGRs for Period)





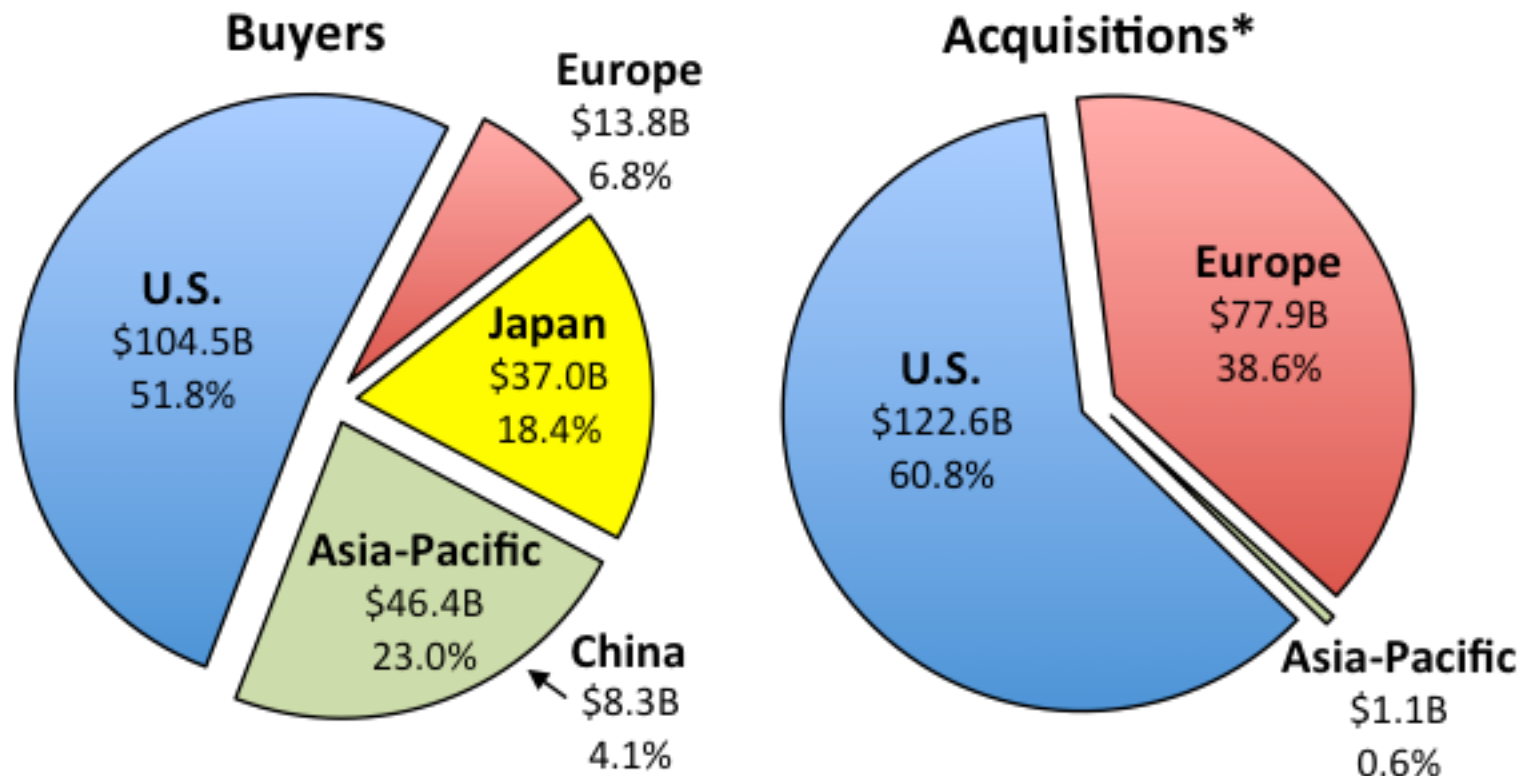
Value of Semiconductor M&A Agreements



Source: IC Insights



Regional Breakdown of 2015-2016 M&A Wave



*One 2015 acquisition agreement in Japan was for a 300mm fab at \$157 million, or < 0.1% of the total.

Source: IC Insights



Biggest Semiconductor Acquisition Agreements

Ranking	Acquisition-Buyer (Year Announced)	Price Tag (\$B)
1	NXP by Qualcomm (2016)	\$39.0
2	Broadcom by Avago (2015)	\$37.0
3	ARM by SoftBank (2016)	\$32.0
4	SanDisk by Western Digital (2015)	\$19.0
5	Freescale by U.S Investment Companies (2006)	\$17.6
6	Altera by Intel (2015)	\$16.7
7	Linear Technology by Analog Devices (2016)	\$14.8
8	Freescale by NXP (2015)	\$11.8
9	Burr Brown by TI (2000)	\$7.6
10	LSI by Avago (2013)	\$6.6
11	National Semiconductor by TI (2011)	\$6.5
12	ATI by AMD (2006)	\$5.4
13	Spansion by Cypress (2014)	\$5.0
14	Agere by LSI (2006)	\$4.0
15	Chartered by GlobalFoundries (2009)	\$3.9
16	Mstar by MediaTek (2012)	\$3.8
17	NetLogic by Broadcom (2011)	\$3.7
18	Atmel by Micrel (2015)	\$3.4
19	Intersil by Renesas (2016)	\$3.2
20	Atheros by Qualcomm (2011)	\$3.1
21	International Rectifier by Infineon (2014)	\$3.0
22	NXP Std. Products by Chinese investors (2016)	\$2.75
23	Elpida by Micron Technology (2012)	\$2.5
-	PMC-Sierra by Microsemi (2015)	\$2.5
-	CSR by Qualcomm (2014)	\$2.5
26	Fairchild by ON Semiconductor (2015)	\$2.4
27	Level One by Intel (1999)	\$2.2

Source: Companies, IC Insights



Top 10 Worldwide Semiconductor Sales Leaders Excluding Foundries (\$B)

Rank	1990		1995		2000		2006		2016		2016 (1)	
1	NEC	4.8	Intel	13.6	Intel	29.7	Intel	31.6	Intel	57.0	Intel	57.0
2	Toshiba	4.8	NEC	12.2	Toshiba	11.0	Samsung	19.7	Samsung	44.3	Samsung	44.3
3	Hitachi	3.9	Toshiba	10.6	NEC	10.9	TI	13.7	Qualcomm (2)	15.4	Qualcomm/NXP	24.9
4	Intel	3.7	Hitachi	9.8	Samsung	10.6	Toshiba	10.0	Broadcom (2)	15.2	Broadcom (2)	15.2
5	Motorola	3.0	Motorola	8.6	TI	9.6	ST	9.9	SK Hynix	14.9	SK Hynix	14.9
6	Fujitsu	2.8	Samsung	8.4	Motorola	7.9	Renesas	8.2	Micron	13.5	Micron	13.5
7	Mitsubishi	2.6	TI	7.9	ST	7.9	Hynix	7.4	TI	12.5	TI	12.5
8	TI	2.5	IBM	5.7	Hitachi	7.4	Freescall	6.1	Toshiba	10.9	Toshiba	10.9
9	Philips	1.9	Mitsubishi	5.1	Infineon	6.8	NXP	5.9	NXP	9.5	MediaTek (2)	8.8
10	Matsushita	1.8	Hyundai	4.4	Philips	6.3	NEC	5.7	MediaTek (2)	8.8	Infineon	7.3
Top 10 Total (\$B)		31.8	86.3		108.1		118.2		202.1		209.3	
Semi Market (\$B)		54.3	154		218.6		265.5		365.6		365.6	
Top 10 % of Total Semi		59%	56%		49%		45%		55%		57%	

Source: IC Insights

(1) Ranking with merged Qualcomm and NXP

(2) Fabless



IC Insights' IC Market Forecast Assumptions for 2017

Factors	<9% IC Market Growth	9% to 13% IC Market Growth	>13% IC Market Growth
Worldwide GDP Growth	<2.5% Growth	2.5%-2.9% Growth	>2.9% Growth
Developing Market Economies GDP Growth	<4.1% Growth	4.1%-4.5% Growth	>4.5% Growth
IC Capacity Utilization	<88% Utilization	88%-90% Utilization	>90% Utilization
IC Unit Volume Shipments	<4% Growth	4%-8% Growth	>8% Growth
Worldwide Electronic System Sales (\$)	<1% Growth	1%-3% Growth	>3% Growth
IC ASP Change	<4% Increase	4%-6% Increase	>6% Increase
Foreign Currency/U.S. Dollar Exchange Rate	Extremely Deflationary	Slightly Deflationary	Neutral
Negative "Event" (e.g., major terrorist attack, earthquake, etc.)	One or More	None	None
IC Insights' Forecasted Probability of Occurrence	10%	70%	20%

