Careers for Physicists, Scientists, and Engineers in the Semiconductor Equipment Industry

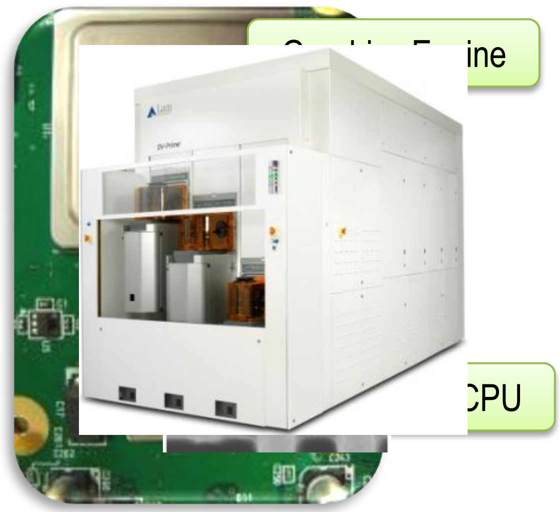
Jerome Hubacek
Managing Director
Lam Research Corporation
Fremont, CA

Careers in the Semiconductor Equipment Industry

- Introduction to the Semiconductor Equipment Industry
- Career opportunities
- Profile of the successful employee
- Transitioning from Graduate School to the Semiconductor Equipment Industry
- Keys to success

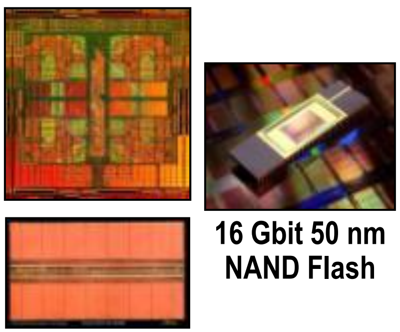
Introduction to the Semiconductor Equipment Industry

Semiconductor Technology Continues to Drive New Capabilities



Market for Wafer Fabrication Equipment (WFE)

Quad Processor
"Barcelona" (AMD)



16 Gbit 50 nm
NAND Flash

1 Gbit 78 nm
DRAM (Micron)

Electronic Equipment (2010)
$1,485 Billion

Semiconductors
$298 Billion

Capital Spending
$57 Billion

WFE
$29B

Five Major Markets

- Computing
- Automotive
- Consumer
- Communication
- Industrial/ Military

Buildings, Computers, and Equipment

Dry etch is ~13% of WFE spending
Lam Research has >50% etch market share

Single-wafer cleaning is ~4% of WFE
Lam Research has >25% market share

Source: Dataquest, Lam Research internal

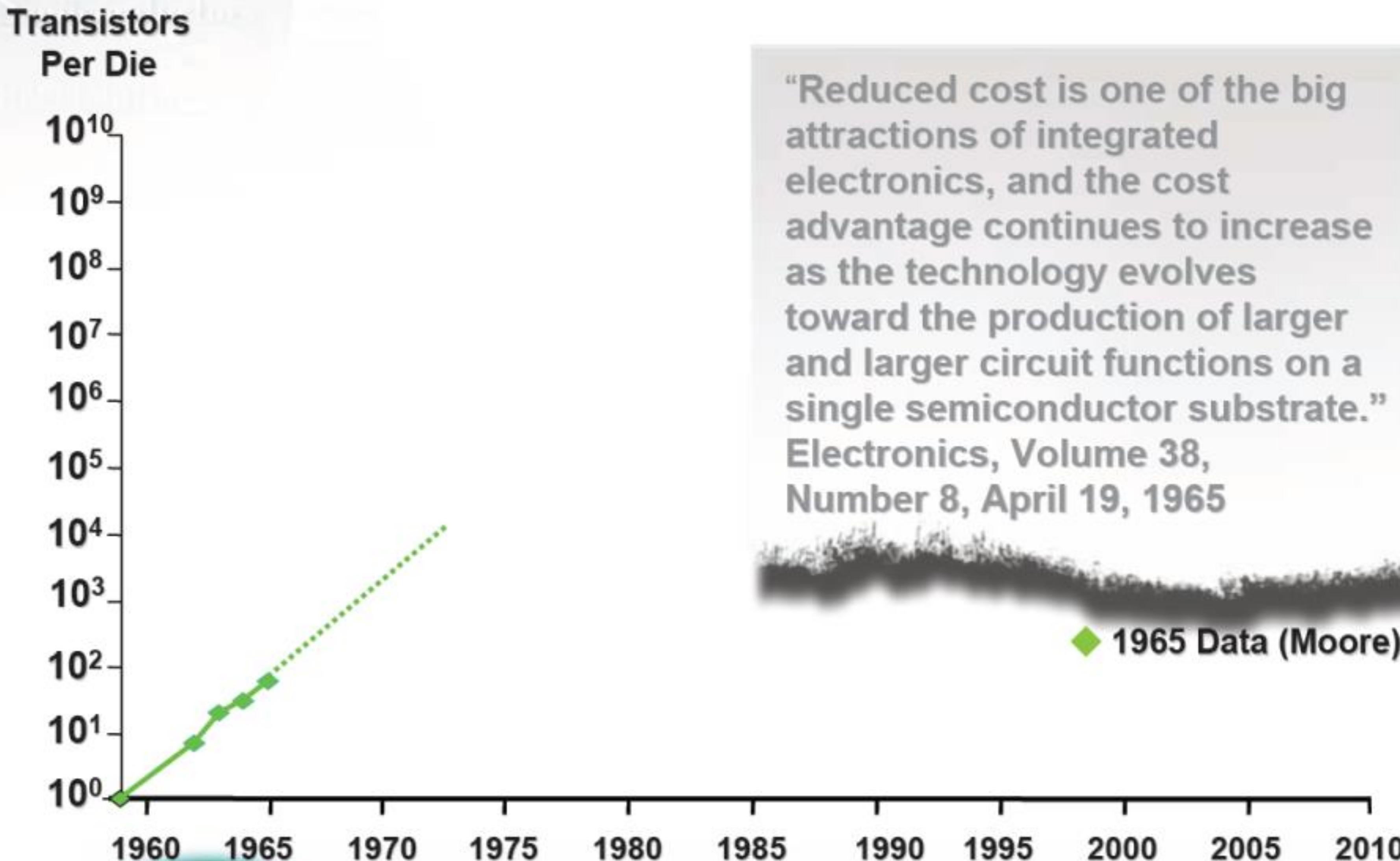
Semiconductor Equipment Manufacturer Revenues

Rank	2006	2007	2008	2009	2010
1	Applied Materials	Applied Materials	Applied Materials	Applied Materials	Applied Materials
2	Tokyo Electron	Tokyo Electron	ASML	ASML	ASML
3	ASML	ASML	Tokyo Electron	Tokyo Electron	Tokyo Electron
4	KLA-Tencor	KLA-Tencor	KLA-Tencor	KLA-Tencor	Lam Research
5	Lam Research	Lam Research	Lam Research*	Lam Research	KLA-Tencor
6	Nikon	Nikon	Nikon	Nikon	Dainippon Screen
7	Novellus Systems	Novellus Systems	Dainippon Screen	Dainippon Screen	Nikon
8	Dainippon Screen	Dainippon Screen	Hitachi High-Tech	Novellus Systems	Novellus Systems
9	Canon	Hitachi High-Tech	Novellus Systems	Aixtron	Aixtron
10	Hitachi High-Tech	Varian	Canon	Hitachi High-Tech	Varian

