8th International EUV Initiative Resist Technical Working Group
February 23, 2006
San Jose, California

Kim Dean, SEMATECH
Serge Tedesco, CEA/LETI

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What is the International EUV Initiative (IEUVI)?

Europe
- MEDEA+
- LETI
- PREUVE
- IMEC
- ASML

Japan
- ASET
- EUVA
- Nikon
- Canon

IEUVI

http://www.ieuvi.org

Chair: Paolo Gargini
- Regular coordination meetings
- Technical Working Groups
- Benchmarking data exchange
- Co-sponsorship of workshops

USA
- EUV LLC
- SEMATECH
- SRC
- VNL
Goals and Objectives of Resist TWG

- Remove resist from #1 top critical issue!

EUV-25: $E_{\text{size}} \approx 7.5 \text{ mJ/cm}^2$

MEDEA results using PSI Zurich interferometer
Goals and Objectives of Resist TWG

• Goal—increased cooperation among EUV resist community world wide
  - Develop resist specification roadmap
  - Coordinate efforts to address top 3 issues

• Objectives—share data and information to speed development of EUV resist
Top Three Issues for TWG Cooperation

1. **What is a safe level of resist outgassing?**
   - Work together to determine specifications, include tool and resist suppliers

2. **How is the resolution limits of chemically amplified resists understood?**
   - Provide enough tool time for cycles of learning

3. **How can photospeed, LWR, shot noise, resolution be optimized?**
   - Provide enough tool time for cycles of learning
# EUV Resist Specification Roadmap (revised)

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>Resolution 1:1</td>
<td>45nm</td>
<td>35nm/45nm (C/S)</td>
<td>32nm</td>
<td></td>
<td>32nm</td>
<td></td>
</tr>
<tr>
<td>Resolution contacts</td>
<td>55nm</td>
<td>TBD</td>
<td>45nm</td>
<td></td>
<td>40nm</td>
<td></td>
</tr>
<tr>
<td>Resolution Isolated Lines</td>
<td>32nm</td>
<td>30nm/40nm (C/S)</td>
<td>22nm</td>
<td>Dense and isolated; DOF at 10% exposure latitude</td>
<td>18nm</td>
<td></td>
</tr>
<tr>
<td>Depth of Focus</td>
<td>200nm</td>
<td>100nm for 35-nm 1:1</td>
<td>225nm</td>
<td></td>
<td>225nm</td>
<td></td>
</tr>
<tr>
<td>Photospeed (mJ/cm²)</td>
<td>10 mJ/cm²</td>
<td>21mJ/cm² E-size @ 50-nm 1:1</td>
<td>7mJ/cm²</td>
<td>Assuming ~30 wph</td>
<td>5mJ/cm²</td>
<td>Assuming &gt; 100 wph if 5 mJ/cm², 115W intermediate focus</td>
</tr>
<tr>
<td>Line Edge Roughness (3σ)</td>
<td>&lt; 4 nm</td>
<td>~4 nm @ 50-nm 1:1</td>
<td>&lt; 3nm</td>
<td></td>
<td>&lt; 1.4 nm</td>
<td>LWR &lt; 8% etched gate length; gate length = 18 nm</td>
</tr>
<tr>
<td>Wall Profile Angle</td>
<td>&gt;85º</td>
<td>80º @ 50-nm 1:1</td>
<td>&gt; 85º Measure cross-sections</td>
<td></td>
<td>&gt; 85º Measure cross-sections</td>
<td></td>
</tr>
<tr>
<td>Outgassing</td>
<td>4.7E13 molecules/cm²-sec</td>
<td>1.60E13</td>
<td>TBD</td>
<td></td>
<td>TBD</td>
<td></td>
</tr>
<tr>
<td>Pattern Collapse</td>
<td>&gt;3</td>
<td>None observed</td>
<td>&gt;3</td>
<td>Aspect ratio 3:1 for all structures</td>
<td>&gt;3</td>
<td>Aspect ratio 3:1 for all structures</td>
</tr>
<tr>
<td>Unexposed Film Thickness Loss</td>
<td>&lt; 10%</td>
<td>10nm</td>
<td>&lt; 5%</td>
<td></td>
<td>&lt; 5%</td>
<td></td>
</tr>
<tr>
<td>PEB Sensitivity</td>
<td>&lt; 2.5 nm/deg C</td>
<td>TBD</td>
<td>&lt;1.5 nm/deg C</td>
<td></td>
<td>&lt; 1 nm/deg C</td>
<td></td>
</tr>
<tr>
<td>Delay Stability @ &lt; 1ppb amine</td>
<td>30min</td>
<td>TBD</td>
<td>30 min</td>
<td>a) pre-exposure, b) under vacuum, c) post-exposure</td>
<td>30 min</td>
<td>a) pre-exposure, b) under vacuum, c) post-exposure</td>
</tr>
<tr>
<td>Etch Resistance</td>
<td>Similar to novolak</td>
<td>TBD</td>
<td>Similar to novolak</td>
<td></td>
<td>Similar to novolak</td>
<td></td>
</tr>
</tbody>
</table>

