Collaboration:
The Semiconductor Industry’s Path to Survival and Growth

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President and CEO
SEMATECH
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Outline

• Environment
  – Economic Challenges
  – Technology Challenges

• Solutions
  – Innovation and Manufacturability through Collaboration
    • SEMATECH examples
“The future ain't what it used to be...”

- Yogi Berra
The Electronics Ecosystem

Global GDP: $36,356T
Electronics: $1,240B
Semiconductors: $213B
Semi. Equipment: $52B
Materials: $28B

Making the world

SMALLER
Growth may slow, but will continue…

Worldwide Semiconductor Market

Sources: Gartner Dataquest and SIA, February 2004
Business Challenges

The new economy for microelectronics

- **Affordability**
  - Increasing costs
    - Capital
    - Manufacturing
    - R&D

- **Manufacturability**
  - Fab and equipment productivity
Semiconductor Manufacturing Challenge

Wafer Fab Cost Trend

Source: IC Insights, Inc. Mclean Report, 2004
Semiconductor R&D Challenge

Chip Making R&D Versus Revenues

Source: VLSI Research Inc., 2004
International Technology Roadmap for Semiconductors

Minimum Feature Size (nm) (DRAM Half-Pitch)

- 1994
- 1997
- 1998/1999
- 2000
- 2001
- 2003/2004

Technology Challenges
Innovation required

Still no known solutions in many areas:
- Lithography
- Front End
- Interconnect
- Metrology

Source: ITRS 2004
Future Transistors
Non-classical CMOS will take us through next 15 years

Many Approaches

UTSOI MOSFET
(100)

Gate

FinFET

Fin

(110)

nMOS MOSFET

pMOS FINFET

Sub 10 nm Beyond CMOS
Already Demonstrated

Transistor on thin SOI

Source: Bruce Doris (IBM)
Future Patterning

Traditional

- Light
- Reticle (mask)
- Lens
- Pattern being repeated onto wafer
- Wafer (with photoresist)

Immersion

- Liquid supply
- Liquid recovery
- Projection optics
- Wafer stage
- Immersion liquid
- (Scanning motion)

EUV

- Drive laser beam
- Reticle stage
- C4 element
- Projection optics
- Wafer stage
- C1 collector
- Gas jet assembly
- Laser-produced plasma
- C2, C3 pupil optics
- Spectral purity filter

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Future Connectivity

2003-2008

- \( k_{\text{eff}} \sim 3.1-3.6 \)
- \( k_{\text{eff}} \sim 2.7-3.0 \)
- \( k_{\text{eff}} \sim 2.3-2.6 \)

Cu Low k & Reliability

Determine; Roadmap
Timelines
Critical Needs

Projects

3D

Optically active Molecules
Nanotubes

Optical Interconnects

Next Generation Interconnect

SEMA TECH
accelerating the next technology revolution.
Future Metrology
CD-SEM of the Future?
Migration of TEM LENS Technology to SEM

Today
- FE source
- Lens
- Scanning coils
- Secondary Electron Detector
- Sample Stage
- Wafer
- Top Down Image
- Tilt Beam for sidewall metrology

Tomorrow
- FE source
- Aberration Correction Lens
- Secondary Electron Detector
- Scanning Coils
- Wafer
- Lens
- Sample Stage
Future Manufacturing

Active ISMI Project
Future projects

On-line Specs & Tool Maintenance Manuals

Faster Cycle time
Fabs for Hot Lots & High Mix

Predictive Maintenance

100% Direct Transport AMHS for Fast Cycle Time

Wafer Level Tracking and Recipe/Parameter Changes

Equipment Data
Efficient Spares Management
Acquisition (EDA) for Rich Standardized Data

Large Scale
Process Control Systems

SECS Control Line

Rapid Process Matching

Equipment Engineering Capabilities (EEC)

Manufacturing Execution Systems

R2R FDC SPC Recipes

Equipment Control Systems

Yield PCS e-Diag. EPT

Factory Scheduler And Material Control

Equipment Data

Partner, Customer Or Supplier

Pervasive Remote Diagnostics

Today
10 chambers
10 variables per chamber
3 Hz rate each
300 values per sec

EDA Goal
10 chambers
50 variables per chamber
10 Hz rate each
10,000 values per sec