Lam acquisition of Novellus projected to close in Q2 2012

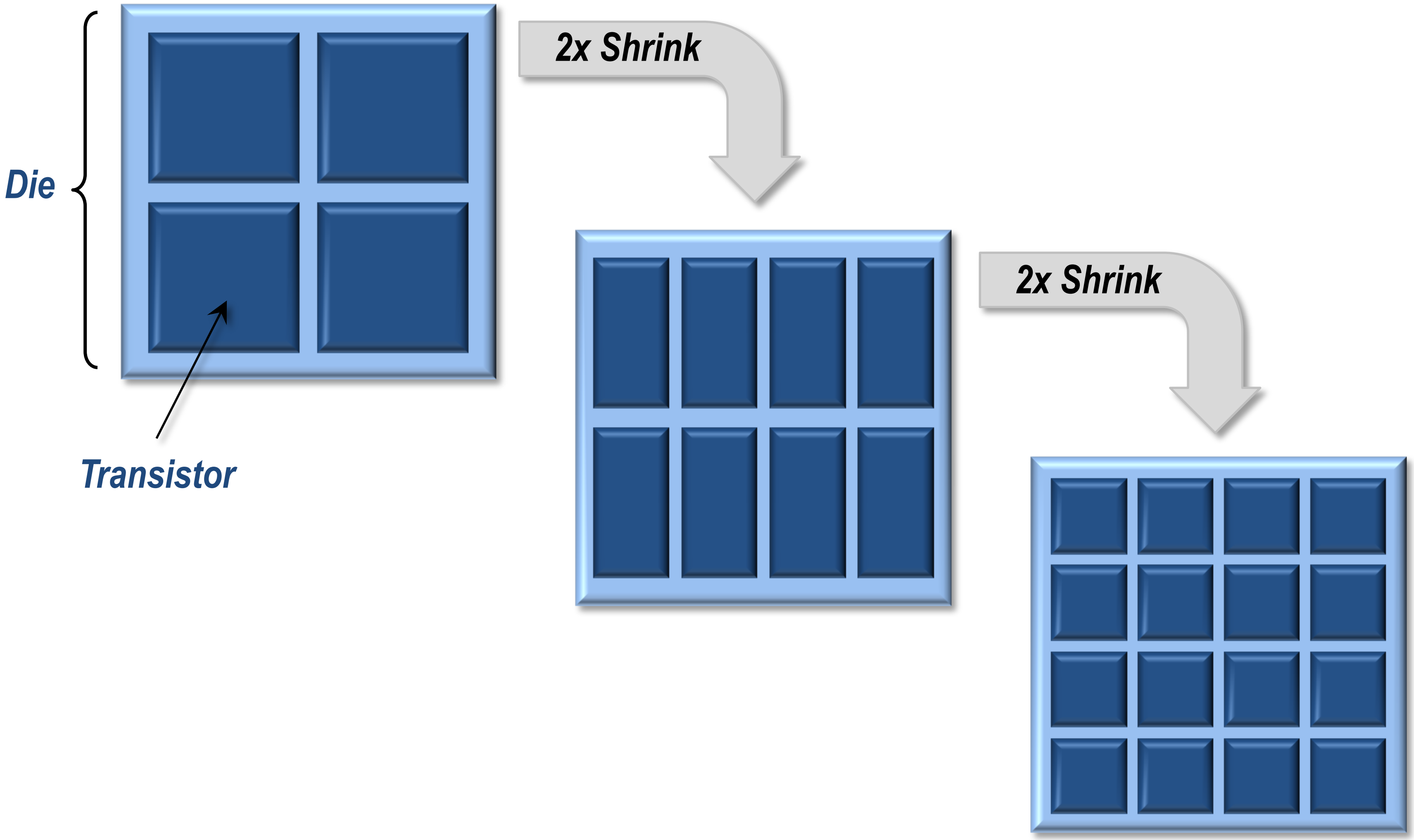
* Includes SEZ AG, acquired 2008
Source: Gartner Dataquest

Moore's Law - 1965

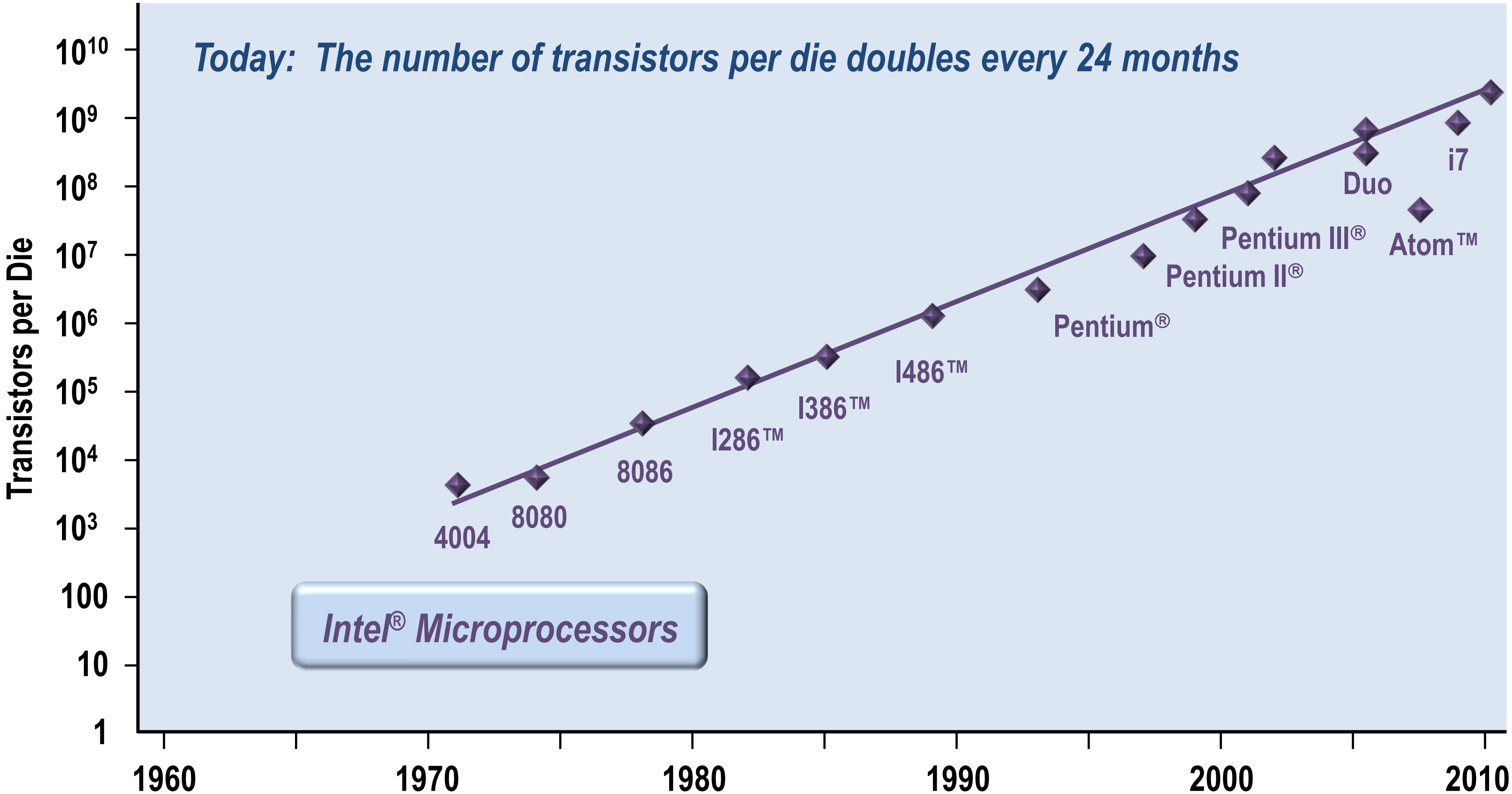


"Reduced cost is one of the big attractions of integrated electronics, and the cost advantage continues to increase as the technology evolves toward the production of larger and larger circuit functions on a single semiconductor substrate." Electronics, Volume 38, Number 8, April 19, 1965