**Measured top down values for Rohm and Haas resist MET-1K. C/S=cross section  Green = spec is met, Orange = spec is not met**
Outgassing Round Robin Background

• The IEUVI resist technical working group (TWG) has initiated an EUV resist round robin

• The goal is to compare results and develop standard methodology for resist outgassing

• Model resist was formulated by MIT LL (Ted Fedynyshyn) and shipped to researchers by SEMATECH
Resist Outgassing Researchers (8)

- **Intel**
  - Synchrotron source, desorption tubes, ongoing
- **Trieste**
  - Synchrotron source, mass spec, ongoing
- **SEMATECH**
  - U. Wis, Synchrotron source, desorption tubes, ongoing
- **SEMATECH**
  - NEW, U. Albany, stand alone source, mass spec, witness plate, open frame; ready April
- **ASET**
  - Synchrotron source, mass spec, ready mid-2005
- **CEA/LET**
  - Standalone source, mass spec, controlled contamination studies
- **BOC Edwards**
  - Standalone source (borrowed), mass spec
- **University of Hyogo**
  - Synchrotron source, mass spec, ongoing
Round Robin Resist Structure
LUVR-99246*

\[
\left(\frac{\text{H}_3\text{C}-\text{H}_2\text{C}-\text{H}_2\text{C}-\text{C}}{\text{H}_2}\right)_4^+ \text{N}^{-} \text{OH} \left(\frac{\text{C}}{\text{F}_2}\right)_2^+ \text{I}^{-} \frac{\text{F}_3\text{C}}{\text{C}} \text{C} \frac{\text{C}}{\text{C}} \text{C} \frac{\text{S}}{\text{O}} \frac{\text{O}}{\text{O}} \frac{\text{S}}{\text{O}} \frac{\text{S}}{\text{O}} \\
\text{OH}
\]

Polymer: 0.940
PAG: 0.050
Base: 0.010
Calculated EUV base 10 absorbance = 2.01 \mu m^{-1}

*Resist provided by MIT LL, Ted Fedynyshyn
# Outgassing Round Robin Results

<table>
<thead>
<tr>
<th>Institution</th>
<th>Method</th>
<th>Result</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel</td>
<td>Synchrotron GC/MS</td>
<td>4.4E+11</td>
<td>25 mW/sec</td>
</tr>
<tr>
<td>SEMATECH</td>
<td>Synchrotron GC/MS</td>
<td>2.6E+12</td>
<td>25 mW/sec, 35-435 amu</td>
</tr>
<tr>
<td>ASET</td>
<td>Synchrotron On line MS</td>
<td>2.4E+11</td>
<td>0.21 mW/cm², 1–200 amu</td>
</tr>
<tr>
<td>BOC-Edwards</td>
<td>Stand-alone source, On line MS</td>
<td>5E+13 (estimated)</td>
<td>44–200 amu</td>
</tr>
<tr>
<td>Trieste</td>
<td>Synchrotron On line MS</td>
<td>N/A</td>
<td>1–100 amu</td>
</tr>
<tr>
<td>U. of Hyogo</td>
<td>Synchrotron On line MS</td>
<td></td>
<td></td>
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</tbody>
</table>
Next Steps--Discussion

• The TWG will develop areas of improvement in outgassing measurement techniques

• What is a reasonable expectation for these values? Is it possible for all researchers to get closer agreement?

• Reminder: Ru-capped multilayer samples available for contamination experiments (contact Kim Dean)
Project Overviews

- **Lawrence Berkeley National Labs**
  - In operation until December 2006
  - See SPIE papers 6151-34, 6151-104

- **Albany MET Resist Test Center**
  - Open to customers
  - Contact Klaus Lowack for scheduling (klaus.lowack@sematech.org)
  - See SPIE 2006 papers 6151-99, 6151-98

- **University of Wisconsin resist outgassing**
  - See SPIE 2006 paper 6153-51
SEMATECH EUV Resist Goals for 2006

Identify at least one resist that meets all these specifications:

- 35nm dense features, confirmed with cross-sections
- 15 mJ/cm2
- LER < 3.5nm (3 sigma)

Note, these specs may not be met with IL results
The Berkeley MET tool: a synchrotron-based programmable coherence EUV exposure station

The Advanced Light Source synchrotron facility at Lawrence Berkeley National Laboratory provides a robust, debris-free, powerful source of EUV.

