New Technology Trends: Expand & Extend

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ECS Meeting: More than Moore Session
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Outline

Semiconductor Market History

Market Segments

Future Direction: Expand and Extend

Author's Note

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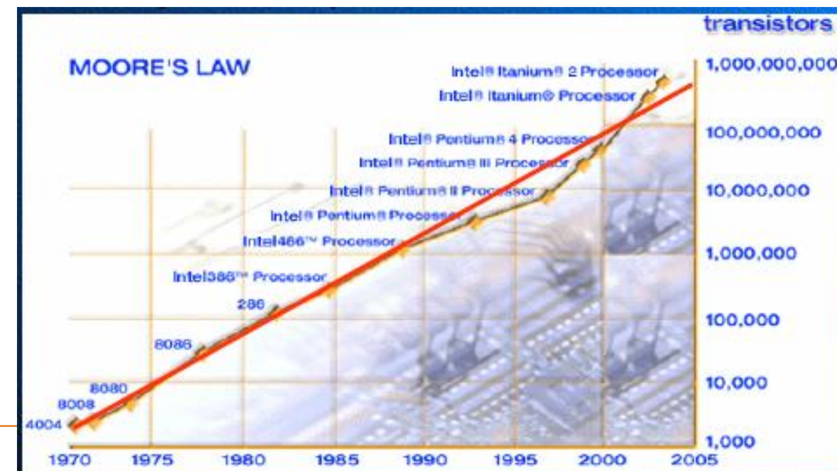
Opinions also do not necessarily represent this conference, its' sponsors, or virtually anyone else.

Your mileage may vary.

Industry Trends

- What drives decisions in the semiconductor mfg? SPEED and COST!
  - New products must be ready on time for market launch
  - Long term efficiency improves competitive strength
- Moore's Law dominated the CMOS industry for >40 years
  - Not affected by cycles, markets, analysts, or the economy
- Photolithography and CMP are two critical process technologies to continue both cost and performance improvements
  - Photolithography enables SHRINKS
  - CMP enables more complex STACKS
- Trend still holds for certain industry segments, but many companies are choosing to pursue other paths



Source: Intel Corporation

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Semiconductor Market

$400
$350
$300
$250
$200
$150
$100
$50
$0

Past:

1) Inception ~ 2003
2) Primary End User = Government & Corporate
3) Product Driver = Performance & Power
4) Market size ≤$150B

Transistor
Military
Mainframes
Calculators
Apple
IBM PC
386 MPU
486 MPU
Pentium
Servers
Internet
Routers
Cell Phones
Broadband
Social Networking Entertainment

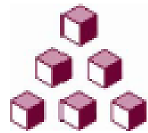
Present:

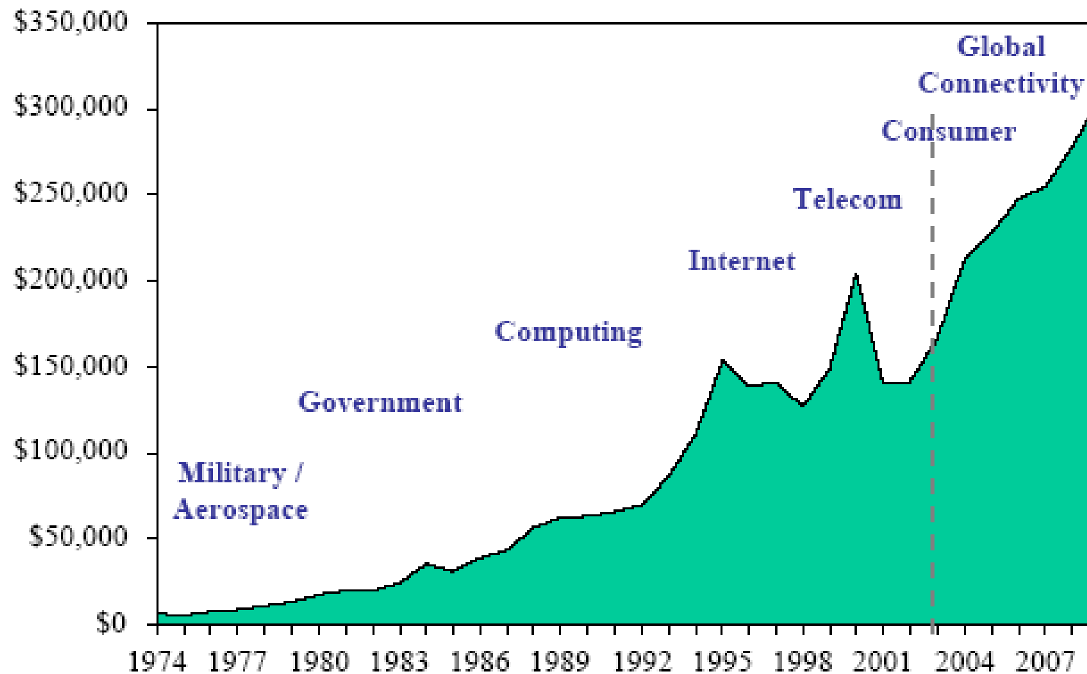
1) 2004 ~ 2015
2) Primary End User = Consumer
3) Product Driver = Mobility & Connectivity
4) Market size $150-$350B

1955 1958 1961 1964 1967 1970 1973 1976 1979 1982 1985 1988 1991 1994 1997 2000 2003 2006 2009 2012

Source: SIA/WSTS and Semico Research Corp.

Primary Drivers





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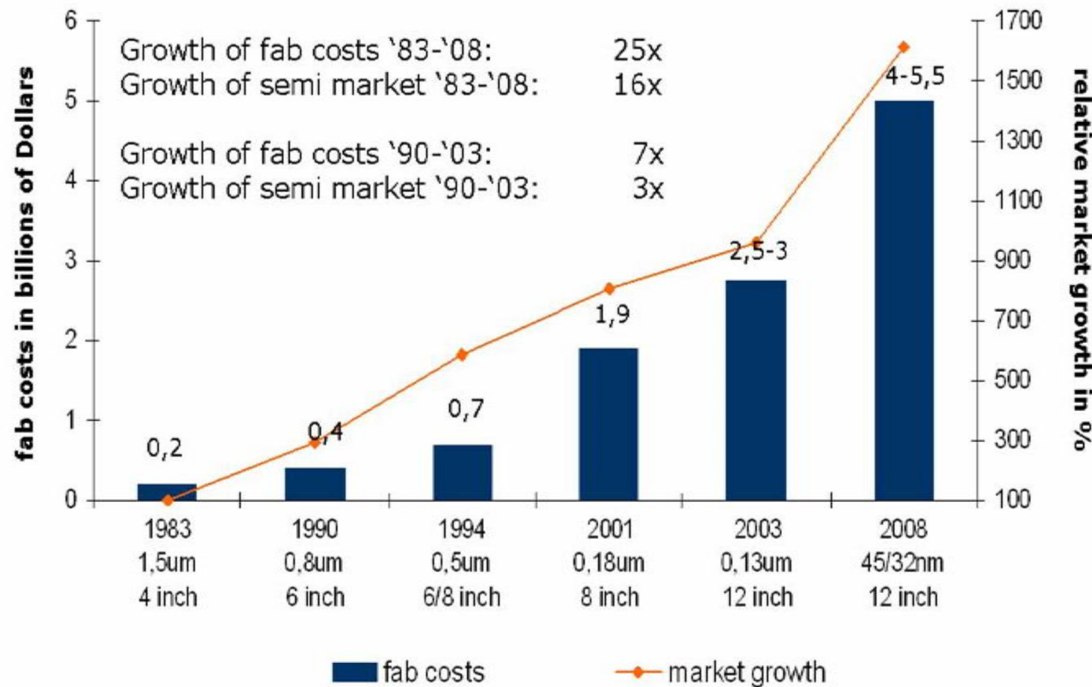
Wafer Fab Investment