Visualizing Moore's Law

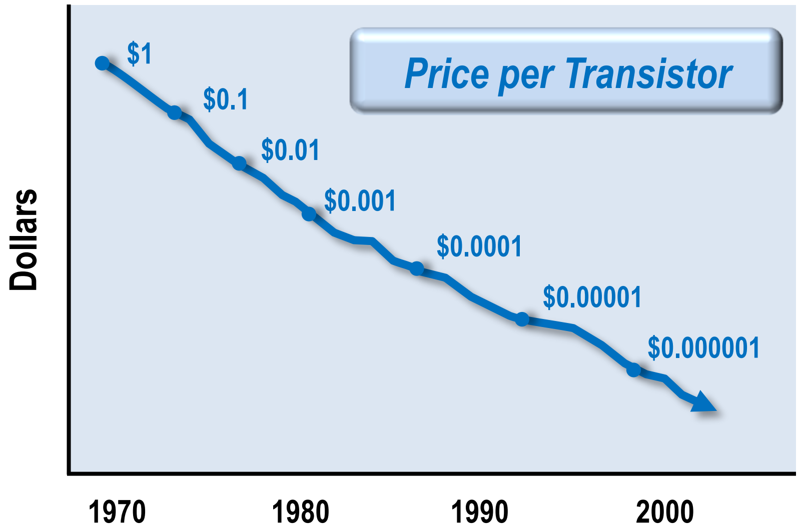


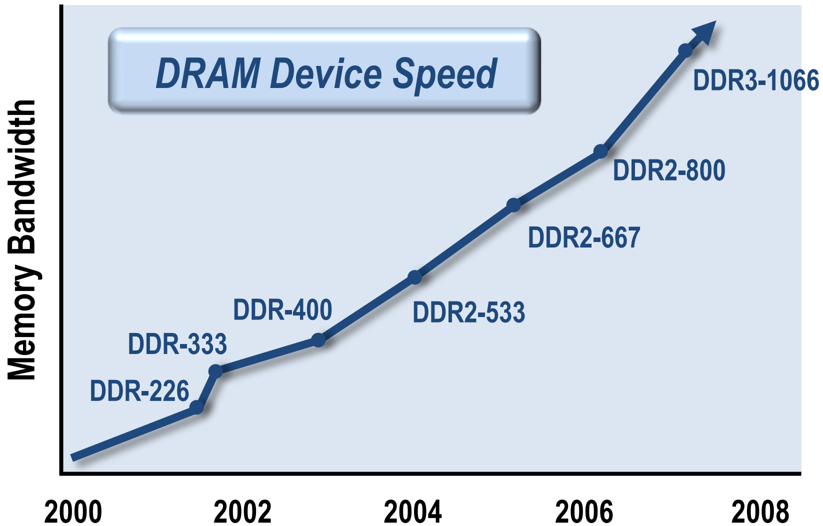
Moore’s Law Has Evolved Over Time



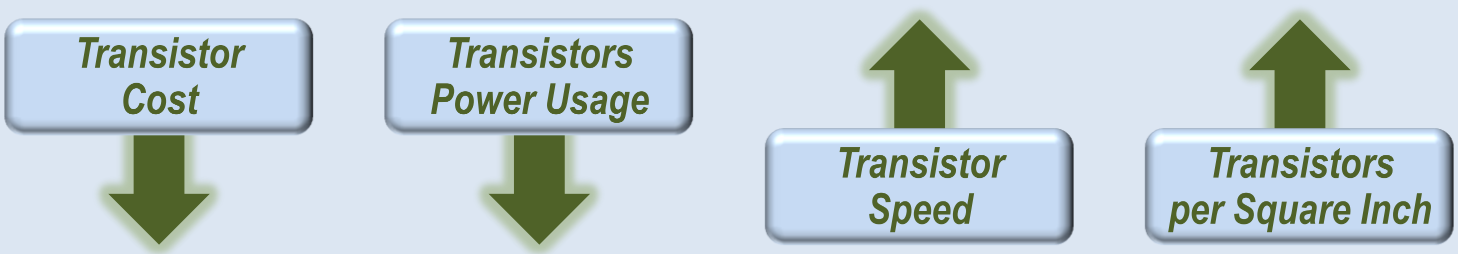
Source: Gordon Moore, ISSCC 2003 & Intel 2010

Implications of Moore's Law: Higher Performance, Lower Cost

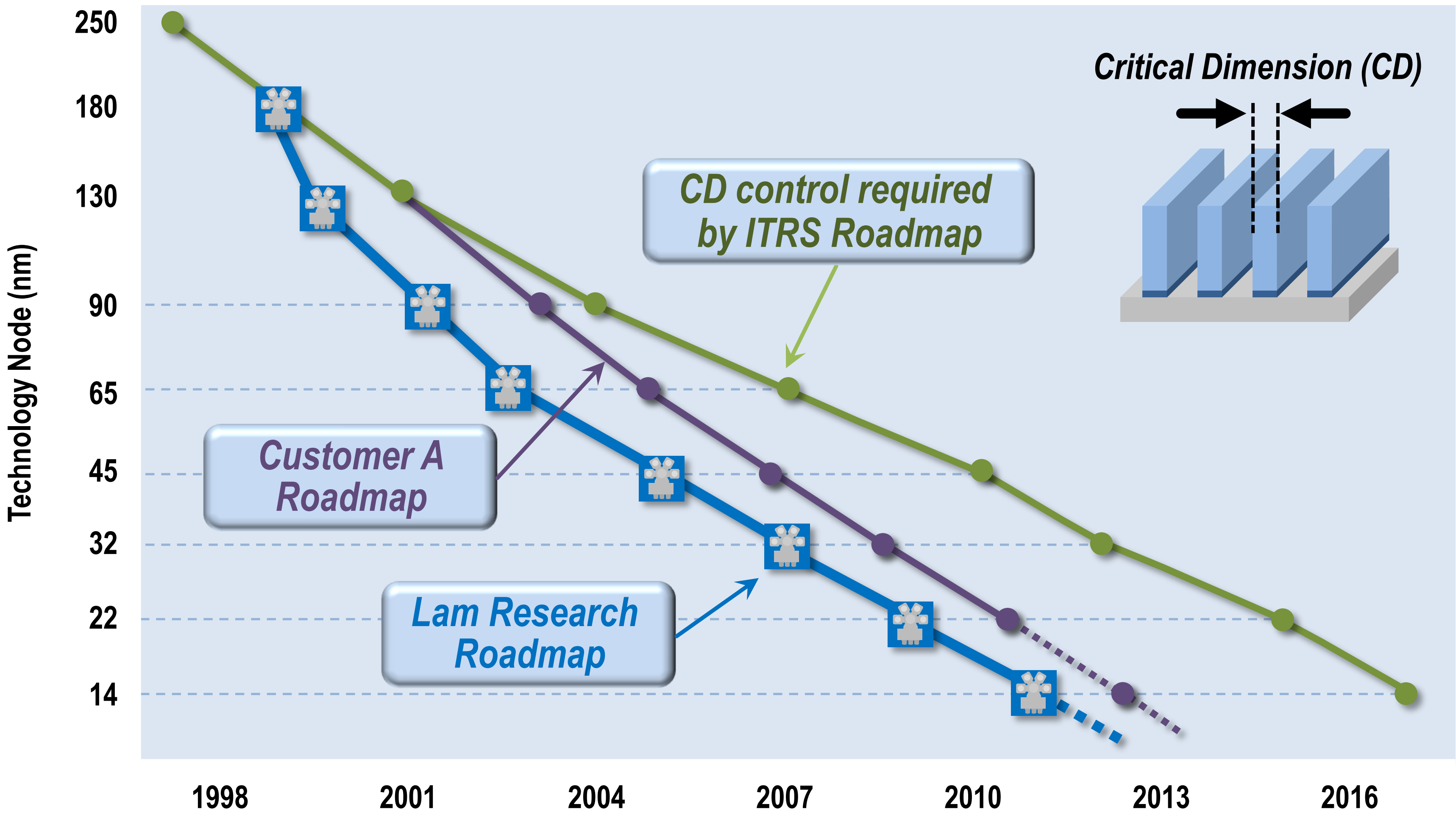




As transistor size gets smaller, everything gets better



Equipment Solutions must be ahead of customer needs to meet roadmap



Predicting the End of Moore's Law: Historical Perspective

Materials Limitations:

"Copper is an intractable material. The reason we don't use copper is NOT because we haven't tried over the years."

Device Physics Limitations:

"…we get to 0.05 micron [50 nm] in something like 2017…so that's the end of Moore's Law!"

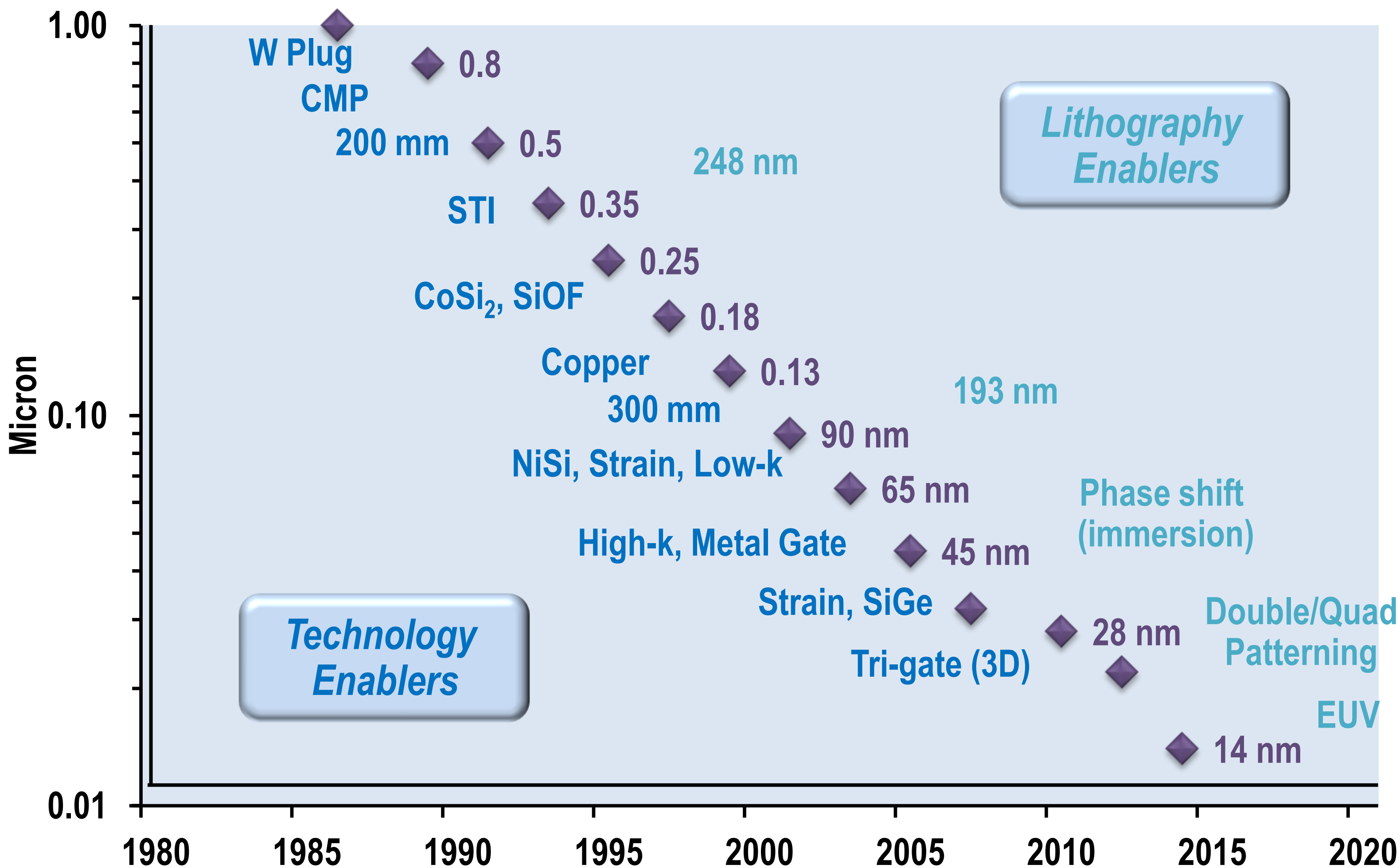
Lithography Limitations:

"[For lithography] to go down to 0.10 micron [100 nm]… there's hardly anything left at 193nm [wavelength]"

Uncertainty around the extendibility of Moore's Law has always existed

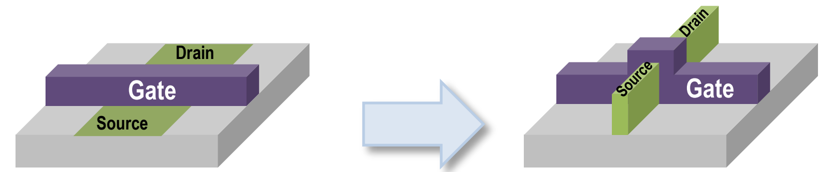
Source: "Moore's Law extended: The return of cleverness", *Solid State Technology*, July 1997

Continuous Innovation Enables Continuation of Moore's Law



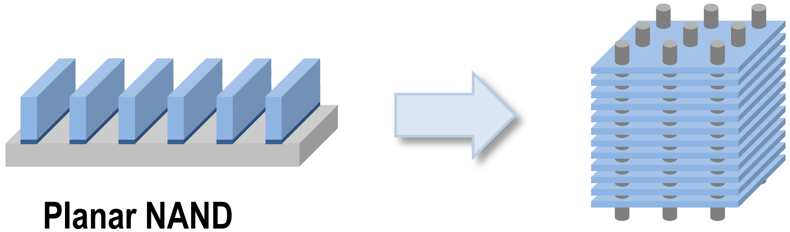
Technology Inflections Enabling Continuation of Moore's Law

- ***Logic/Foundry:*** **2D to 3D architecture**
  - FinFET structures at 20-14 nm
  - Additional metal layers in back-end-of-line (BEOL)



Planar MOSFET → FinFET

- ***Flash:*** **2D to 3D architecture**
  - New architectures likely introduced at the mid-to-low 1x node



Planar NAND → Vertical NAND

- ***Multiple patterning:***
  - Foundry leaders: DPT starting at 22 nm
  - Memory leaders: increasing DPT layers and going beyond double patterning

Litho-Only Patterning → Double Patterning (DPT) → Quadruple Patterning

Lam Research Corporation

Materials Used in Semiconductor Devices in the 1980's

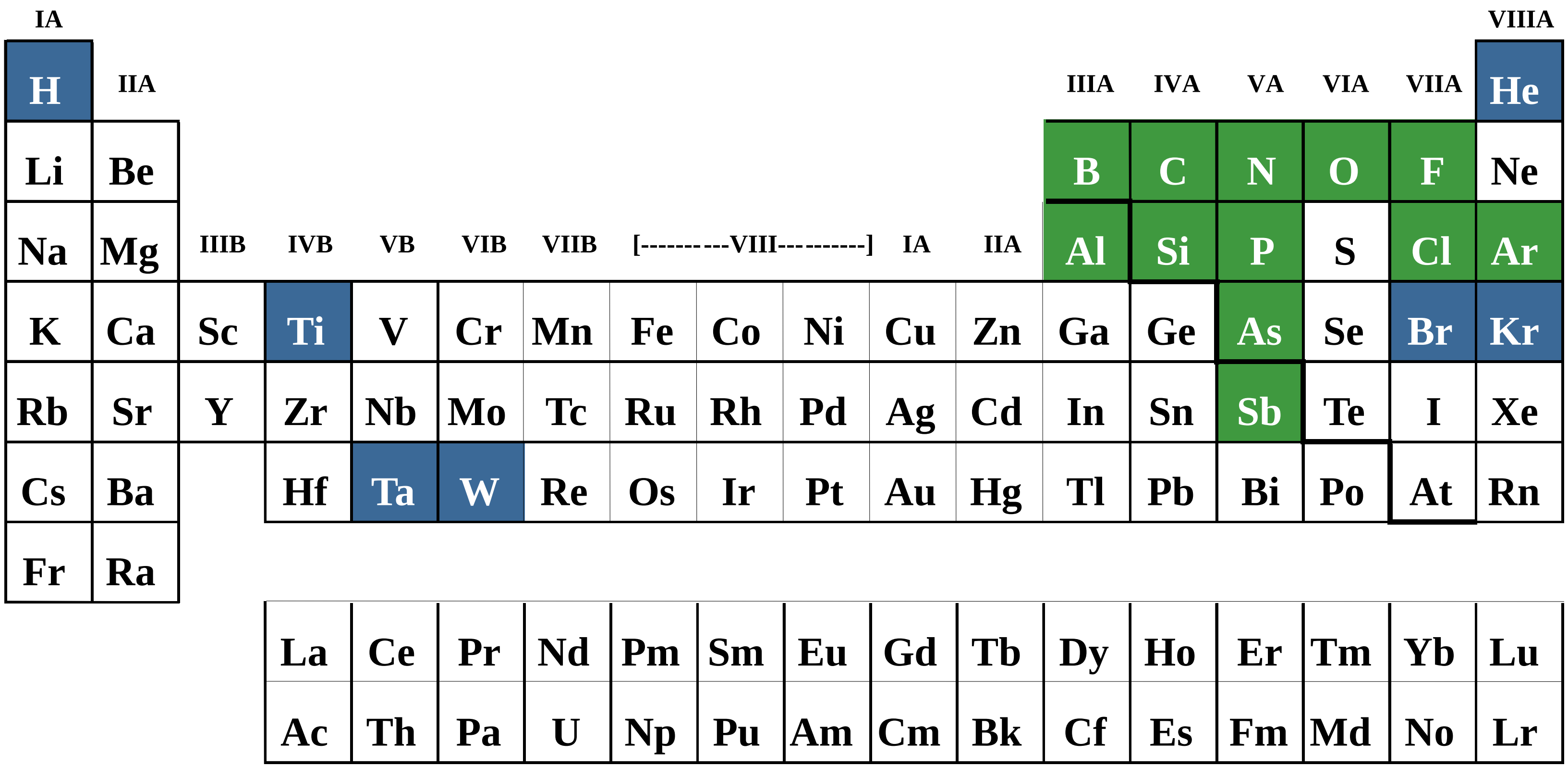
IA																	VIIIA
H	IIA											IIIA	IVA	VA	VIA	VIIA	He
Li	Be											**B**	**C**	**N**	**O**	**F**	Ne
Na	Mg	IIIB	IVB	VB	VIB	VIIB	[----------VIII----------]			IA	IIA	**Al**	**Si**	**P**	S	**Cl**	**Ar**
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	**As**	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	**Sb**	Te	I	Xe
Cs	Ba		Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra																

