The SEMATECH New York Experience

Growing the Semiconductor Industry in New York: Challenges and Opportunities

Dan Armbrust
President and CEO, SEMATECH
April 4, 2013
Semiconductor Industry

*Virtuous cycle*

- More R&D (innovation)
- Lower cost/function
- Increasing semiconductor revenue
- Expanding applications (more silicon)

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Moore's Law

Microprocessor Transistor Counts
1971-2011 & Moore’s Law
Semiconductor Industry

Virtuous cycle

More R&D (innovation)  Lower cost/function

Increasing semiconductor revenue  Expanding applications (more silicon)

$’s

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SEMATECH Context
Semiconductor supply chain

Industry structure: then and now

Integrated Device Manufacturer (IDM)
- Systems
- Design
- Packaging and Assembly
- Chip Technology
- EDA Tools

Equipment and Materials

System
- Memory Logic IDM
- Fabless Fablite
- Foundries
- Package and Assembly
- EDA Equipment Materials

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## Industry Challenges

### Key stakeholders

<table>
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<th>Scaling</th>
<th>AMS, MEMs &amp; Sensors</th>
<th>EUV</th>
<th>3D Interconnect</th>
<th>Factory Productivity</th>
<th>450 mm</th>
<th>ESH</th>
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*Technology roadmap participant*
Too Many Challenges to Solve Alone

- Success in semiconductors is driven by technology innovation and advances in manufacturing
- Success depends on comprehensive industry-wide collaboration
  - Challenges are global, and cut across industry ecosystem
  - Solutions require significant investment, leveraged funding
SEMATECH Overview

History

- **1987**: SEMATECH created
- **1995**: Formed subsidiary for 300 mm wafer conversion
- **2000**: Expanded membership to include industry supply chain companies
- **2003**: Entered alliance with New York State (Phase I)
- **2007**: Created subsidiary for manufacturing
- **2008**: Continued alliance with New York State (Phase II)
- **2010**: SEMATECH and CNSE launch PVMC
- **2011**: 450 mm wafer conversion G450C
Bridging Research, Development, and Manufacturing

- A membership-driven global consortium
- Driving technical consensus for the industry
- Pulling research into the industry mainstream
- Leading major programs to address critical industry transitions
- Focus on manufacturability
SEMATECH Members
# SEMATECH Programs Attract Growth

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<th>2007</th>
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<td>Texas Instruments (ESH)</td>
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New members since 2007:
- Canon-Anelva (FEP)
- ASML (FEP)
- AMD (ISMI)
- Freescale (ISMI)
- Infineon (ISMI)
- NXP (ISMI)
- STMicro (ISMI)
- AMD (ISMI)
- Nissan Chem (Litho)
- KLA-Tencor (Litho)
- Infineon (ISMI)
- Micron (ISMI)
- Aixtron (FEP)
- Soltec (FEP, Met)
- Dal Nippon Screen (FEP)
- Hoya (Litho)
- Texas Instruments (ESH)
Consortium Success Factors

• A clear industry-led model and mission
• Leadership from industry champions
• Industry with adequate revenue and maturity
• Ideally, a crisis
• Leveraging of government and industry funds
• Member engagement
• Agility to adapt to changing needs
Industry/University/Government Collaboration in Albany

CNSE Albany NanoTech Complex

Investment to date: more than $14 billion
Facility space to date: 800,000 square feet
Employees onsite: 2,750

- Lithography
  - EUV Mask Blanks
  - Resist Center
- 3D Interconnect
- Front End Technologies
- Metrology
- Manufacturing

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R&D Costs

(Worldwide in $M)

Semiconductor revenue

Total R&D

Source: IC Insights
Trends & Challenges

• Rising R&D costs; fewer funders
• Consolidation – device makers, supply chain
• Supply chain challenges
  — Insufficient early feedback
  — Affordable infrastructure
  — Broken business models
  — Greater share of the R&D burden
• Increasing need/pressure to collaborate
• A growing and compelling collaborative model in Albany and clear pathway to 450 mm activities
SEMATECH Focused on Materials & Nanostructures

Advanced Materials
- 2009: Bulk/SOI Si, Gate stack
- 2011: Bulk/SOI Si, Channels, contacts, USJ
- 2013: High μ Fin/NW
- 2015: Si Fin/Gate, High mobility Fins/Nanowires
- 2017: NEMS

Advanced Structures
- 2009: HfOx, Si, Metal High-k InGaAs
- 2011: SEMATECH Si Nanowire
- 2013: Graphene
- 2015: TFET
- 2017: Control STEEP