Source: Semico Research Corp

EE Times Asia

TSMC preps for $26B fab

Posted: 16 Dec 2011

Central Taiwan Science Park in Taichung, Taiwan has appropriated a 50-hectare lot for TSMC to build a *450mm wafer fab at a projected cost of around $26 billion* (more than NT800 billion), or nearly three times the cost of TSMC's Fab 15 Gigafab currently being built on the science park.

Technology Nodes

- Historical progression for >20 years

  0.5 um → 0.35 → 0.25 → 0.18 → 0.15 → 90 nm → 65 nm → etc.

- Devices, equipment platforms, even entire fabs were identified by their "target node"

- Industry language referenced the expectations

  Leading edge – mainstream – trailing edge

  Early adopters – fast followers – late stage

  Etc.

Still applies to some segments of CMOS devices ….

But no longer universal terminology.

Industry Segments

Particularly from a CMP perspective

- Segment I – More Moore
  - Wafer sizes: 300mm & likely 450mm
  - Technology nodes: 32nm, 25nm and below
  - Materials: high k, metal gates, ULK, advanced barriers, etc.

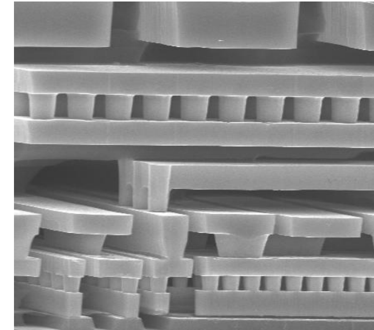


Photo displayed with permission of Freescale Semiconductor, Inc.

- Segment II – More than Moore (New Mainstream)
  - Wafer sizes: 300mm (some), 200mm & 150mm
  - Technology nodes: 90nm to 350nm and above
  - Materials for CMP: oxides, tungsten, etc.
- Segment III – More than Moore (Emerging)
  - Wafer sizes: 200mm, 150mm, 100mm and smaller
  - Technology nodes: various
  - Materials: wide range of metals, oxides, polymers, and more
  - MEMS, nanotechnology, SiC, GaN, optics, etc.

Segment I
More Moore

Financial Factors and Trends Across 3 Industry Segments						
Financial Factor	More Moore		New Mainstream		Emerging	
	Level	Direction	Level	Direction	Level	Direction
Average Annual Capital	High	↑				
Technology R&D	High	↑				
Manufacturing Cost/chip	High	↓				
Volume	High	-				
Average Selling Price (ASP)	High	↓				