La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

Source: ITRS 2005, Lam Research

Materials used in the 80s

Materials Used in Semiconductor Devices in the 1990's



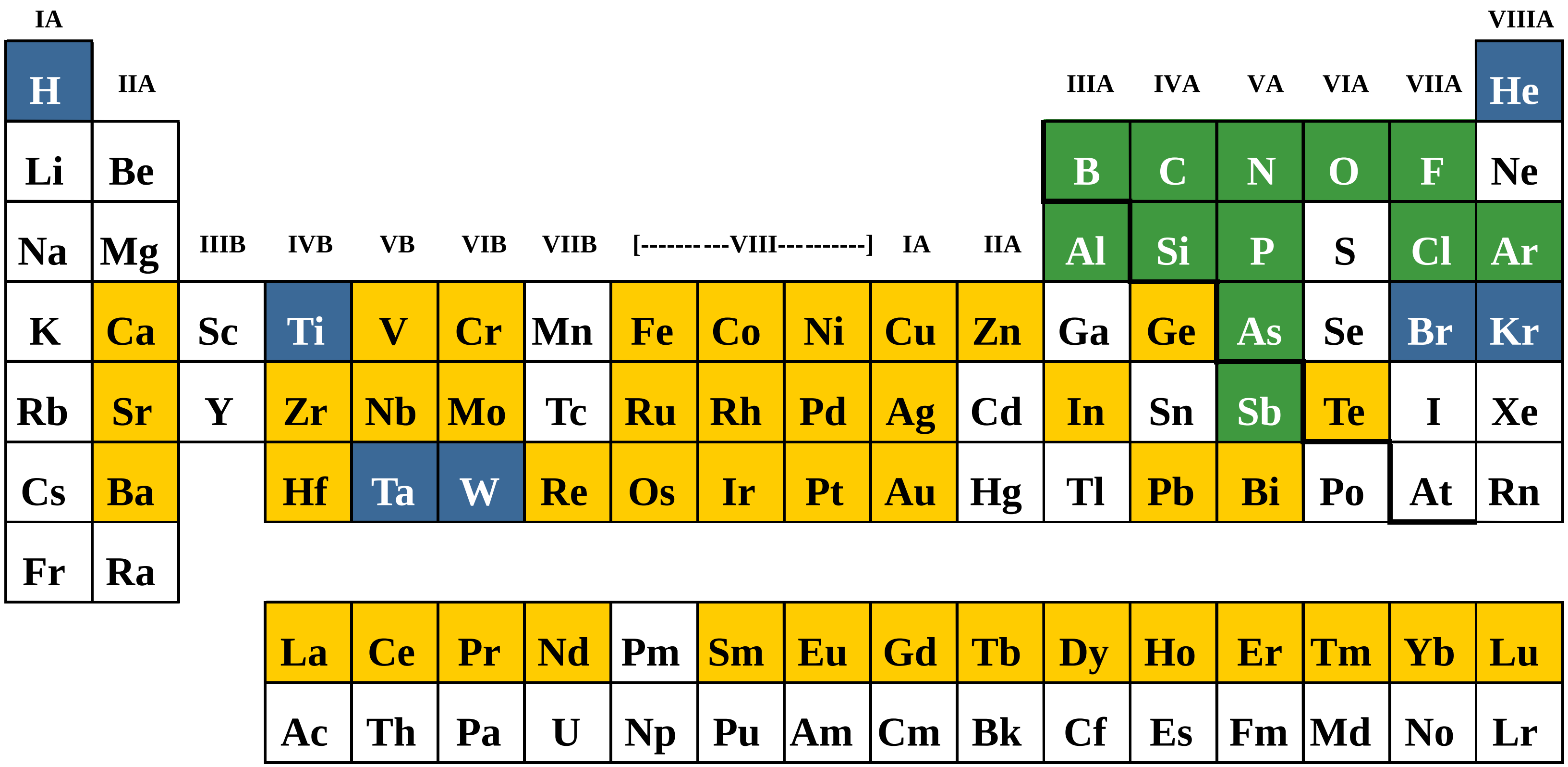
Source: ITRS 2005, Lam Research

Materials in the 80s

Materials added in the 90s

The Next Challenge – Growth in Potential New Materials

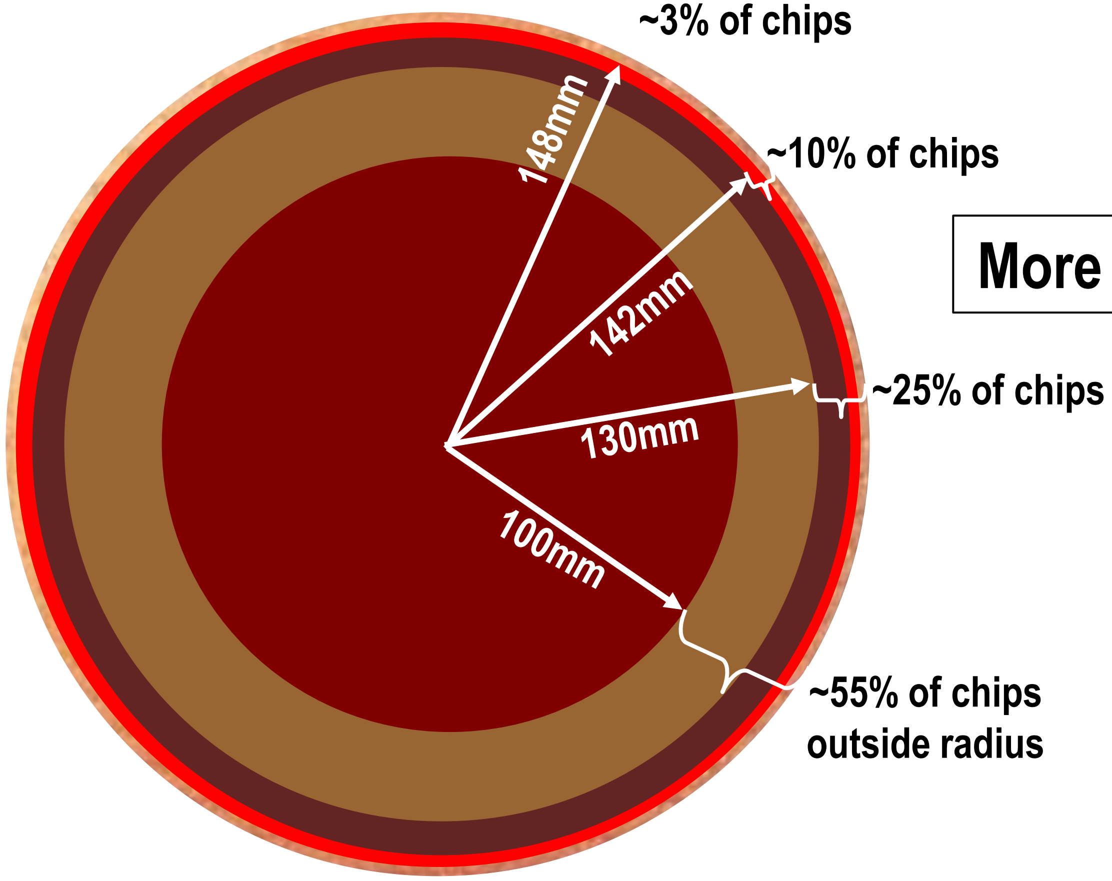
Etching and cleaning vastly different materials



Source: ITRS 2005, Lam Research

Materials in the 80s
Materials added in the 90s
Materials added or evaluated since 2000

The Edge of the Wafer Plays a Critical Role in Overall Economics



More good chips = More $$$$$

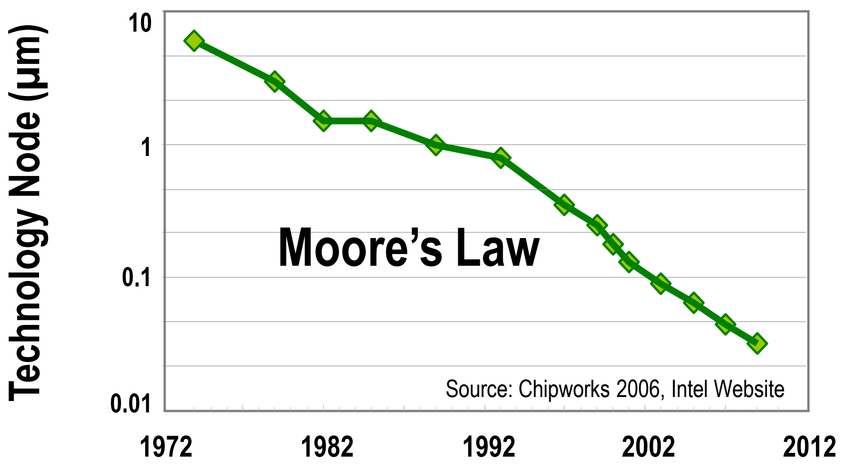
What variables define the available process space? - Etch Example