SEATECH
Accelerating the next technology revolution.
The New Economy for Microelectronics

• Slower growth of industry foreseen, compared to last 30 years
• Escalating R&D, capital, and manufacturing costs
  – A new factory at 90nm technology on 300mm wafers has a capital cost of $2-3B
  – Rising technology R&D product cycle costs
• Staggering technology challenges
  – 193 immersion/EUV, high/low-k, masks, 3D interconnect, 300mm/450mm
• Changing business models in the industry
  – Foundries, fabless and fab-lite
  – New alliances and partnerships
Collaboration at All Levels

- **Device manufacturers**
  - Crolles cluster: Freescale, Philips, STMicro, TSMC
  - IBM cluster: AMD, IBM, Infineon, Samsung

- **Equipment and materials suppliers and device manufacturers**
  - SEMATECH, Selete, individual companies

- **Universities**
  - SRC/MARCO Focus Centers
  - SEMATECH AMRC programs

- **Governments**
  - Texas Advanced Materials Center
  - Albany Nanotech
  - IMEC

- **Suppliers**
SEMATECH: Focus on Innovation and Manufacturability

- SEMATECH is the catalyst for accelerating the commercialization of technology innovations into manufacturing solutions
  - Accelerated commercialization of university research (AMRC)
  - Advanced technology innovations (SEMATECH)
  - Manufacturing productivity (ISMI)
  - World-class R&D processing & prototyping (ATDF)

- Benefits of collaboration
  - Save money
  - Reduce risk
  - Accelerate development
  - Increase productivity
SEMATECH
Accelerating the next technology revolution

SEMATECH
Accelerating the next technology revolution
FOSTERING INNOVATION
Advanced Gate Stack for 45nm Node
Fundamental Materials Understanding

Began high-k program with Ta₂O₅, TiO₂, etc

FEP-RC identified HfO₂

Hf based oxide

Metal/high-k stack

Implementation strategy

Aggressive targets for HP 45nm node

EOT ~ 0.6nm

µ ~ 65%

85%

90%

Electrical test methods

Metal electrode materials

SEMATECH FEP/Advanced Gate Stack Program

SRC/FEP-RC

SRC/FEP-TC

AMRC

Suppliers

Working with more than 40 universities, suppliers, and consortia
Advanced Materials Research Center

State of Texas

SEMATECH

Select Semiconductor Programs

Advanced Materials Research Center (AMRC)

Select programs in: Semiconductors, Nanotechnology

Texas Universities

Attributes
- Accelerate commercialization from universities to corporate products
- Provide technology pipeline
  - Fundamental understanding
  - High-quality students, technical skills