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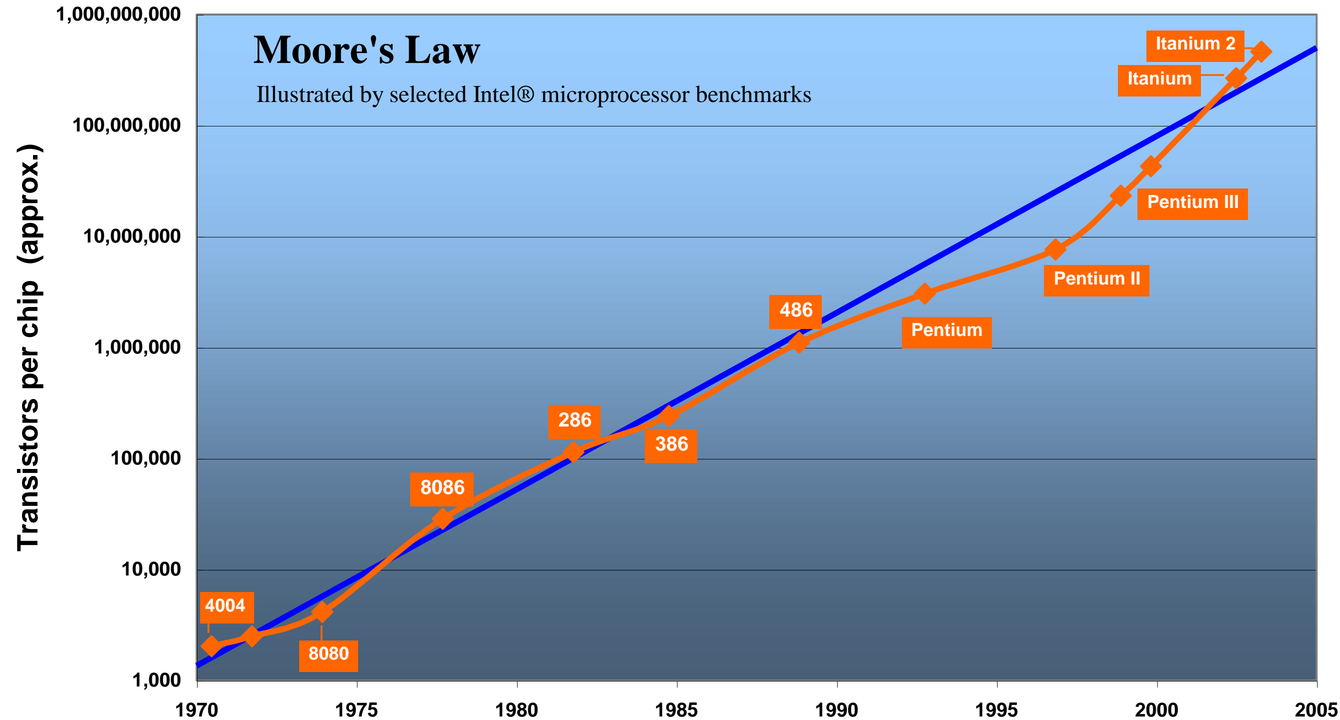
Moore's Law

Microprocessor transistors per chip have increased by over 5 orders of magnitude in 40 years.

Current generation chips have more than 1.7 billion transistors

Photo and CMP are 2 critical processes required to stay on trend line:

- **Photo → SHRINKS**
- **CMP → STACKS**



Moore's Law has not been derailed by industry cycles, technology hurdles, or the economy ... but it does not really apply to every semiconductor company

Segment I Key Points

- Typical companies: microprocessor and memory makers, large-scale foundries
- Willing to spend capital on new fab construction (300 mm and soon 450 mm)
- Willing to adapt new materials or processes as needed to achieve performance
- Designs AND process technology both change at a rapid pace
- Design focus = performance
- Process focus = speed at acceptable yield

Segment II
New Mainstream

Financial Factors and Trends Across 3 Industry Segments						
Financial Factor	More Moore		New Mainstream		Emerging	
	Level	Direction	Level	Direction	Level	Direction
Average Annual Capital	High	↑	Moderate	↓↓		
Technology R&D	High	↑	Moderate	↓		
Manufacturing Cost/chip	High	↓	Moderate	↓↓		
Volume	High	-	High	↑		
Average Selling Price (ASP)	High	↓	Low	-		

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Segment II Key Points

- Wide range of companies and products including digital, analog, mixed signal, power, etc.
- Adapting to a world of flat or falling ASP's
- Cost factors and yield becoming MUCH more important than technology factors
- Some devices enjoy long lifecycles (but not all)
- Designs may change rapidly, but process technology intentionally being held much more stable
- Design focus = features and simplicity
- Process focus = cost and maximizing yield