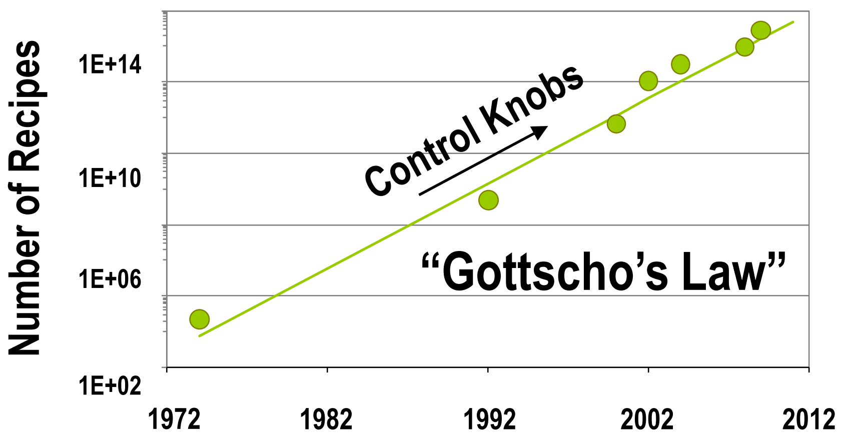
- List of Process Variables (# different settings that can change the result on a wafer)
  - Pressure (10mT, 20mT, … 100mT) = 10 settings
  - Reactant Gas #1 flow rate (0sccm, 10sccm, 100sccm) = 10
  - Reactant Gas #2 flow rate (0sccm, 1sccm, 10sccm) = 10
  - …
  - Reactant Gas #16 flow rate (0sccm, 100sccm, 500sccm) = 5
  - Power @ frequency #1 (0W, 100W, …, 3000W) = 30
  - Power @ frequency #2 (0W, 50W, …, 500W) = 10
  - Power @ frequency #3 (0W, 100W, …, 1000W) = 10
  - …

- 10 x 10 x 10 … x 5 x 30 x 10 x 10 x … = $10^{\text{(really big number)}}$

Now add in hardware and wafer variables…

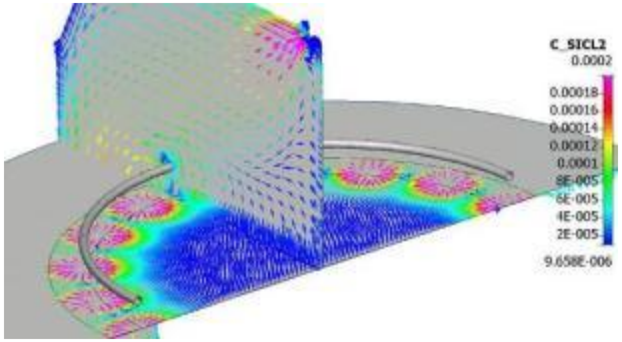
- Process Variables (different settings that can change the result on a wafer)
  - Pressure (10mT, 20mT, … 100mT) = 10 settings
  - Reactant Gas #1 flow rate (0sccm, 10sccm, 100sccm) = 10
  - Reactant Gas #2 flow rate (0sccm, 1sccm, 10sccm) = 10
  - …
  - Reactant Gas #16 flow rate (0sccm, 100sccm, 500sccm) = 5
  - Power @ frequency #1 (0W, 100W, …, 3000W) = 30
  - Power @ frequency #2 (0W, 50W, …, 500W) = 10
  - Power @ frequency #3 (0W, 100W, …, 1000W) = 10
  - …
- Hardware variables
  - Chamber diameter
  - Chamber heights
  - Chamber temperature
  - Wafer temperature
  - Chamber materials chemical properties
  - Chamber materials electrical properties
  - …
- Wafer variables
  - Material being etched
  - Type of mask (photoresist)
  - Percent exposed area of wafer being etched
  - Substrate resistivity
  - …





How Can We Possibly Pick "One in a Trillion"

- Learn from past experience (Knowledge Management).
- Use modeling to help narrow the space.
- Use sensors, diagnostics and "smart" software.
- Hire really smart and motivated people.
- Run lots of experiments.



Semiconductor Equipment Industry Career Opportunities

Semiconductor Equipment Industry Jobs

- Design/Hardware Engineer: Creates the knobs
- Supplier Engineer: Develops suppliers to make the knobs
- Process Engineer: Determines what knobs are needed and turns the knobs to optimize for customer applications
- Product Engineer: Optimizes the knobs
- Field Engineer: Solves problems with the knobs on site

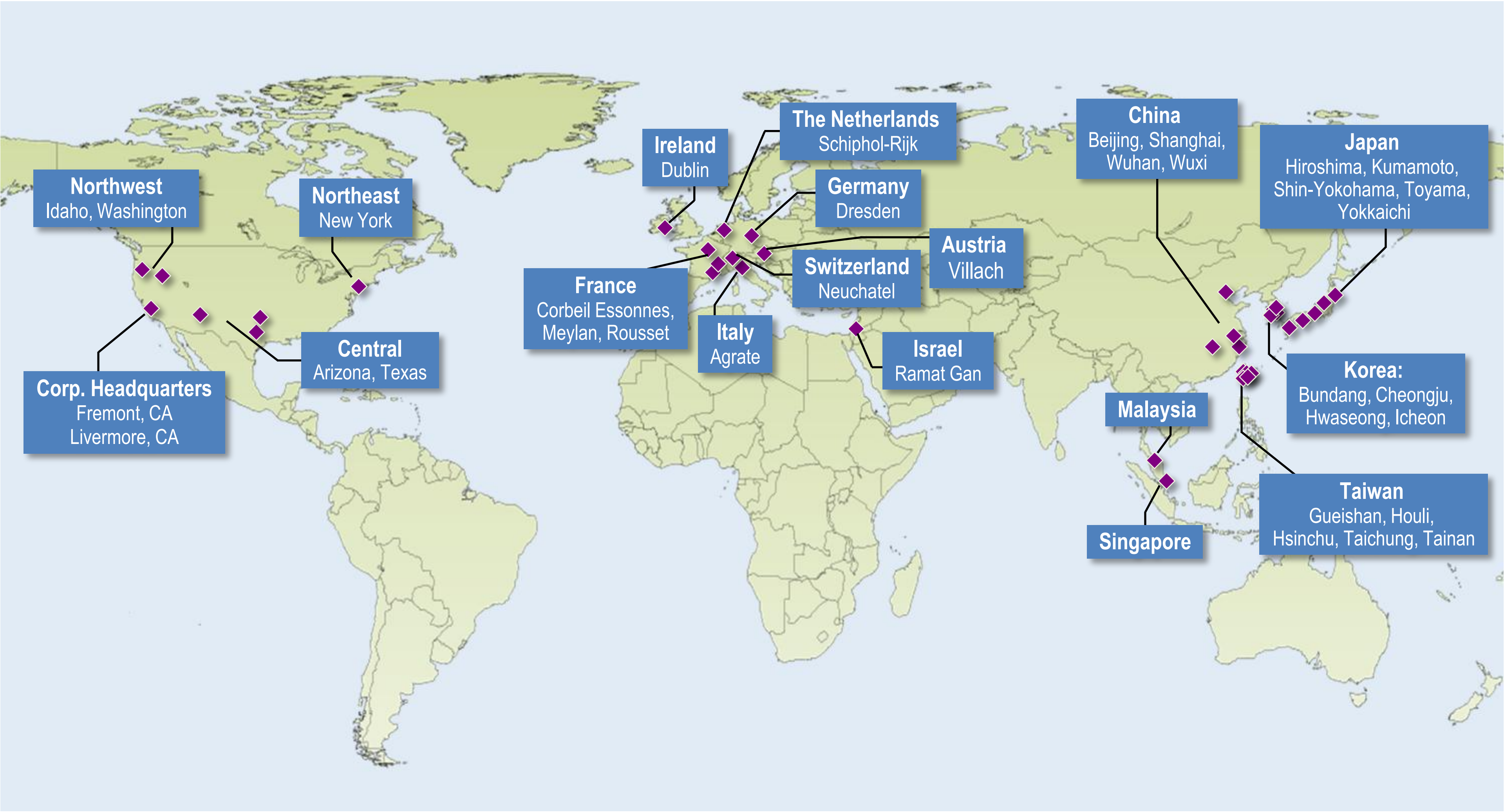
- Technical background and industry experience are required for many product development functions including Technical Marketing, Product Management, Supplier Business Management

Semiconductor Equipment Industry Employee Profile

Semiconductor Equipment Industry: Employee Profile

- Majors:
  - Physics
  - Chemistry
  - Engineering (Electrical, Chemical, Mechanical, Materials Science)
  - Computer Science
- Education: PhD, MS, BS
- Lam Research Statistics
  - Total Employees: >3800
  - Advanced Degrees: ~1200
  - PhD’s: ~400
  - UIUC Grads: 21 (13 PhD’s)
- Advanced degrees with experimental experience are preferred
  - Direct semiconductor experience is NOT required
  - Strong foundation in coursework and experimental work (wafer processing, vacuum, low temp, plasmas, metrology, transport measurements, optics, etc.)
  - Design, Simulation, and Modeling experience (CAD, FEA, CFD, plasmas, etc.)
  - Managing research projects (budget, plan, and build experimental setups, write proposals)
- Multi-cultural: Semiconductor Equipment is a global industry