Structure/Scope
- Participating facilities include:
  - SEMATECH/ATDF
  - Microelectronics Research Center
  - Texas Materials Institute
  - Center for Nano & Molecular Science and Technology
- Focus on future transistors, interconnects, patterning, metrology; emerging nanotechnology applications
<table>
<thead>
<tr>
<th>Topic</th>
<th>Details</th>
<th>UT Lead</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced CMOS Materials &amp; Processes</td>
<td>Gate Stack Materials</td>
<td>Lee</td>
<td>PVD High-K Dielectrics: Reliability Issues</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Kwong</td>
<td>Materials and Structures fmg and Characterization of Key Issues Related to High-K Gate Dielectrics and Metal Gate Electrodes</td>
</tr>
<tr>
<td></td>
<td>Channel Materials</td>
<td>Register</td>
<td>Modeling of Gate Stack Materials</td>
</tr>
<tr>
<td></td>
<td>Ultra-Shallow Junctions</td>
<td>Banerjee</td>
<td>Ultra Shallow Junctions</td>
</tr>
<tr>
<td>Beyond CMOS Novel Transistors</td>
<td>New Transistors on Strained Silicon + SOI</td>
<td>Singh / Banerjee</td>
<td>Novel Transistors: Multi-gate SOI MOSFETs, FinFETs, and Vertical MOSFETs</td>
</tr>
<tr>
<td></td>
<td>NanoTechnology</td>
<td>Register</td>
<td>Transport Models for Strained Si and FinFETs</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Dodabalapur</td>
<td>Advanced Organic/Silicon Devices for chemical and Biosensing</td>
</tr>
<tr>
<td>Materials and Structure for Future Transistors (FEP)</td>
<td></td>
<td>Ekerdt</td>
<td>Quantum Dot Floating Gate Flash Memories</td>
</tr>
<tr>
<td>Advanced Cu &amp; Low-K Interconnects</td>
<td>Barrier Materials / Low-k</td>
<td>Ekerdt / White</td>
<td>Ultra Thin Diffusion Barrier and Pore Sealing Techniques for 45 nm and Beyond</td>
</tr>
<tr>
<td>Future Connectivity</td>
<td>Nano-Conductors / Low-k</td>
<td>Ho</td>
<td>Nanoconductors for Future Interconnects</td>
</tr>
<tr>
<td></td>
<td>3-D Technology</td>
<td>Neikirk</td>
<td>Measurement, Electrical Characterization, and Design of Advanced Interconnects</td>
</tr>
<tr>
<td></td>
<td>Optical Interconnect</td>
<td>R. Chen</td>
<td>Optical Interconnects</td>
</tr>
<tr>
<td></td>
<td>Optical Detectors for Interconnect</td>
<td>Deppe</td>
<td>Optical Interconnects</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Campbell</td>
<td>Optical Interconnects</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Holmes</td>
<td>Optical Interconnects</td>
</tr>
<tr>
<td>Patterning of Materials and Structures (Litho)</td>
<td></td>
<td>Ekerdt / White</td>
<td>Functional Resist</td>
</tr>
<tr>
<td>Immersions Lithography Studies</td>
<td>Willson / Ekerdt / Shi</td>
<td>Willson / White</td>
<td>Functional Resists</td>
</tr>
<tr>
<td>Nanotechnology Patterning</td>
<td>Common Resist for 193nm, eBeam, &amp; Imprint Template</td>
<td>Willson / Ekerdt / Shi</td>
<td>Common Electron Beam Resists</td>
</tr>
<tr>
<td>Field Assisted Lithography</td>
<td>Willson / Sreenivasan</td>
<td>Willson / Ekerdt / Shi</td>
<td>Field Assisted Lithography</td>
</tr>
<tr>
<td>Optical Extension</td>
<td></td>
<td>Downer</td>
<td>Spectroscopic Methods for Profiling High-K Dielectric Films and Nanometer-Scale SOI Structures</td>
</tr>
<tr>
<td>Future Transistors</td>
<td>Advanced CMOS</td>
<td>Shih</td>
<td>Dopant Profiling with STM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yacaman</td>
<td>Transition Electron Microscopy Studies</td>
</tr>
<tr>
<td></td>
<td>Beyond CMOS</td>
<td>Campion</td>
<td>Strain Measurement by Raman Spectroscopy</td>
</tr>
<tr>
<td>Patterning</td>
<td>Patterning &amp; Standards</td>
<td>Korgel</td>
<td>Nanowires and Nanodots for Metrology Standards</td>
</tr>
<tr>
<td>Defects</td>
<td></td>
<td>De Lozzane</td>
<td>STM Studies for Metrology</td>
</tr>
</tbody>
</table>
AMRC Metrology Programs

Innovative approaches

- Spectroscopic Methods for Profiling High-K Dielectric Films and Nanometer-Scale SOI Structures
- Dopant Profiling with STM
- Transmission Electron Microscopy Studies
- Strain Measurement by Raman Spectroscopy
- Nanowires and Nanodots for Metrology Standards
- STM Studies for Metrology
  - Conductivity of nanowires
XIDEX Carbon Nanotube Tip for SPM
Accelerating commercialization
Advanced Technology Development Facility (ATDF): R&D processing and prototyping

- Start-up Companies
- Device Makers
- Universities
- Equipment & Materials Suppliers
- Wafer Services
- Supplier Rooms
- Custom Projects
- SEMATECH Divisions
- Proprietary IP projects possible
Non-classical CMOS MuGFET