Source: IC Insights



Largest IC Product Categories, 2017F

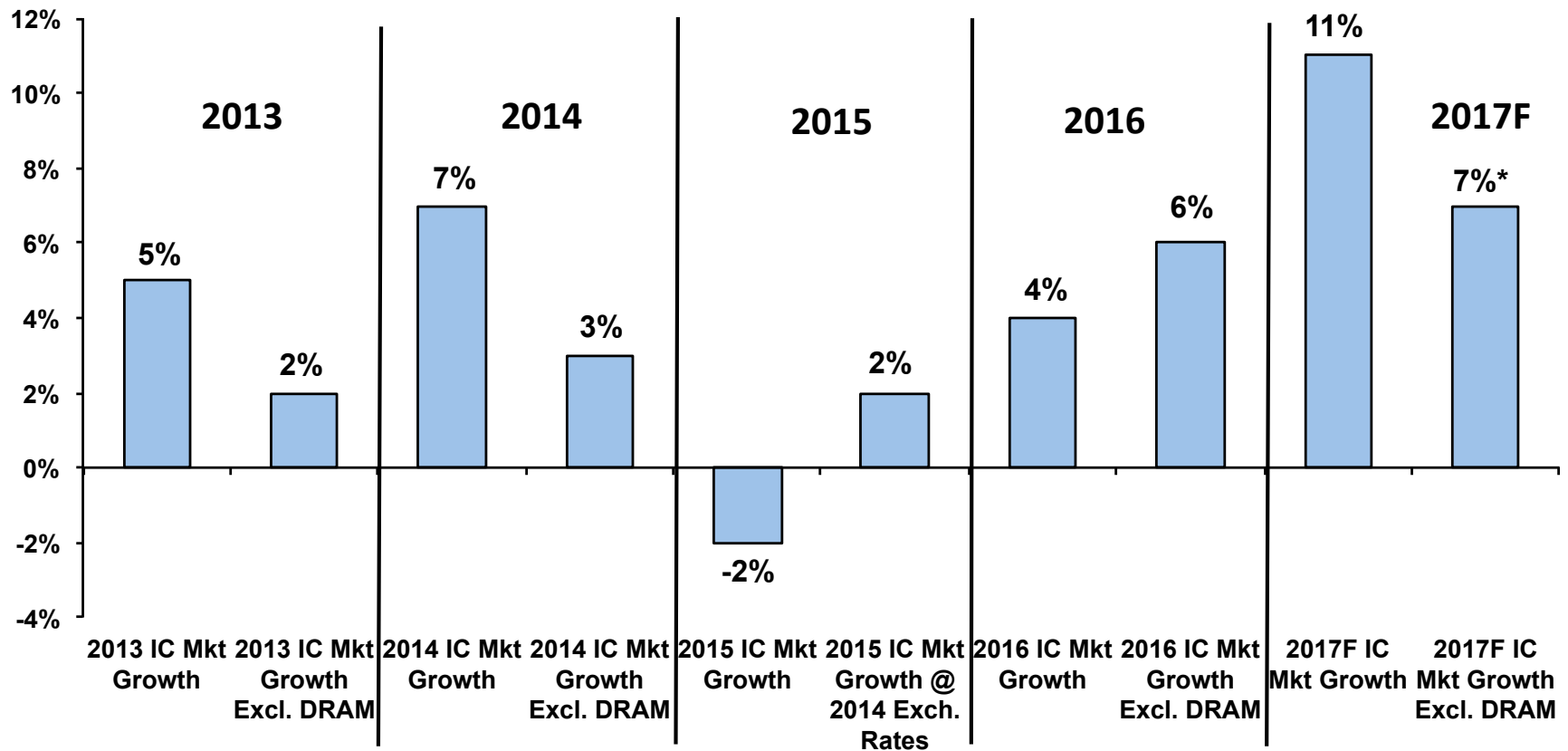
Rank	Market	\$B
1	DRAM	\$57,320
2	Std PC, Server MPU	\$47,100
3	NAND Flash	\$43,207
4	Wireless Comm—Spcl Purp Logic	\$24,311
5	Computer and Periph—Spcl Purp Logic	\$21,116

Rank	Shipments	Units, M
1	Power Management Analog	58,318
2	Wireless Comm—App Specific Analog	19,200
3	DRAM	15,760
4	Industrial—App Specific Analog	13,821
5	Automotive—App Specific Analog	13,343

Source: IC Insights



Recent Major Impacts on Worldwide IC Market Growth (\$)

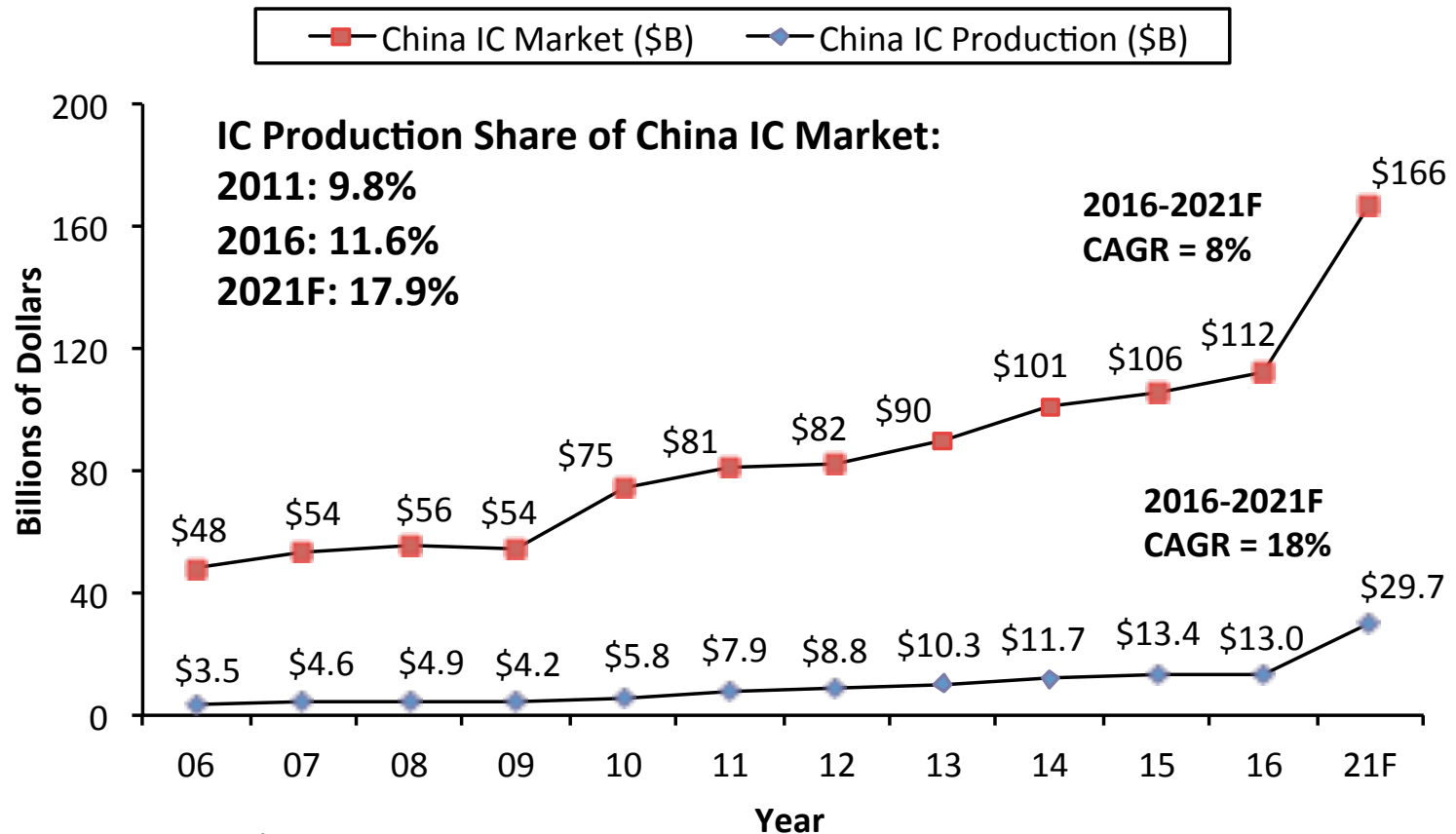


Source: IC Insights

*4% when excluding DRAM & NAND flash



China IC Market vs. China IC Production Trends



Source: IC Insights



Major IC Manufacturers in China

2016 Rank	Company	2010 IC Sales (\$M)	2011 IC Sales (\$M)	2012 IC Sales (\$M)	2013 IC Sales (\$M)	2014 IC Sales (\$M)	2015 IC Sales (\$M)	2016 IC Sales (\$M)	Products	2021 IC Sales (\$M, Fcst)
1	SK Hynix*	2,040	2,450	2,360	3,200	4,040	4,100	3,680	DRAM	5,500
2	SMIC**	1,555	1,320	1,542	1,962	1,970	2,236	2,914	Foundry	5,100
3	Samsung*	0	0	0	0	270	2,370	2,725	3D NAND Flash	6,100
4	Hua Hong Semi	0	0	571	585	665	650	721	Foundry	1,000
5	TSMC*	263	366	470	510	550	590	635	Foundry	1,500
6	Intel*	30	1,865	2,380	2,650	2,710	1,830	520	3D NAND Flash	2,700
7	Shanghai Huali	0	0	70	210	295	370	460	Foundry	1,100
8	CR Micro	259	213	179	165	180	190	205	Foundry/Std ICs	290
9	Diodes-BCD	119	125	139	155	170	180	200	Foundry/Std ICs	275
10	XMC**	0	0	160	150	165	175	205	Foundry/3D NAND	1,300
11	ASMC	145	147	135	117	130	119	120	Foundry	140
—	HeJian***	223	208	215	0	0	0	0	Foundry	0
—	Others	1,211	1,211	590	575	590	605	625	—	4,700
—	Total Chinese IC Production	\$5,845	\$7,905	\$8,811	\$10,279	\$11,735	\$13,415	\$13,010	—	\$29,705
—	WW IC Market (\$B)	\$267.8	\$270.3	\$259.3	\$271.9	\$291.6	\$286.9	\$297.7	—	\$392.1
—	Chinese Companies' Share of WW IC Market	2.18%	2.92%	3.40%	3.78%	4.02%	4.68%	4.37%	—	7.58%

*China fab production only.