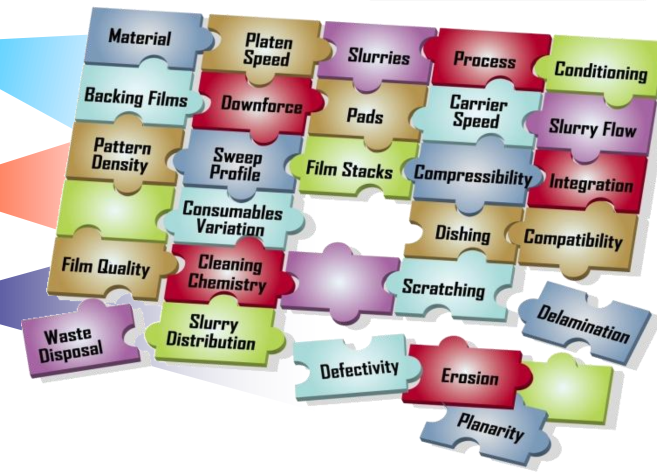
Segment III
Emerging Technology

Financial Factors and Trends Across 3 Industry Segments						
Financial Factor	More Moore		New Mainstream		Emerging	
	Level	Direction	Level	Direction	Level	Direction
Average Annual Capital	High	↑	Moderate	↓↓	Low	-
Technology R&D	High	↑	Moderate	↓	High	↓
Manufacturing Cost/chip	High	↓	Moderate	↓↓	High	↓
Volume	High	-	High	↑	Low	↑↑
Average Selling Price (ASP)	High	↓	Low	-	High	↓

Emerging CMP

1995 - Qty ≤ 2	2001 - Qty ≤ 5	2011 - Qty ≥ 40		
CMOS	CMOS	CMOS	New Apps	Substrate/Epi
Oxide	Oxide	Oxide	MEMS	GaAs & AlGaAs
Tungsten	Tungsten	Tungsten	Nanodevices	poly-AlN & GaN
	Cu (Ta barrier)	Cu (Ta barrier)	Direct Wafer Bond	InP & InGaP
	Shallow Trench	Shallow Trench	Noble Metals	CdTe & HgCdTe
	Polysilicon	Polysilicon	Through Si Vias	Ge & SiGe
		Low k	3D Packaging	SiC
		Capped Ultra Low k	Ultra Thin Wafers	Diamond & DLC
		Metal Gates	NiFe & NiFeCo	Si and SOI
		Gate Insulators	Al & Stainless	Lithium Niobate
		High k Dielectrics	Detector Arrays	Quartz & Glass
		Ir & Pt Electrodes	Polymers	Titanium
		Novel barrier metals	Magnetics	Sapphire
			Integrated Optics	entrepix

36+ highly complex puzzles



→ *Early stage prototype development*
→ *Integration and process optimization*
→ *Qualification and transition to manufacturing*
→ *Yield improvements and cost reductions*

Growth in Applications

CMP is still evolving for CMOS applications ...

And many newer applications are now also being developed beyond “traditional” CMP.

- ***MEMS***
  - Oxides (doped or undoped)
  - Polysilicon (usually structural)
  - Nitrides and oxynitrides
  - Separation layer (MEMS-first or MEMS-last)
  - Metals (esp. for reflective surfaces)
- ***Advanced Substrates***
  - Strained layer epi substrates
  - Custom III-IV and II-IV epi layers
  - SOI
  - GaN, GaP, SiC, etc.
  - Various surfaces for direct wafer bonding
- ***Advanced Packaging***
  - 3D Thru Silicon Vias
  - Direct Wafer Bonding
  - Interposer Technology
- ***Other***
  - Embedded waveguides
  - Integrated optical elements
  - New memory materials
  - Photoresist and other polymers
  - Magnetic materials (active or shielding)
  - Advanced packaging
  - 3D IC’s and similar device technologies

Segment III Key Points

- Many products not even based on traditional CMOS
- Often adapting silicon CMOS process techniques
- Startup or new entry mentality
- Frequently start on smaller wafer sizes and transition up as volume production increases
- Process flow is generally not mature due to some fraction of “creative” steps
- Design focus = new devices
- Process focus = achieving acceptable yield and ramp