Lam Research Global Support – Close to Our Customers



Transitioning from Grad School to the Semiconductor Equipment Industry

Similarities b/w Grad School and the Semiconductor Equipment Industry

- Have a passion for what you do – you are going to be doing it for a long time
  - Time from entering college to graduation with a PhD: ~8-11 years
  - Time in your career: >>20 years
- Learn at every opportunity
  - On the job, in the lab, coursework, outside reading, seminars
- Communication is critical
  - Good ideas can go to waste if not properly communicated
  - Confront small issues before they get big
- Hard work is necessary to maximize your opportunities
  - "The more you practice, the luckier you get."
- You have very few customers – treat them well
  - Grad School: Your advisor, your professors, colleagues
  - Industry: 70% of capital equipment purchases are made by 10 customers

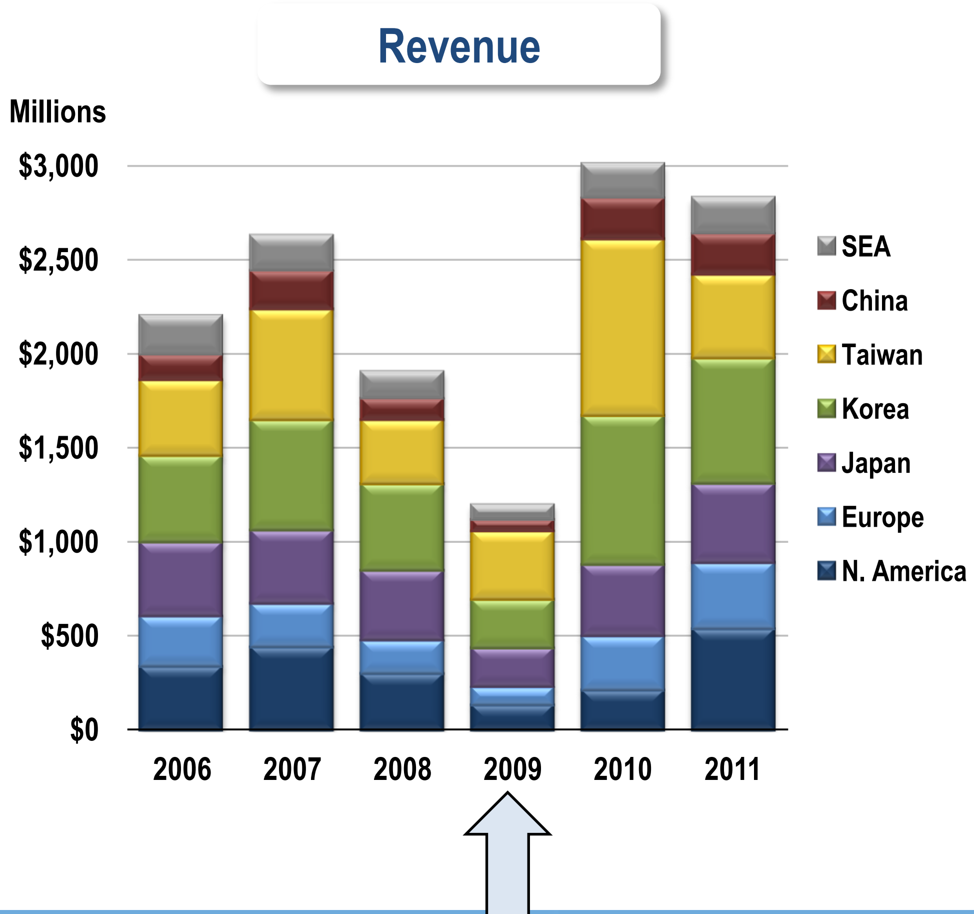
Differences b/w Grad School and the Semiconductor Equipment Industry

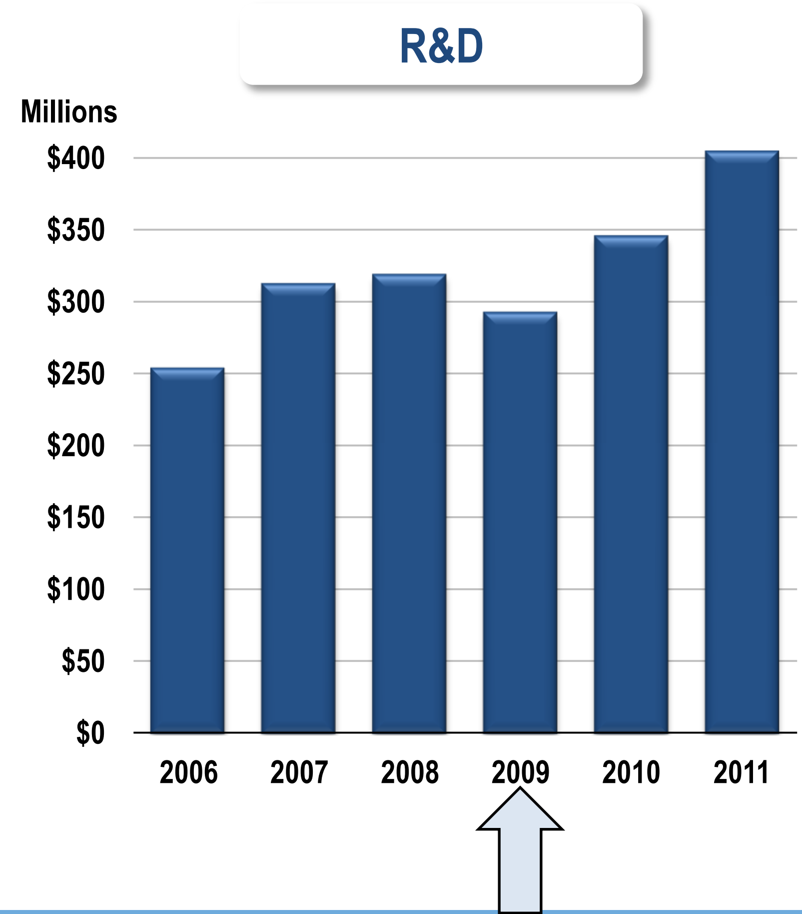
- The product is different (How you keep score)
  - Grad school: Teaching, learning (grades), papers, grants (Publish or Perish)
  - Industry: Selling goods and services for profit (Profit or Perish)
- The approach is different
  - Grad school: Learning on the job ➔ mistakes are expected and ok (as long as you learn from them); nothing is "beneath" you; prove a concept
  - Industry: Mistakes must be minimized; employees work on things at or above their grade level; prove in production
- The customer is different
  - Grad school: Work is directed by advisors, professors, and funding agencies based on broad guidelines; students are the primary users of experimental equipment
  - Industry: Work is dictated by shareholders, markets, competition, and detailed customer requirements; customers (operators) are the primary users of the equipment

    Not allowed: "Designed by PhD's for PhD's"
- The milestones are different
  - Grad school: Milestones are based on exam dates, graduation dates, conferences
  - Industry: Milestones are customer and finance driven; patents are part of development
- The money is different

Lam Research Continues to Invest Through the Cycles

- Revenue of $2.8B in CY 2011
- More than $1B invested in R&D over last three years
- R&D investment continues through downturns ➔ Moore's Lam holds through cycles





Keys to Success in the Semiconductor Equipment Industry

Keys to Success in the Semiconductor Equipment Industry

- Solve problems systematically
  - Know what problem you are trying to solve (Listen carefully)
  - Involve all stakeholders in the process
  - Know what success looks like
  - Determine the root cause and consider all solution options
  - Implement the solution and make sure it sticks
- Set aggressive targets for yourself and achieve them
- Make data-driven decisions
- Be a leader, not a "status-er"
- Be a simplifier, not a complicator ➔ know when to focus
- Communicate openly (up, down, left, and right) and ask for help before the situation is irresolvable (no surprises)
- Demonstrate Versatility, Flexibility, and Agility (if business changes, you adapt)
- Demonstrate Core Values
- Remember that the customer is always right**
- And…..

Be

FAST to Customer Solutions™

Lam RESEARCH

The results…

Conductor Etch

2300® Kiyo® Product Family

Dielectric Etch

2300® Flex™ Product Family

Metal Etch

2300® Versys® Metal Product Family

TSV Etch for 3-D IC

2300® Syndion®

MEMS & Deep Si Etch

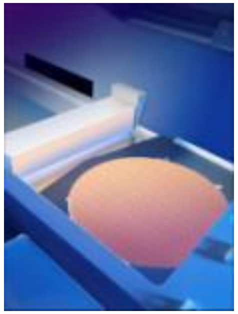
TCP® 9400DSiE™ Product

Spin Wet Clean

DV-Prime™

Linear Wet Clean

2300® Serene®



Plasma Bevel Clean

2300® Coronus®

… technology driven products enabling Moore's Law.