** XMC's sales listed separately from SMIC starting in 2012.

***Merged with UMC beginning in 2013.

Source: IC Insights' *Strategic Reviews* database,
CCID, CSIA, PwC



The Three Phases of China's IC Industry Strategy

Phase	Approach	Timeframe Initiated	Successful?
1	Build a strong indigenous pure-play foundry industry	Late 1990s - Early 2000s	No
2	Build a strong presence in the fabless IC supplier space	Early 2000s - Mid 2000s	No
3	Build a strong China-based IC supplier/manufacturer base with startups, acquisitions, and mergers	Mid 2010s - Late 2010s	????

Source: IC Insights



Issues Regarding China's Semiconductor Industry Initiatives (Part 1)

- **"Made in China 2025" Initiative** —Seeks to boost China's self-sufficiency rate in semiconductors from <20% in 2015 to 40% in 2020 and 70% in 2025. (Anything less than 100% is not self-sufficient)
- **ZTE Situation** —The semiconductor trade embargo placed on ZTE by the U.S. government in March 2016, for shipping communications systems to Iran, increased China's resolve to become more self-sufficient in semiconductors. (ZTE paid a record fine of \$900 million to settle the case in March 2017)
- **No Apparent Cohesive Strategy** — China's Phase 3 company acquisitions and targets appear to be following a "shotgun" approach.
- **U.S. and China History of Espionage** — Given the mutual distrust, there is very little chance that the U.S. government will allow future acquisitions of U.S.-based semiconductor companies by Chinese entities. Tsinghua's offer for Micron was a "wakeup call" to U.S. government agencies. The 1Q17 report by the U.S. government made its opinion on this topic public.

Source: IC Insights



Important Issues Regarding China's Semiconductor Industry Initiatives (Part 2)

- **Taiwan "Pushback"** — In June of 2016, Morris Chang, Chairman of TSMC, said that in order to protect intellectual property, Chinese companies should not get board seats in Taiwanese companies in which they invest. Chinese offers to purchase 25% shares of Taiwan-based OSAT suppliers Powertech, ChipMOS, and SPIL all fell through from lack of support from the Taiwan government.
- **Opportunity Fades** — With many governments on "high alert" with regard to China's semiconductor industry ambitions, the "window of opportunity" for major acquisitions has closed.
- **Legal Issues Loom** — IC Insights believes it will be almost impossible to develop new DRAM and 3D NAND flash technology without infringing on numerous patents. Chinese companies also must be careful about hiring employees away from existing IC producers in China (i.e., the 2003-2005 TSMC/SMIC example).
- **Money isn't Everything** — All of the newly announced IC fabs to be constructed by indigenous Chinese companies will be at least one generation behind the leading technology when they come online.

Massive investment to have no significant impact on leading-edge IC technology for many years.

Without technology, China's IC industry goals are likely to fall short.

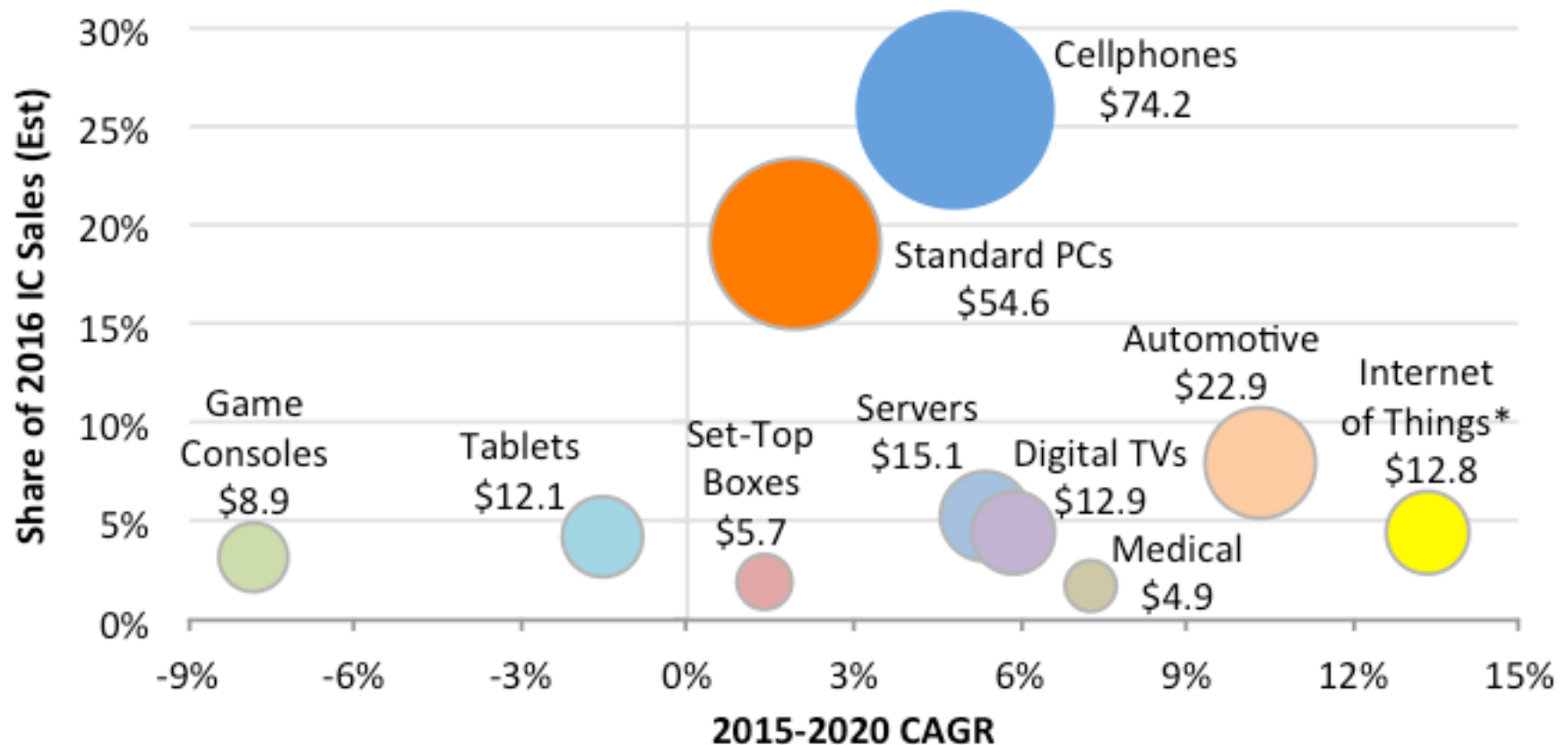
Source: IC Insights



Applications Driving IC Market Growth



IC End-Use Markets (\$B) and Growth Rates



*Covers only the Internet connection portion of systems.

Source: IC Insights



Trends Shaping Semiconductor Growth In Automobiles

Vehicle Production	Drivers for semiconductor content per car		
	CO2 reduction	Advanced safety	Comfort, premium
• New car shipments growing ~2%/yr • More growth in Western Europe, China • Electro-mobility gaining momentum, especially in China	• Driven by legislation • Improvements to electric steering, electric pumps, and electric motors • Adoption of EV/HEV	• 2015-2020: assisted driving (automatic braking, blindspot detection) • 2020-2025: automated driving in specific situations (parking, highway) • 2025-2030: autonomous driving	• Premium, luxury cars are early adopters of high-end comfort and safety features • Tech trickles down to mid- and low-range cars more quickly

ADAS/autonomous • Connectivity • Advanced security

Source: Infineon



The Intelligent Car

(Almost) as Smart as You

Car owners and buyers want the latest technologies in their vehicles—safety is key.

Collision Avoidance

60% of roadway collisions could be avoided with half a second's warning.
90% of roadway collisions could be avoided with a full second's warning.

Intelligent Maintenance

Local analytics could be applied to thousands of on-board sensors to flag abnormal events and take corrective action. Data then sent to automakers for deeper insight into trends across the entire fleet.

Data Everywhere

Connected cars to generate 11 petabytes of data annually by 2020. Intelligent cars could collect data from each other, the cloud, and the transportation infrastructure to keep drivers safe.

Smart Traffic Environments

Smarter traffic management could reduce vehicle wait time by 40% and travel time by 26%.
Smart lights, road, and signs that display or communicate relevant location-based data.