Common Themes

Two common themes have emerged

EXTEND and **EXPAND**

Fab Longevity

INTERNATIONAL SEMATECH
ISMI
MANUFACTURING INITIATIVE

Lab / Fab Wafer Profile

2001 - 2009 SEMI Silicon Manufacturers Group (circa: March, 2010)
2010 - 2024 ISMI Industry Economic Model v12.1sssu (circa: December, 2010)

SEMI SMG (with lead time offset) excludes reclaim, non-polished and SOI silicon demand

- 50/75/100mm History
- 125/150mm History
- 200mm History
- 300mm History
- 50/75/100mm Scenario
- 125/150mm Scenario
- 200mm Scenario
- 300mm Scenario
- 450mm Scenario

Plan of Record: ITRS 2009

Projected 300mm - 450mm Silicon Area Crossover

200mm - 300mm Silicon Area Crossover

125/150mm - 200mm Silicon Area Crossover

Silicon Area (M cm^2)

0, 20000, 40000, 60000, 80000, 100000, 120000, 140000, 160000

1993, 1995, 1997, 1999, 2001, 2003, 2005, 2007, 2009, 2011, 2013, 2015, 2017, 2019, 2021, 2023, 2025

150mm was introduced around 1985, it peaked in 1999 and has steadily decreased since.

200mm was introduced in 1992. It peaked in 2005 and has remained relatively stable…through 2025!

Fabs & Products Utilizing ≤200mm Wafers

Semiconductor Units from ≤200mm Wafers

200mm products

Billions of Units

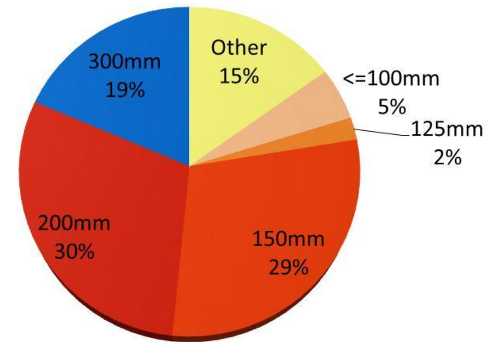
800
700
600
500
400
300
200
100
0

1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012

- Bipolar
- Optos
- Discrete
- Analog
- General Purpose Logic
- Gate Array
- Oth Memory
- MCU
- Standard Cell
- PLD
- MOS Logic
- DSP
- MPU
- NOR
- NAND
- DRAM

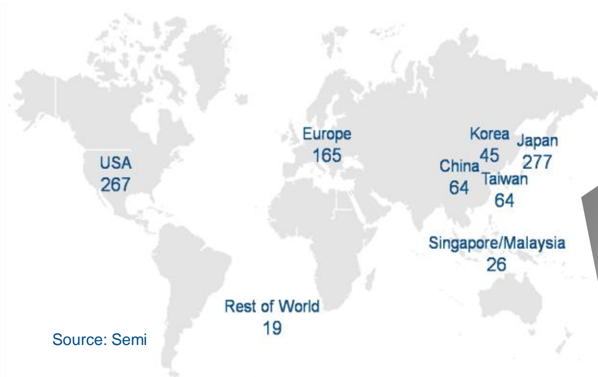
Source: SIA/WSTS and Semico Research Corp