This unique programmable coherence exposure tool provides unparalleled imaging capabilities (down to 12 nm) enabling advanced resist, mask, process, and metrology methods testing.
MET printing station designed to meet the challenges of 0.3-NA printing

- Fixed-exposure-time dose control
- Field-uniformity scanner
- Programmable coherence illuminator
- Reticle dose/illumination sensor
- Reticle stage with manual transfer
- Wafer-height sensors
- Wafer dose sensor
- E-chuck
- Wafer stage with vacuum load-lock manual transfer
- nm-resolution focus stage
- Pupil-fill monitor

Patrick Naulleau
Y monopole enables definitive resist-resolution limit testing

<table>
<thead>
<tr>
<th>Supplier</th>
<th>MET 1K</th>
<th>Supplier A</th>
<th>Supplier C</th>
</tr>
</thead>
<tbody>
<tr>
<td>50-nm</td>
<td><img src="50-nm.png" alt="Image" /></td>
<td><img src="50-nm.png" alt="Image" /></td>
<td><img src="50-nm.png" alt="Image" /></td>
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<tr>
<td>45-nm</td>
<td><img src="45-nm.png" alt="Image" /></td>
<td><img src="45-nm.png" alt="Image" /></td>
<td><img src="45-nm.png" alt="Image" /></td>
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<tr>
<td>40-nm</td>
<td><img src="40-nm.png" alt="Image" /></td>
<td><img src="40-nm.png" alt="Image" /></td>
<td><img src="40-nm.png" alt="Image" /></td>
</tr>
<tr>
<td>35-nm</td>
<td><img src="35-nm.png" alt="Image" /></td>
<td><img src="35-nm.png" alt="Image" /></td>
<td><img src="35-nm.png" alt="Image" /></td>
</tr>
</tbody>
</table>
### Summary of top-tier chemically-amplified resist performance

<table>
<thead>
<tr>
<th>Resist</th>
<th>Speed (mJ/cm²)</th>
<th>Res. * (nm)</th>
<th>LER (nm)</th>
<th>Failure Mechanism</th>
<th>Intrinsic Bias (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUV 2D</td>
<td>6.8</td>
<td>50</td>
<td>6.6</td>
<td>Top Loss</td>
<td>NA</td>
</tr>
<tr>
<td>Supplier A</td>
<td>11</td>
<td>35</td>
<td>4.5</td>
<td>Top Loss</td>
<td>4</td>
</tr>
<tr>
<td>KRS</td>
<td>19</td>
<td>32.5</td>
<td>3.3</td>
<td>Collapse/Top Loss</td>
<td>19</td>
</tr>
<tr>
<td>MET 1K</td>
<td>21</td>
<td>35</td>
<td>3.6</td>
<td>Top Loss</td>
<td>&gt; 16</td>
</tr>
<tr>
<td>Supplier D</td>
<td>21</td>
<td>45</td>
<td>3.0</td>
<td>Collapse</td>
<td>NA</td>
</tr>
<tr>
<td>Supplier C</td>
<td>46</td>
<td>35</td>
<td>2.5</td>
<td>Collapse</td>
<td>4</td>
</tr>
</tbody>
</table>

* Resolution defined as smallest observed well-defined half pitch
Berkeley MET Access in 2006

• SEMATECH controls access, scheduling, and outgassing requirements on Berkeley MET
  ▶ Currently, all shifts are allocated
  ▶ Contact Kim Dean for information about access, kim.dean@sematech.org

• Contact Patrick Naulleau about technical issues, how to ship resists, mask requirements, etc.
  pnaulleau@lbl.gov
EUV RTC @ SEMATECH North, Albany

- EUV RTC is part of the SEMATECH North program, a joint 5-year program between SUNY and SEMATECH.

- The EUV Resist Test Center supports the development of commercial EUV photoresists to meet production requirements. The EUV RTC can also support mask development.

- Resist supplier, member company, university/institute, and SEMATECH researchers can use the RTC.
Albany Toolset

TEL ACT-12 and Exitech MS-13 MET

Hitachi S-9380

Therma-Wave Optiprobe OP-5340

All tools are equipped to process 200 and/or 300 mm wafers. 200 mm wafers are processed in 300 mm FOUPs with 200 mm inserts.
Exitech EUV MET Resolution Status

50 nm 1:1

45 nm 1:1

40 nm 1:1

35 nm 1:1

30 nm 1:1

25 nm 1:1

Resist: Rohm & Haas MET 1K
Albany Scheduling Process for Customers

Three customer types:
1. Internal projects
2. Member companies
3. Resist suppliers/universities/institutes

Each group gets about 1/3 of available shifts.

Scheduling of customer shifts on a month-by-month basis.

Preferred operation mode: remote
1. Schedule tool time
2. Send resists and exposure plans
3. SEM ATECH will do the experiments and send back the results.

Contact Klaus Lowack (klaus.lowack@sematech.org) to schedule tool time
Plans for Next TWG Meetings

- Mid-year teleconference 2006
- EUVL Symposium October, 2006
  - Barcelona, Spain
Backup Slides
Exposure Tool Availability

- **MET at ALS Berkeley**: operations continue into 2006
- **Exitech Intel**: operational; for Intel development
- **HiNA3 ASET**: operational; available, but limited throughput (2 wafers per day)
- **PSI Zurich interferometer**: operational; available for others, pay per shift
- **Exitech Albany**: operational
- **ASML alpha tools**: scheduled operational late-2006; tools located at Albany and IMEC