Vehicle-to-Vehicle Communication

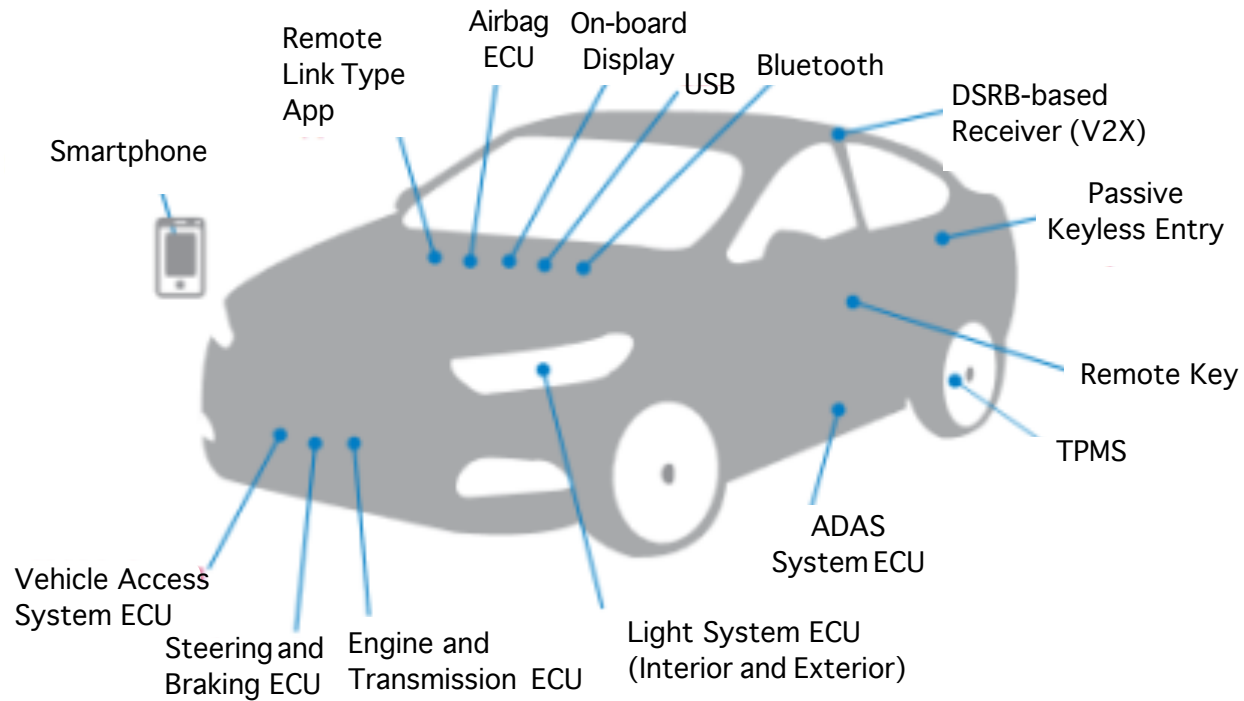
Intelligent cars have the potential to reduce 79% of crashes by exchanging information about location, speed, and direction.

- 69% of new car buyers would like to use a semi-autonomous lane-keeping system.
- 63% of new car buyers would like to use car-to-car communications.
- 63% of new car buyers would welcome a fatigue warning device in their vehicles.

Source: Intel Corp.



15 of the Most Hackable and Exposed Points on a Connected Car

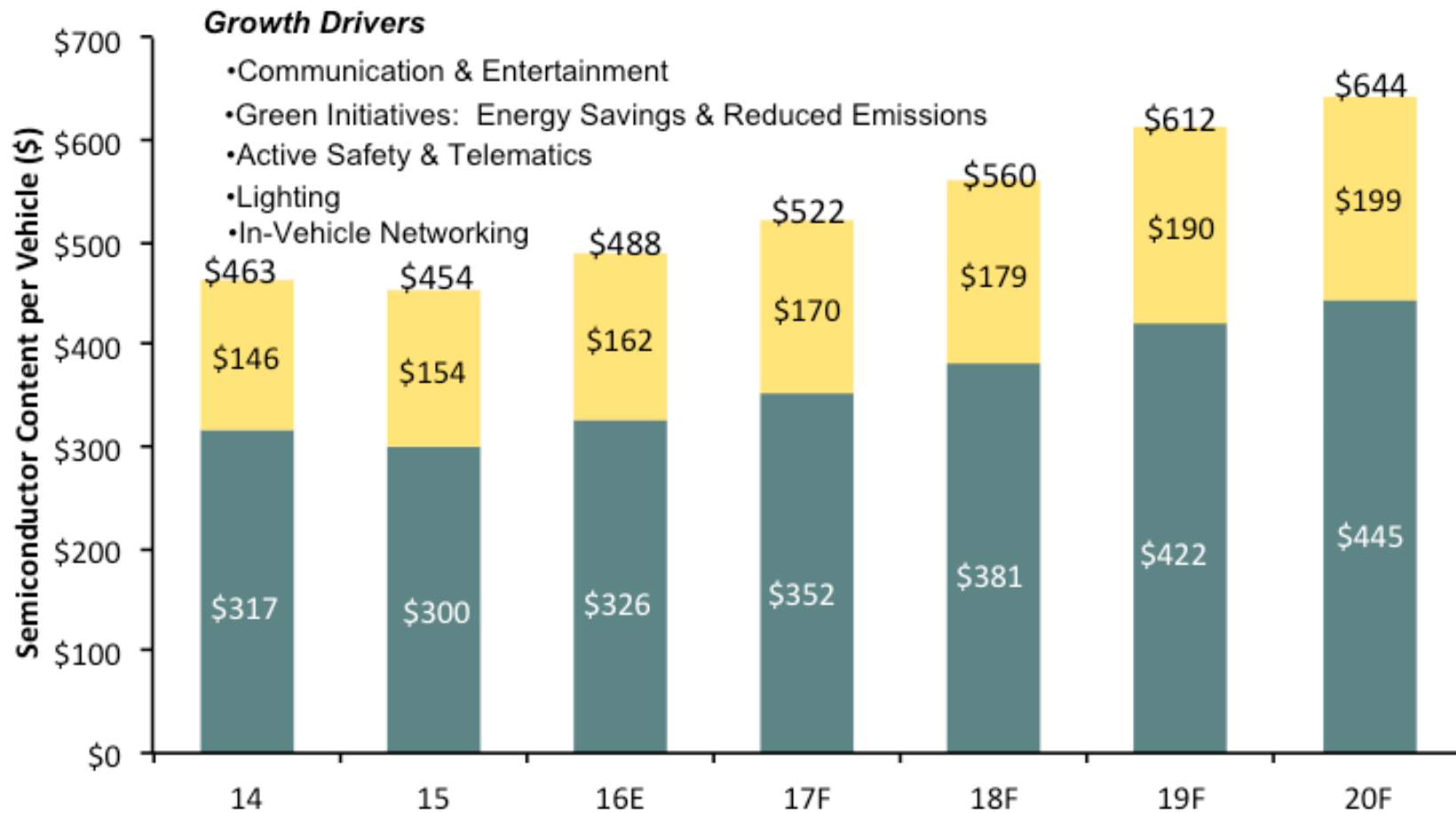


Source: Intel



Average Semiconductor Content per Vehicle (\$)