80 nm Gate Line
ASSURING MANUFACTURABILITY
Immersion Coatings Test Chamber

- Laser
- Sample Manipulator
- Sample Chamber
- Spectrometer
- Light Source
- Syringe Pump for Controlled Contamination
- In-Situ Ellipsometer
- Spectrometer Light Source
Immersion Technology Center (iTC)
Focus on high-NA applications, future extensibility

- Austin-based iTC will support the development of commercial immersion materials for high-NA applications to meet production requirements
  - Centerpiece is 1.3NA 193nm microstepper (Exitech/Tropel)
  - Design study, and option for manufacture and 2006 delivery of ~1.5NA lens
    - Fluid development required
  - Interference lithography tool to provide complementary platform for high-index fluid development
- Additional objective to understand extensibility of immersion lithography
SEMATECH EUV Program at Albany
Accelerate EUV infrastructure development

- 5-year strategic alliance
- EUV Mask Blank Development Center will speed the development of commercial EUV masks
- EUV Resist Test Center will support the development of commercial EUV photoresists to meet production requirements
EUV Mask Blank Development
Collaborative model

Commercial Mask Infrastructure

Research Partners
Consortia
VNL
Universities

Researchers
IP, Data
Cleaning
ML Deposition
Defect Analysis
Metrology
Material Development

SEMATECH North EUV Mask Blank Development Center

Technology transfer

Commercial Supplier Partners

Contracts

SEMATECH Members

Products

Data

Researchers

Products
Manufacturing Initiative (ISMI)
Improving manufacturing effectiveness and productivity

- Fab benchmarking – today’s installed base
  Cost reductions
  Resist reduction $1.4M-1.6M/year savings
- Tool improvements (EPITs)
  ~8% improvement in scanner availability
- Factories of the future
  - e-Manufacturing
  - Next wafer size
- Yield enhancement
- Metrology
- ESH

<table>
<thead>
<tr>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>cost ($)</td>
</tr>
<tr>
<td>area (cm²)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Design</th>
<th>Lithography</th>
<th>Metrology</th>
<th>Front-End Process</th>
<th>Interconnect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wafers</td>
<td>Tool set</td>
<td>OEE</td>
<td>COO</td>
<td></td>
</tr>
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Moore’s Law

cost ($)
area (cm²)

Reduce Operating Cost ($)
Increase Good Wafer Output
Wafer Size Conversion
Design Lithography Metrology Front-End Process Interconnect
Sharing Manufacturing Excellence through councils and benchmarking

- Manufacturing Methods Councils
  - 20% productivity improvement in Members’ wafer fabs over last two years

- Water optimization and reduction
  - Savings of over 42M gallons per year

- Energy reduction
  - Savings of over $3M per year
ISMI Strategic Directions

Improving productivity and yields

- Short cycle time
- “Monitor-free” manufacturing
- Plug & play equipment
- Continuous scaling
- Next wafer size transition
- Green fab
- Fully automated fab (hardware, software)
- People productivity
- Zero defects, 100% yield
Semiconductor is the Platform for Emerging Technologies

Transistor Structure

The dots are at the atomic level

MEMS Airbag Sensor

Micro-machined needles for “painless” injections

Quantum Dot Transistor

Novel Data Storage System

Diamond or silicon (111) surface

Potential Storage: $10^{18}$ bytes/cm$^2$
(vs. $10^9$, state of the art)
Collaboration is the Key at SEMATECH

- Global Collaboration
  - SEMATECH & Selete
    - 300mm, masks, resists
  - SEMATECH & SEMI
    - Industry Executive Forum
  - SEMATECH & IMEC
    - High-k, 157nm → 193i lithography, EUV
  - SEMATECH & Semiconductor Research Corporation
    - FEP Transition Center, FORCe, ERC
  - SEMATECH & Albany Nanotech
  - SEMATECH & the Texas Technology Initiative
Catalyst for Commercialization

Innovation  
Accelerated  
Manufacturability

University Research  
Technology Development  
Productivity

R&D Processing & Prototyping