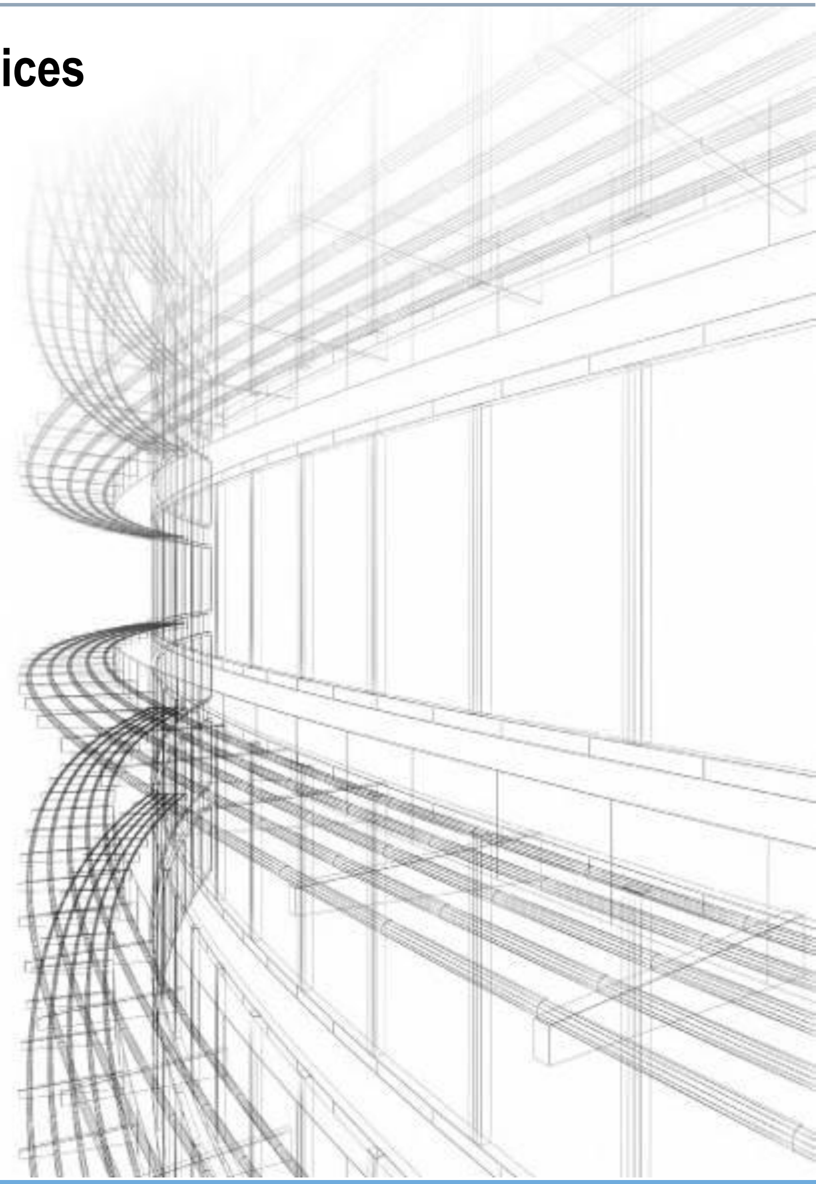
Acknowledgements

- Professor Lance Cooper for giving me the opportunity to speak today
- Dave Hemker, Lam VP of R&D, for many of the introductory slides
- Jim Bagley, Lam Chairman, for excerpts from his “Top 10 things a manager should do” presentation
- Steve Newberry and Martin Anstice, former and current Lam CEO’s, for excerpts from the “Lam Problem Solving and Decision Making Process”
- Lam Corporate Marketing Team for Lam and industry overview slides

FAST to Customer Solutions™

Lam Research at a Glance

- Major supplier of wafer fab equipment and services
  - Headquartered in Fremont, California, with facilities in Asia, Europe, and North America
  - ~3,850 Employees worldwide
  - Revenue of $2.8B in CY 2011
- Etch and Clean product lines offer leading technologies for performance and extendibility
  - Conductor, dielectric, MEMS, deep silicon, and through-silicon via (TSV) etch
  - Wet and plasma-based single-wafer clean
- Customer Support Business Group (CSBG) dedicated to optimizing installed equipment performance and operational efficiency



Lam Research: Mission, Vision, and Core Values

Mission:

Lam Research is dedicated to the success of our customers by being a world-class provider of innovative productivity solutions to the semiconductor industry.

Vision Objectives:

- #1 in customer trust
- #1 in market share
- A company where successful people want to work
- A multi-product company
- Financial performance appropriate to:
  - Support the productivity solutions our customers require
  - What our shareholders expect

Core Values:

- Achievement
- Ownership and accountability
- Mutual trust and respect
- Honesty and integrity
- Innovation and continuous improvement
- Open communication
- Teamwork
- Think: customer, company, individual

Lam Research Product & Technology Milestones

1980 | 1985 | 1990 | 1995 | 2000 | 2005 | 2010 | 2015

- First product, AutoEtch
- Rainbow® Etch Series
- Invented spin technology for single-wafer clean
- Transformer Coupled Plasma™ based products for silicon and metal etch
- Alliance® cluster tool platform for etch
- Dual Frequency Confined™ technology for dielectric etch
- 2300® platform offers first 200 mm/300 mm capability
- Da Vinci® spin clean platform
- 2300® Exelan® Flex™ & 2300® Versys® Kiyo® for dielectric & conductor etch
- DV-Prime® next-generation spin clean system
- 2300® Coronus® plasma bevel clean system
- 2300® Syndion® system, first 300 mm TSV etch
- 2300® Kiyo® C Series conductor etch system
- 2300® Flex™ D Series dielectric etch system
- Shipped 7,500th etch process module for the 2300® platform
- Shipped 3,000th single-wafer spin clean process module
- Next-generation 2300e4® & 2300e5® platforms

Lam Research – Where Successful People Want to Work

Company

Advancing semiconductor manufacturing for more than 30 years

- Market share leader
- Financially sound
- Operations excellence
- Open and collaborative environment that fosters innovation

Leadership

Experienced management team with proven record of success

- Lam's senior management recognized among the best leaders in the industry
- Technology experts in Etch and Clean
- Local management in each region

Employees

Experienced, talented, and dedicated global workforce

- Multi-cultural and diverse
- Actively demonstrate Lam's Core Values
- Cross-functional teams work in collaborative environment
- 75% of promotions from within the Company

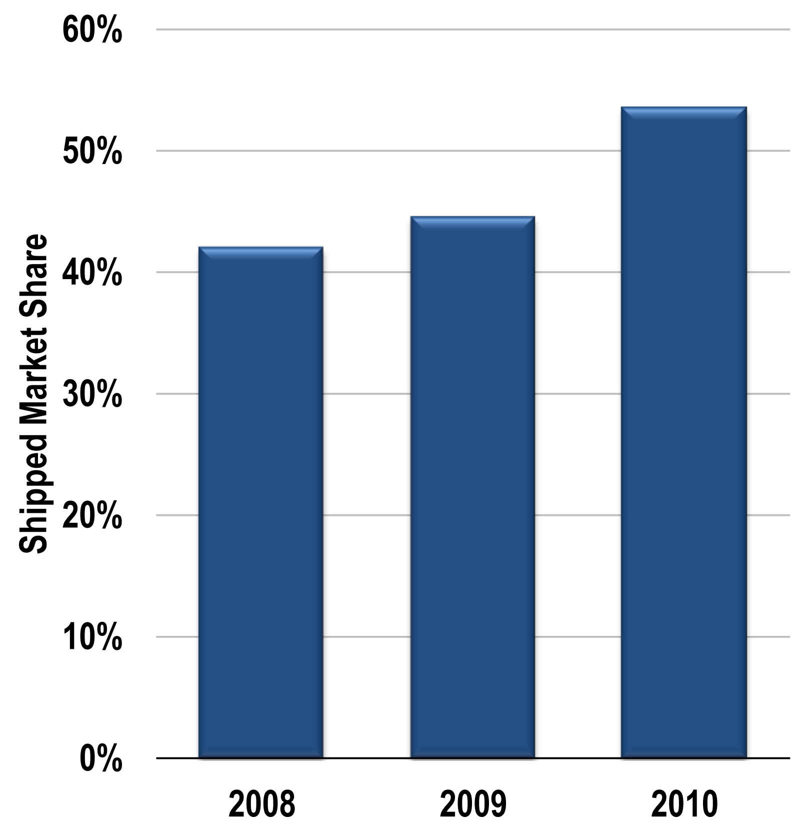
Community

Extension of the Company's Core Values into our employees' communities

- Lam Research Foundation grants
- Core Values Scholarship program
- Employee gift/volunteer time matching
- Food drive, toy drive, blood drives, and other outreach activities

Lam Research Is #1 in Etch Shipped Market Share

Rank	2007	2008	2009	2010
1	Lam Research	Lam Research	Lam Research	Lam Research
2	Tokyo Electron	Tokyo Electron	Tokyo Electron	Tokyo Electron
3	Applied Materials	Applied Materials	Applied Materials	Applied Materials
4	Hitachi	Hitachi	Hitachi	Hitachi



Lam Research surpassed 50% market share in 2010

Source: Lam Research Corp.

FAST to Customer Solutions™

Lam Research