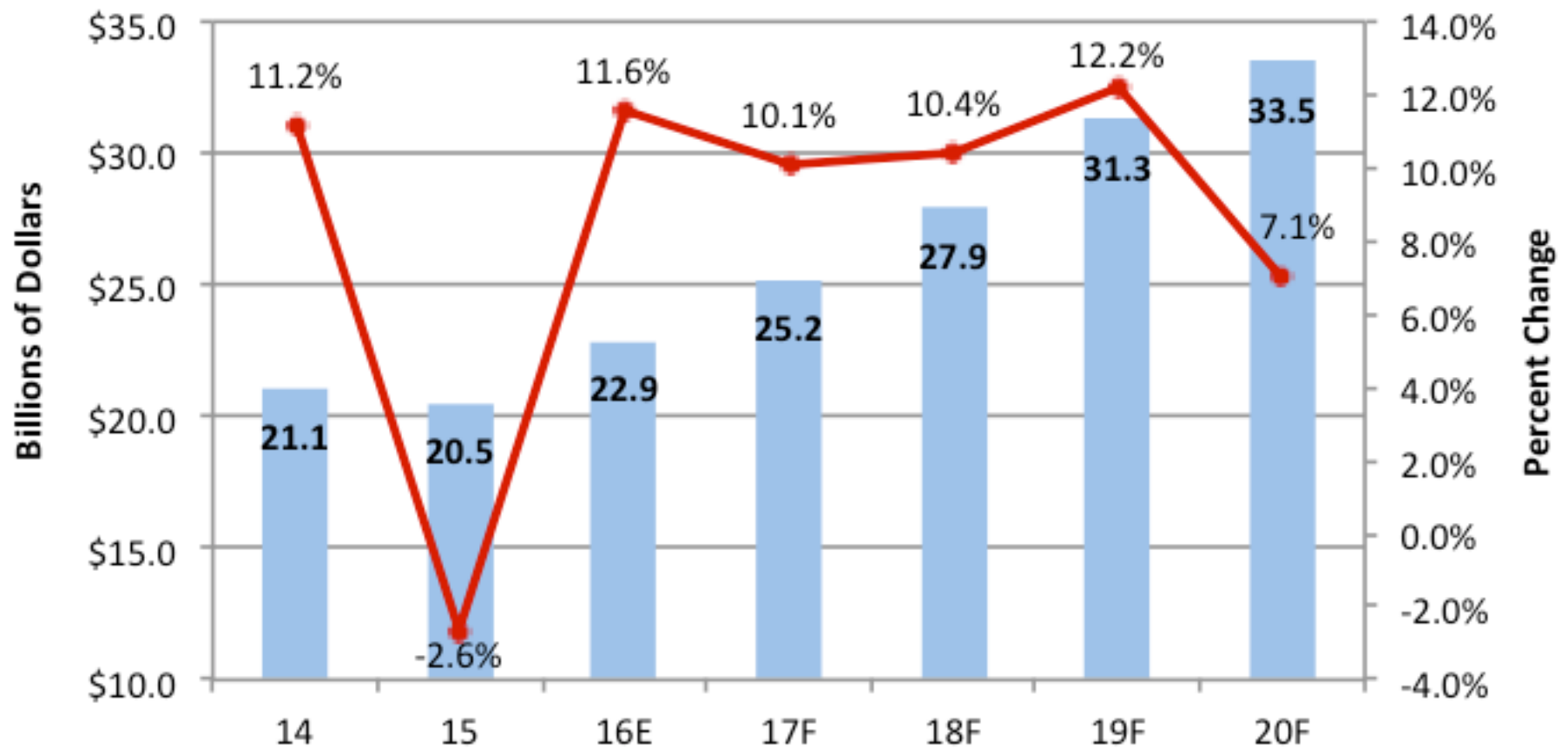
■ Avg. IC Content ■ Avg. OSD Content



Source: IC Insights



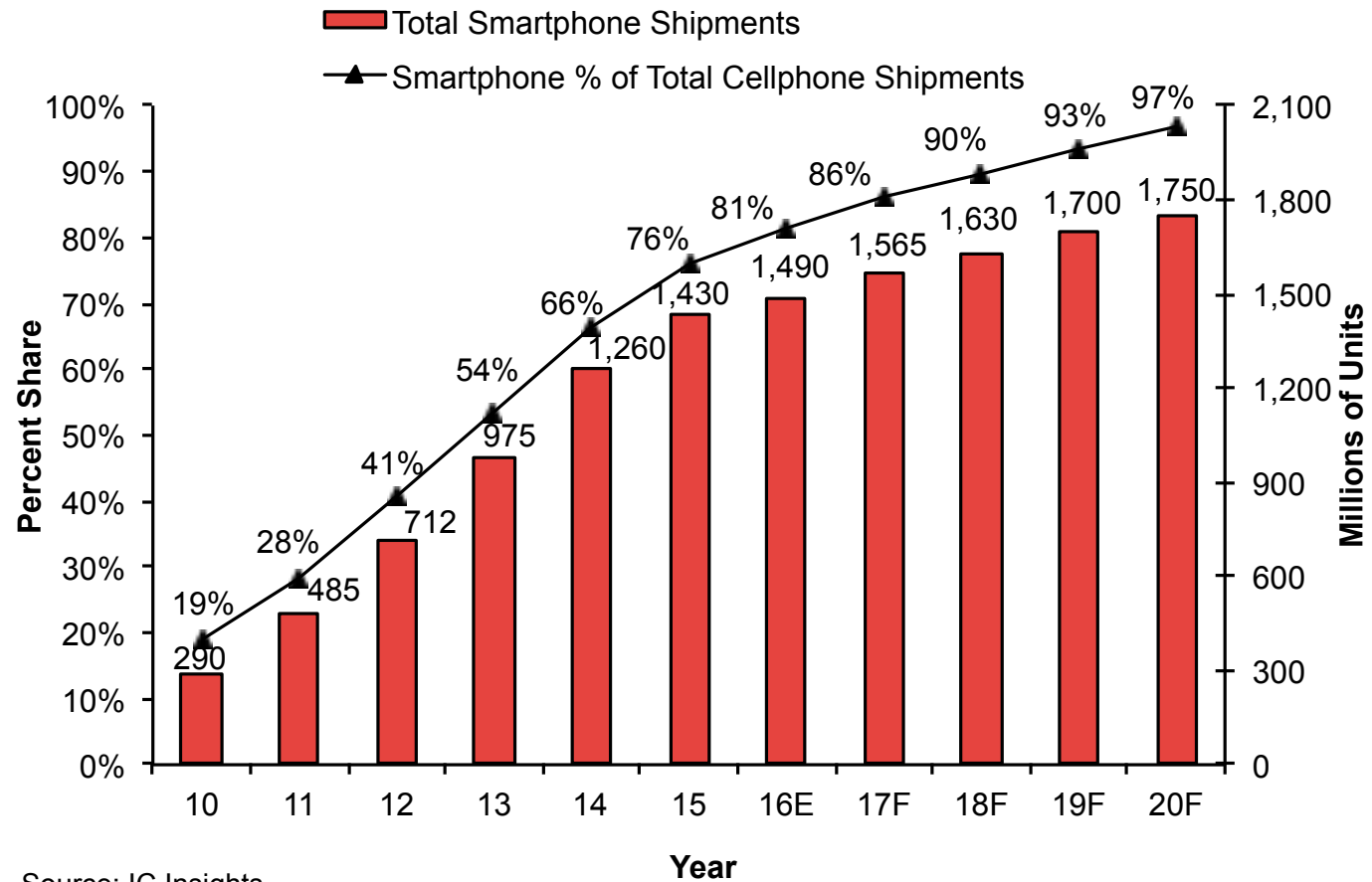
2014-2020F Automotive IC Market



Source: IC Insights



Smartphone Shipment Forecast (Units, M)



Source: IC Insights



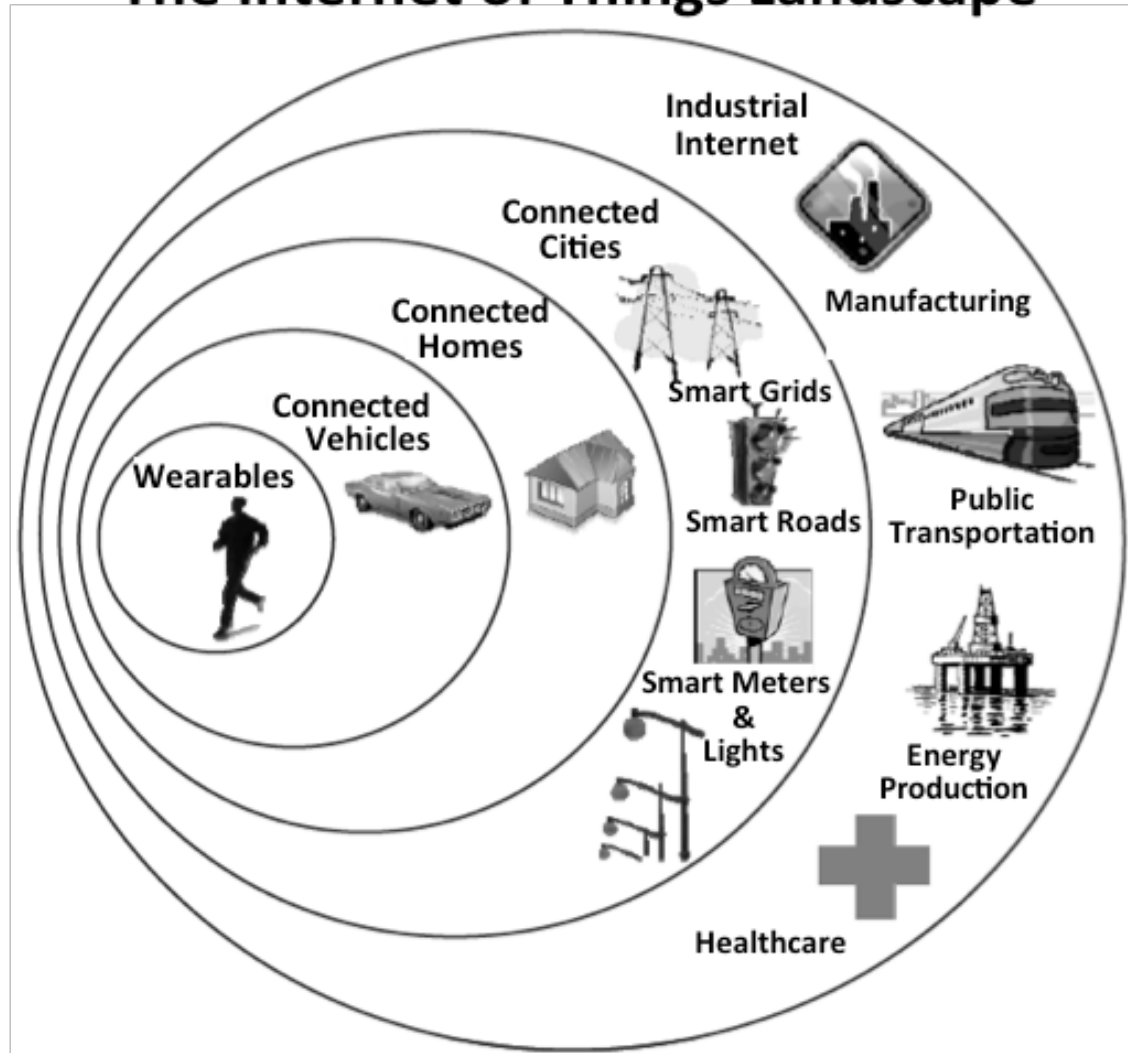
Average IC Content in Cellular Handsets (2016E)