Fabs by Wafer Size

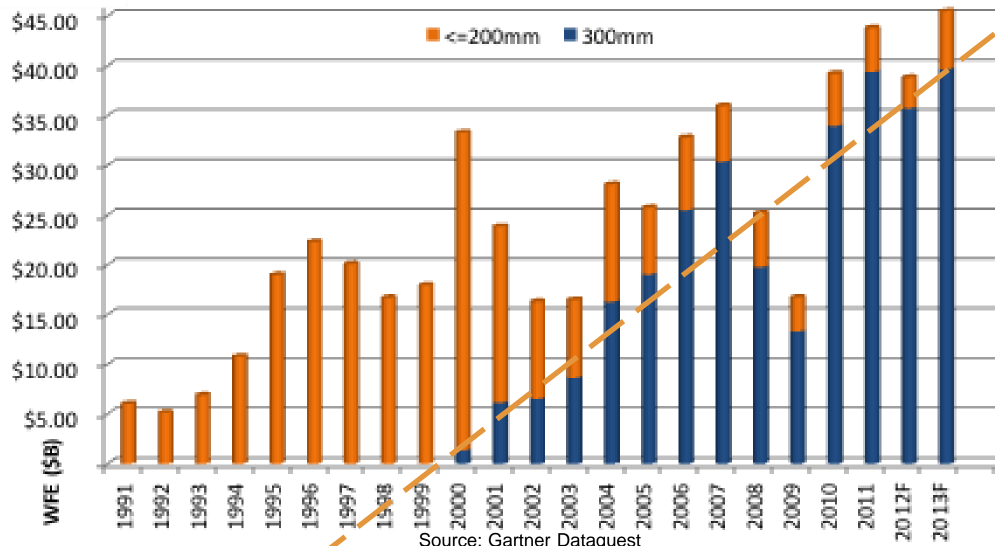


Source: Semico Fab Database

WFE: A Market Divided



>80% of Production Fabs are ≤200mm
(represents approximately 6M wafers/month)



Source: Gartner Dataquest

Mainstream = More than Moore

- Extend valuable assets
- ROIC

Long-term support:

- Who?
- How?
- What?
- Where?

Leading Edge = More Moore

- Equipment support
- Process support

Long-term support:

- OEM resources

Decisions

How is any of this information useful?

Management decisions are influenced by certain perspectives and trends. These vary depending on business model and market segment.

More Moore	
DEVICE DESIGN	Push for maximum performance (speed, low power, etc.) Extreme innovation is often necessary
EQUIPMENT	Willing to build new fabs or retool existing fabs (extend infrastructure) Drive improvements in both capability and productivity
CONSUMABLES	Push performance in nearly every aspect of CMP Defectivity is a primary focus at every CMP process step
MATERIALS	Adapt existing materials whenever feasible, but … Will not hesitate to integrate new materials when necessary

Decisions

New Mainstream	
DEVICE DESIGN	Expand product portfolio by leveraging existing process technology More focus on functionality and cost than raw speed
EQUIPMENT	Preserve capital and extend life of depreciated tools Buy tools only for "must have" capacity expansions Generally staying on wafer sizes 200mm and below
CONSUMABLES	Extreme focus on reducing cost per wafer Defectivity and other factors to improve yield are key
MATERIALS	Adapt proven materials and process methods … period. Optimize process flows for simplicity and yield

Decisions

Emerging Technology	
DEVICE DESIGN	Highly customized to the type of device (usually non-CMOS) Startup mentality "find something that works"
EQUIPMENT	Preserve capital and minimize overhead Outsourcing is a strong trend (fabless) Generally start at small wafer sizes and work up as volume ramps
CONSUMABLES	Not locked in to "traditional" CMP pad/slurry offerings Lots of niche opportunities that are growing as markets evolve
MATERIALS	Willing to explore a wide range of materials for unique properties Process requirements vary by several orders of magnitude

The Future

- Trends vary by segment within the industry
  - More Moore: Continue investment to achieve performance
  - More than Moore: New Mainstream
    Focus on expanding product portfolio and efficient ROIC
  - More than Moore: Emerging Technologies
    Focus on new devices or applications (startup mentality)
- Extend the life of existing capital assets
  - Depreciated fabs can be highly profitable
  - Different mindset than previous migration through technology nodes
- Expand range of products made in each fab
  - New designs that utilize existing process technologies
  - Combination technologies (analog/RF, digital/MEMS, etc.)
  - One successful strategy can be to repurpose existing fabs

Acknowledgements

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- For additional information, please contact:

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