Beyond CMOS Materials/Structures
- 2019: Graphene

LOGIC
- 2009: CT Flash
- 2011: ReRAM
- 2013: 1T DRAM
- 2015: <20 nm ReRAM
- 2017: STTRAM
- 2019: ReRAM/Nanowire 3DArray

MEMORY

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**Technology Gap**

Early learning and infrastructure development

**Solution**

SEamatech Center for Next-Generation Devices

- R&D center that *champions* and *enables* next-generation technologies
- Participation from universities, equipment and materials makers, and chip manufacturers
- Establishes complete pilot line for research, development, manufacturing enablement

- Atomic-level chemistries
- <10 nm advanced structures
- Simulation
- Fabrication flows
- Nanoscale equipment
Lithography Scaling

Year

Microns


6.1 μm (Nodes)

3 μm

2 μm

1.5 μm

1 μm

0.8 μm

0.7 μm

0.5 μm

0.35 μm

356 nm

248 nm

193 nm

193 nm wet

400 - 440 nm

436 nm

180 nm

130 nm

90 nm

65 nm

45 nm

32 nm

22 nm

15 nm

13.5 nm

EUV
EUV Progress

Critical enablers

- First EUV tools installed in Albany & Belgium
- EUV is REAL Bacus/EUV Symposium
- EUV Mask Consortium EMI
- 3100’s in the Field
- EUV in Dev @ IDMS

<table>
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<tr>
<th>Year</th>
<th>Source power</th>
<th>Defect-free mask</th>
<th>Resist resolution</th>
<th>Reticle protection</th>
<th>Optics quality</th>
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<td>2009</td>
<td>&gt;100 W @ IF reliable source required</td>
<td>~10-50X defect reduction required for HVM</td>
<td>LWR needs 2X improvement for MPU (OK for Memory)</td>
<td>Commercial reticle handling solution available</td>
<td>3300 optics complete</td>
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- Overcome 30 nm resolution brick wall
- Integrated reticle handling 0 defects
- <4% flare optics

Source: www.sematech.org
Technology Gap

Underinvestment in EUV mask metrology equipment

Solution

SEMATECH EUV Equipment Manufacturing Initiative (EMI)

- Advanced defect metrology for EUV
- Large prototype investment
- Uncertainty in timing
- Common infrastructure
Technology Gap

Lack of affordable early access to EUV imaging

- Limited access to EUV tools for research
- Need for early full-field exposures

Solution

SEMATECH Resist and Materials Development Center (RMDC)

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<th>Systems &amp; Design</th>
<th>Development</th>
<th>Manufacturing</th>
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<td>IDM &amp; Foundries</td>
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- Albanyt ADT (0.25 NA)
- SEMATECH Albany MET (0.3 NA)
- SEMATECH Berkeley MET (0.3 NA)

Materials Processed by RMDC

- 2008: 1000
- 2009: 2000
- 2010: 3000
- 2011: 4000
- 2012: 5000
Technology Gap

Insufficient defect identification and mitigation

- As defect requirements become more stringent, interdisciplinary knowledge is needed to understand defect generation processes
- Characterizing small-sized defects is costly and time consuming

Solution

SEMAPTECH Nanodefect Center

- Centralized facility providing a critical mass of expensive infrastructure with extensive forensics and analytical capabilities
New Solar Consortium – U.S. PVMC

- Launched the U.S. Photovoltaic Manufacturing Consortium (PVMC) in September 2011 with CNSE
- Public/private investment of ~$300M over 5 years from U.S. Department of Energy ($62M from SunShot Initiative), industry, New York State
- Partnership with ~40 companies and organizations throughout the industry supply chain

Facilities and Equipment Scale-Up Strategy

- **R&D**
  - Lab Scale & Testing
  - NREL, Sandia, CNSE, Industry, University

- **Pilot Prototyping**
  - 100 kW
  - PVMC, Halfmoon, NY

- **Manufacturing Development**
  - 10 MW
  - PVMC, NY

- **Manufacturing**
  - >100 MW
  - Industry Sites
Lessons Learned from SEMATECH’s Proven Consortium Model

- Need an ambitious national and regional strategy to drive broad collaboration at sufficient scale to:
  - Build R&D and manufacturing infrastructure
  - Provide access to pilot facilities to demonstrate innovations at manufacturing scale
  - Create technology roadmaps and standards
  - Conduct both collaborative and proprietary technology programs

- SEMATECH has benefited enormously from the shared capabilities at CNSE in Albany, with consistent NY State government support

- Industry participation in NY will continue to expand across the semiconductor industry’s supply chain and into adjacent industries

- It’s all about shared public and private investments in infrastructure and ecosystems