Product Family	Basic Phone	Enhanced Phone	Low-End Smartphone*	High-End Smartphone**
Memory	\$1.35	\$2.80	\$6.60	\$19.10
RF/analog/mixed signal	\$2.05	\$2.65	\$3.90	\$11.50
Applications processor	—	\$2.80	\$6.95	\$17.10
Misc. logic	—	\$1.10	\$1.70	\$3.70
Camera chip	—	\$1.65	\$1.95	\$4.10
Digital baseband	\$1.95	\$2.05	\$2.20	\$3.55
Multimedia processor	—	\$1.25	\$1.60	\$3.35
Bluetooth module	—	\$1.65	\$1.65	\$1.65
Total ICs	\$5.35	\$15.95	\$26.55	\$64.05
			*<\$200	**≥\$200

Source: Portelligent, EET, Nokia, IC Insights



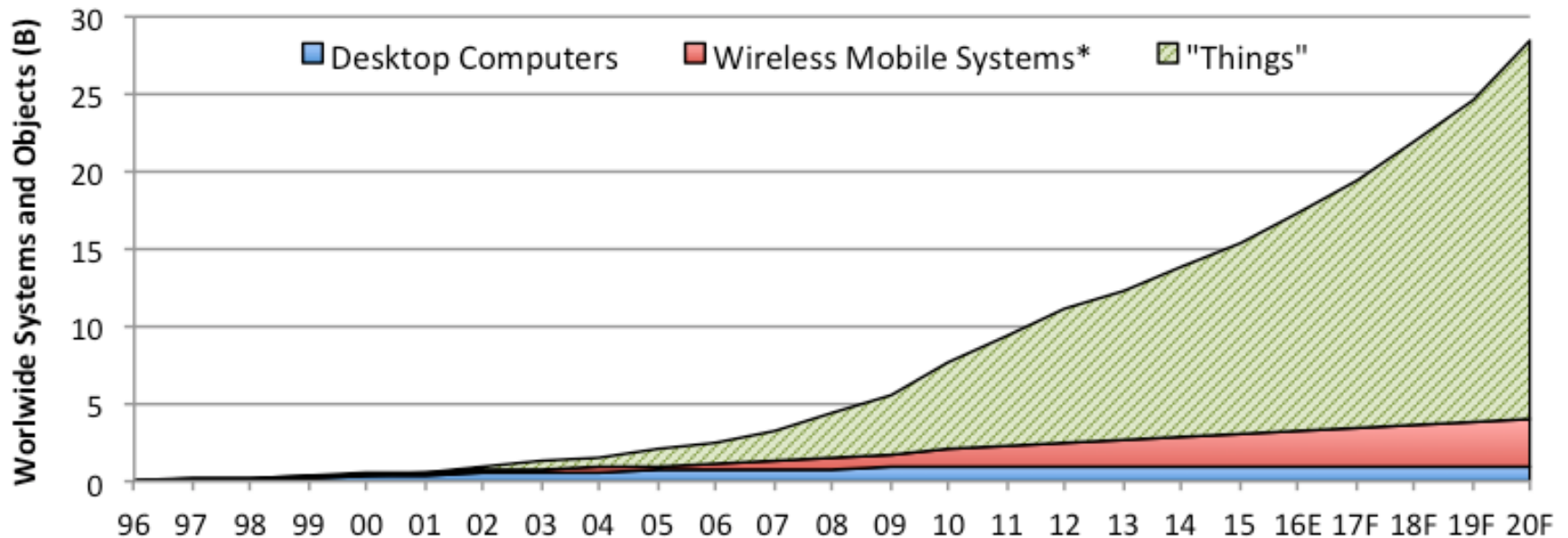
The Internet of Things Landscape



Source: Goldman Sachs



Total Number of Installed Connections to the Internet

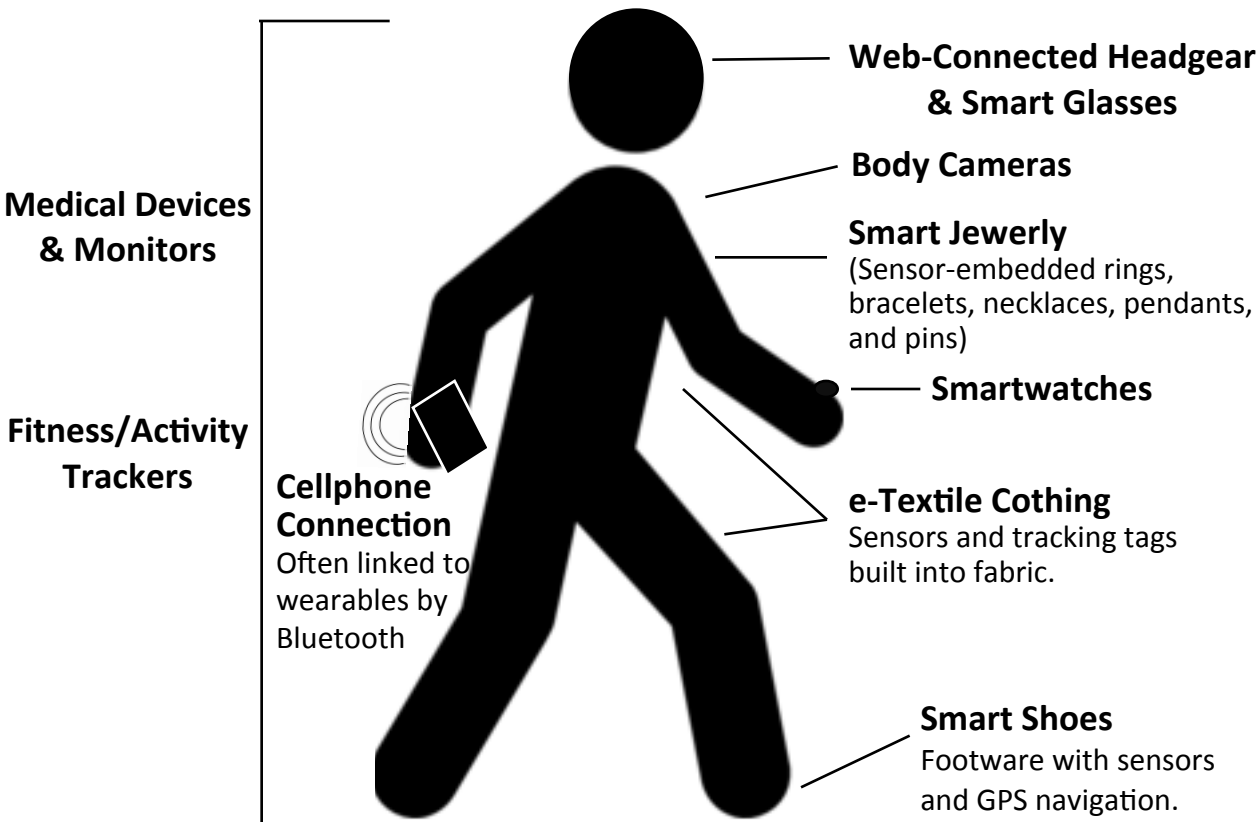


* Cellphones, tablets, notebook PCs, PDAs, thin-client laptops, and other portable systems for human Internet use.

Source: IC Insights



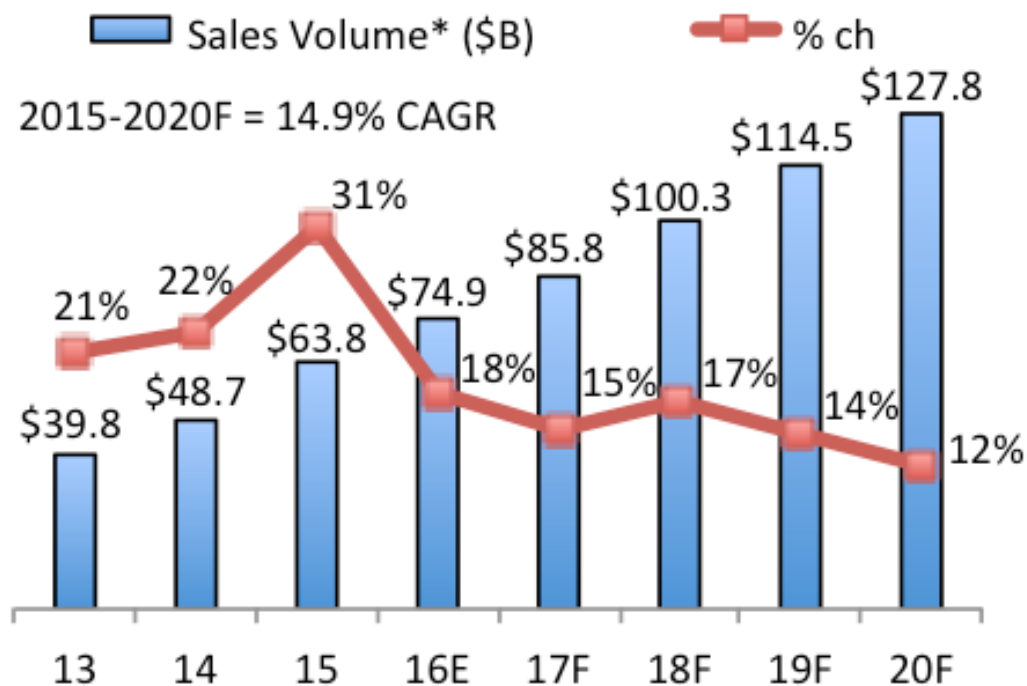
Wearable Systems Could Cover the Entire Body



Source: IC Insights



Market Value of IoT Function in "Things"



*Revenues associated with attachment, sensing, and control functions

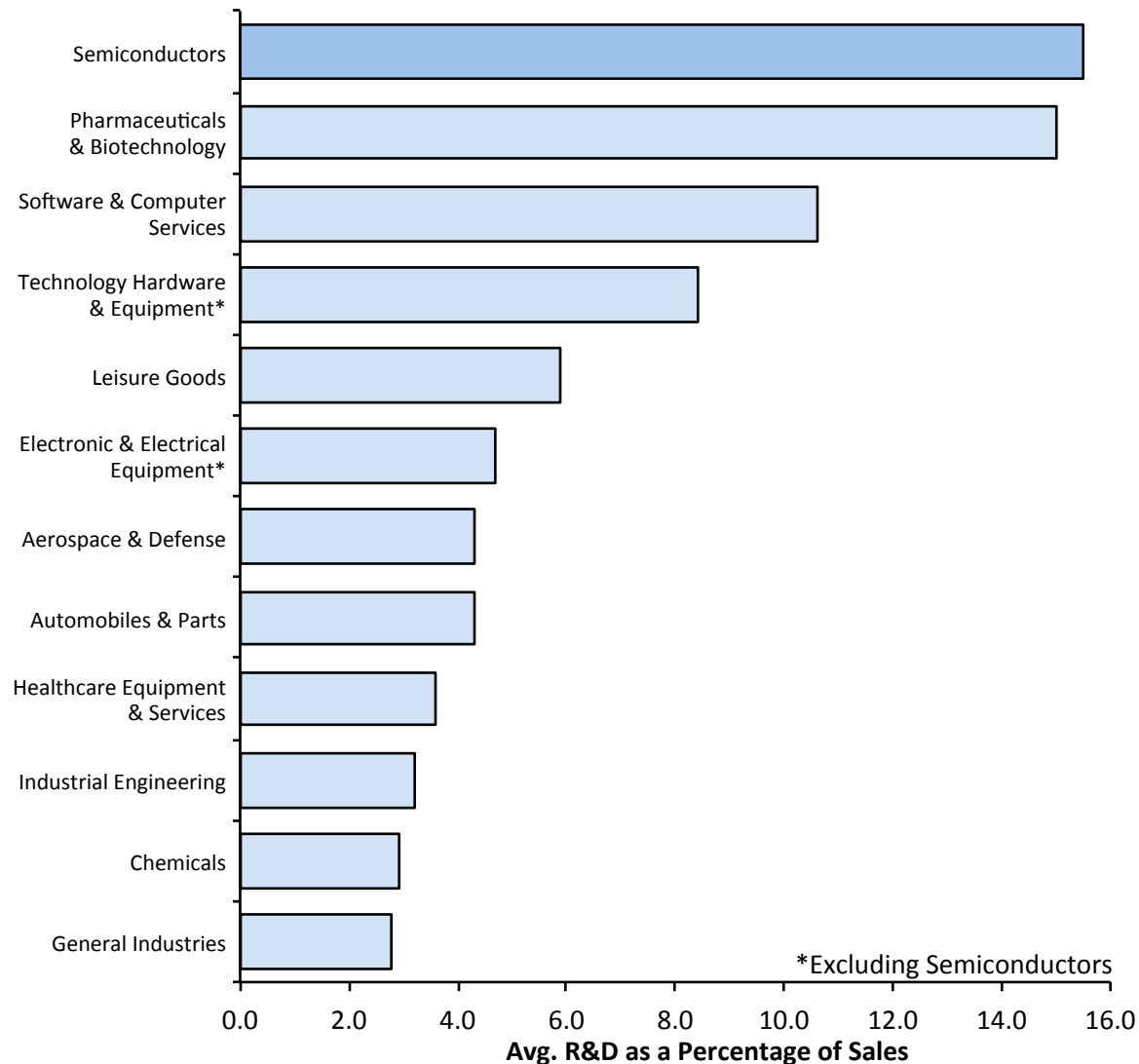
Source: IC Insights



Technology Trends



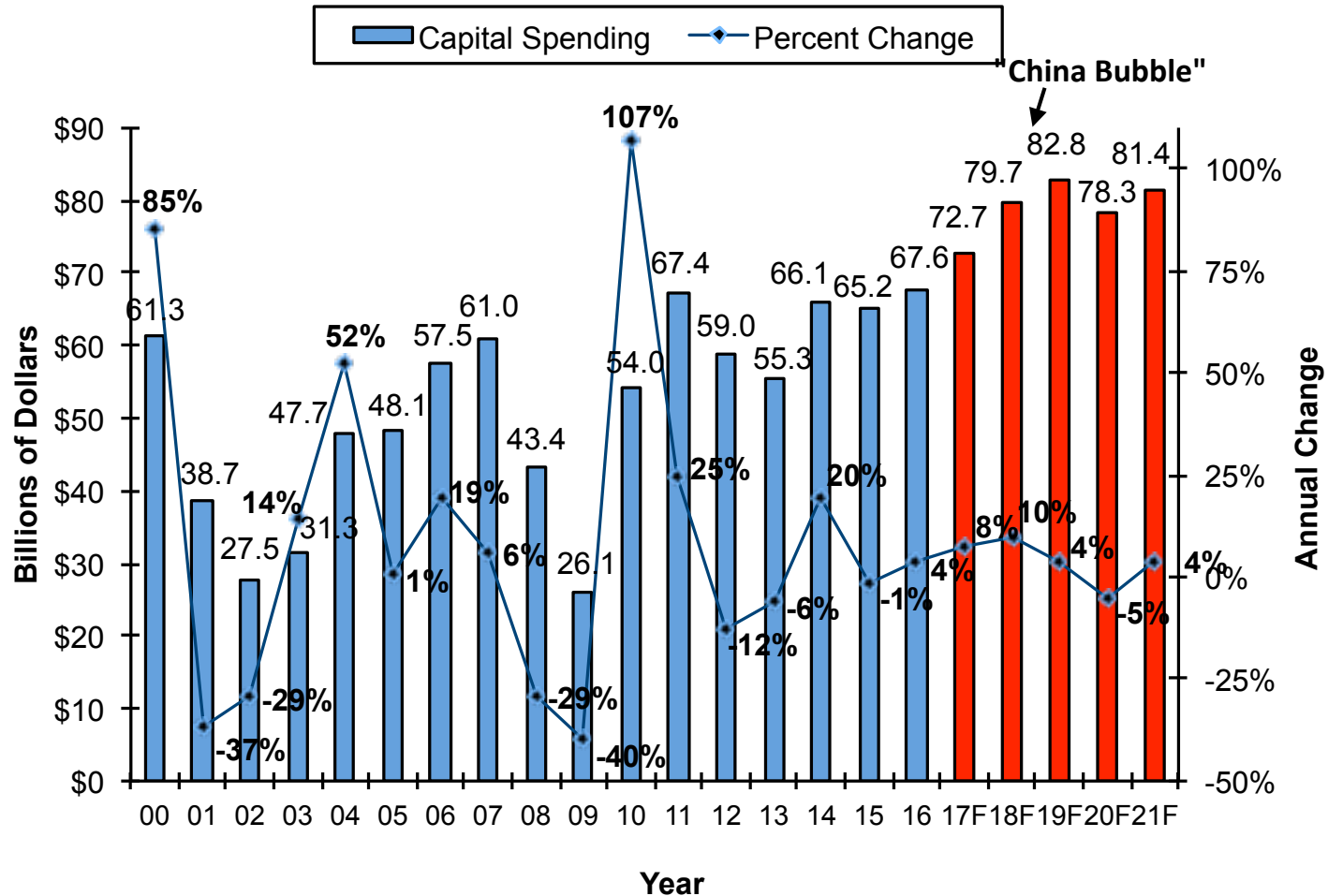
Semiconductor Industry Has Highest R&D Intensity (2015-2016 Data from the World's Top 2,500 Companies)



Source: EU Industrial R&D Investment Scoreboard, IC Insights



Worldwide Semiconductor Capital Spending Trends (2000-2021F)



Source: IC Insights



Examples of Devices Built on 200mm Wafers

SMARTPHONE AND TABLET PCs



Device Technologies	CDs
MEMS	0.7 μ m-2 μ m
PMIC	130nm-65nm
RF	90nm-1 μ m
Microcontroller	180nm-90nm
WLP & TSV	> 1 μ m

INDUSTRIAL APPLICATIONS



Device Technologies	CDs
MEMS	0.7 μ m-2 μ m
PMIC	130nm-65nm
Power Diode	> 1 μ m
Microcontroller	180nm-90nm

AUTOMOTIVE (Safety, Navigation, ECM, etc.)



Device Technologies	CDs
MEMS	0.7 μ m-2 μ m
PMIC	130nm-65nm
CIS	$\leq$ 1 μ m
RF	90nm-1 μ m
Microcontroller	180nm-90nm
WLP & TSV	> 1 μ m

WEARABLES AND HEALTH MONITORING

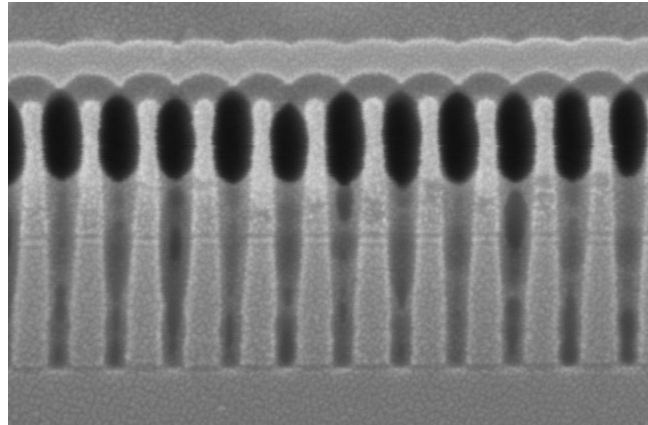


Device Technologies	CDs
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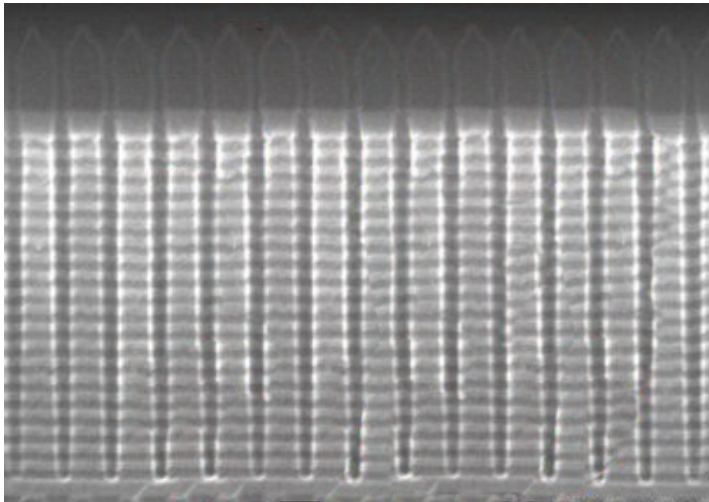
Source: Applied Materials



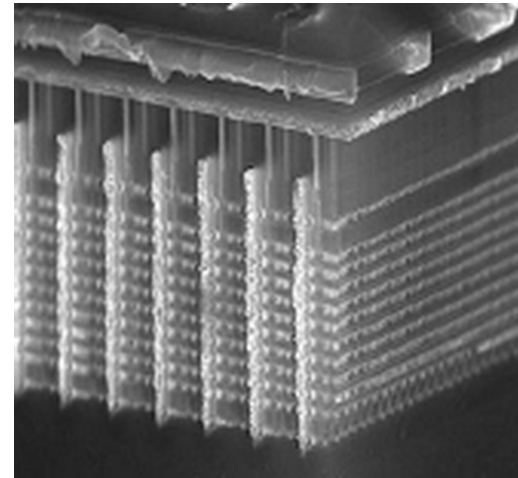
Samsung's 3D V-NAND Flash Memory



A. Standard planar (2D) flash. Charge stored on the horizontal plane across the top.



B. Two dimensional view of 3D NAND—The charges (bits) are not stored at the top layer. They are stored within all of the smaller, thinner layers below it.



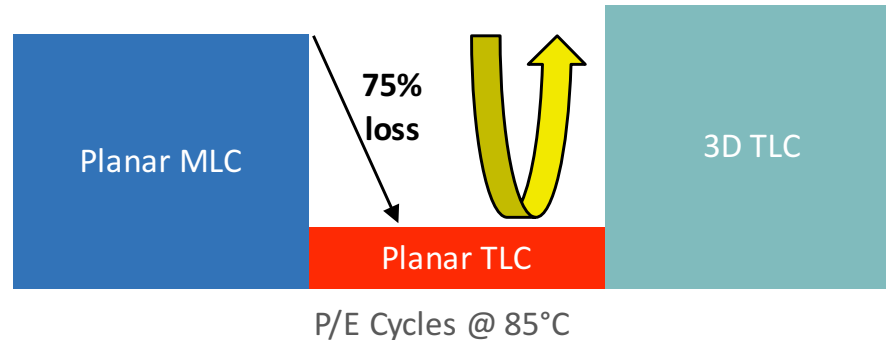
C. Three dimensional view of 3D NAND.

Source: PC Perspective, Samsung

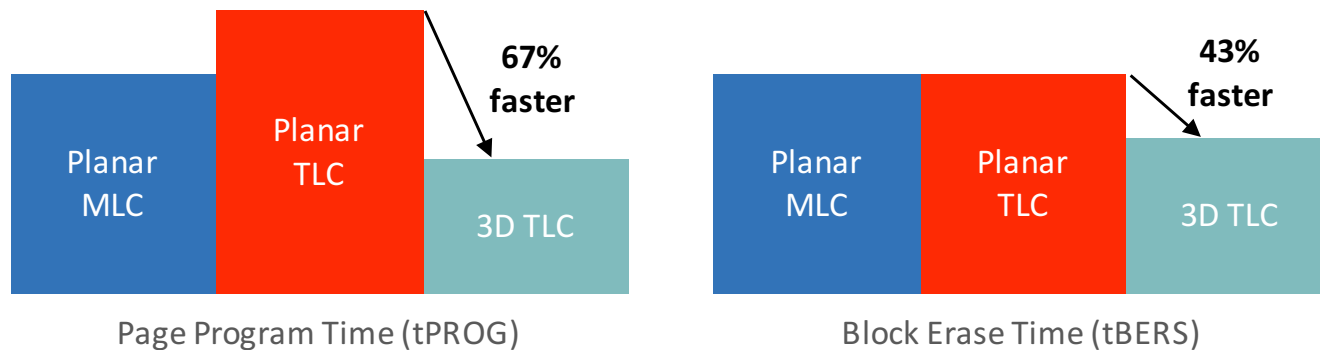


3D NAND Gains Back What was Lost Going to TLC

Higher is Better/More reliable



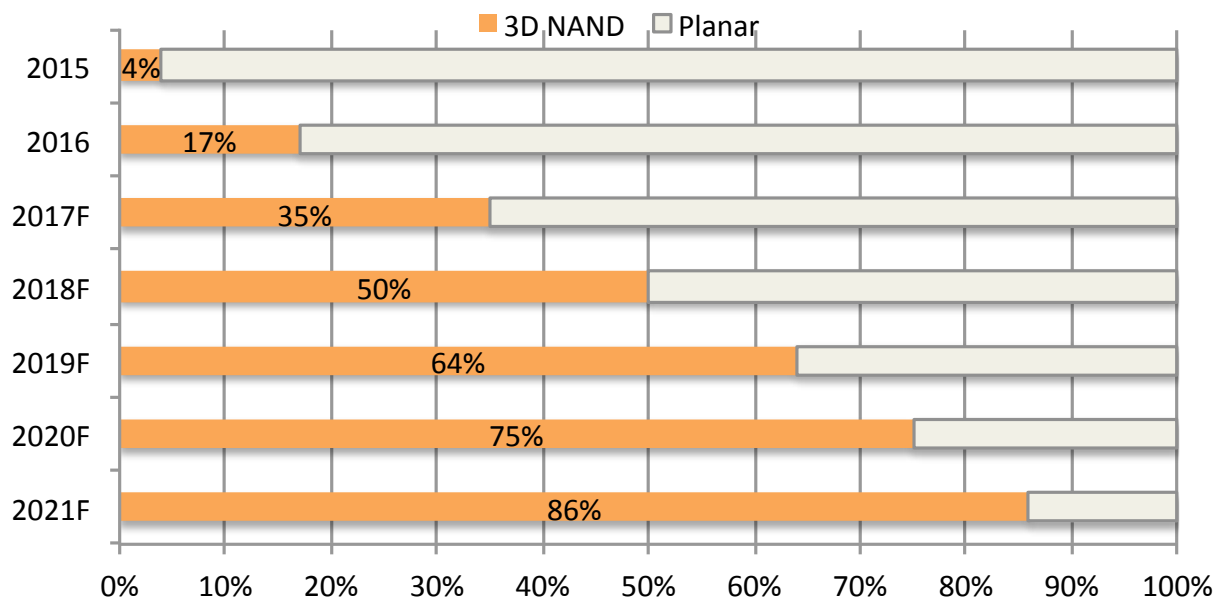
Lower is Better/Faster



Source: Samsung



3D NAND Bit Volume Ramp Begins (Percent of Total)



Source: IC Insights



Thank you for your attention!

Additional information

www.icinsights.com

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