Title
Characterization of advanced EUV resists using the Berkeley MET tool

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Characterization of advanced EUV resists using the Berkeley MET tool

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*University of California, Berkeley*

Ryoung-han Kim, Bruno La Fontaine, Tom Wallow

*AMD*
Outline

• Capabilities of the Berkeley MET tool
• Demonstration of resist-limited performance
• Constraints on resist development
• Metrics for intrinsic resolution
• Champion resist results from the Berkeley MET tool
• Summary
Berkeley MET exposure tool

- Based on MET optic
- Magnification = 5x, NA = 0.3
- Rayleigh resolution = 27 nm
- Field size = 200x600 μm
- Programmable coherence illuminator for low $k_1$
- Reticle and wafer load-lock systems
- nm-resolution wafer-height sensor and focus actuation
- Pupil-fill monitor
Berkeley MET modeled to have good DOF down to 25 nm with annular illumination

Predicted aerial-image DOF:

- +/-10% CD control
- 10% Total EL contrast > 45%
- ILS > 20

Bossungs based on 10% dose increments
Programmable coherence capabilities enable ultra-high resolution printing

- Pro lith modeling results including EUV-measured wavefront.
Even with best EUV resists, resolution limit determined by resist not aerial image

![Graph showing contrast vs. CD (nm)]

- Predicted aerial-image contrast

KRS resist provided by Carl Larson and Greg Wallraff, IBM

LBNL-MET, annular
Status in late 2005 showed a resolution limit in EUV CAR of ~32 nm
Dose limitations places severe restrictions on levers available for improved resolution

Materials and data courtesy of Roger Nassar, RHEM

LBNL-MET
Y-Monopole

24nm hp, 79.1mJ/cm²
Ultrathin film effects limit the effectiveness of thickness reduction for improved resolution

- Top-loss and LER become worse with decreasing thickness
- Film dominated by interface effects
- Is it possible to mitigate these effects with BARC and/or topcoat?

Data courtesy of
Tom Wallow, AMD
PEB reduction improves exposure latitude, but at the cost of reduced sensitivity

Data courtesy of Tom Wallow, AMD
PEB reduction gains quickly saturate

Data courtesy of Tom Wallow, AMD
What is the best metric for characterizing intrinsic resolution?

- **KRS**
- **MET 1K**
- **Supplier C**

LBNL-MET, Y-Monopole
Resist based MTF measurements provide insight into resist and system properties

• MTF = pitch-dependent contrast
• Contrast determined from:
  - $D_{\text{max}}$, the dose at which resist lines first begin to clear
  - $D_{\text{min}}$, the dose at which resist lines disappear

\[
Contrast = \frac{I_{\text{max}} - I_{\text{min}}}{I_{\text{max}} + I_{\text{min}}} = \frac{D_{\text{max}} - D_{\text{min}}}{D_{\text{max}} + D_{\text{min}}}
\]
Resist performance has strong impact on measured contrast

Feature Size (nm) vs. Contrast

- Modeling
- EUV 2D
- KRS
- MET 1K
- Supplier D
- Supplier A
- Supplier C
Modeling Resist Using Simple Point-Spread-Function (PSF) Method

- PSF resist modeling* is fast and convenient
- Model easily generated
- Provides intuitive link to resist resolution limit
- Few parameters makes model less susceptible to extrapolation errors
- Resist process well approximated by deprotection function**

Extracting the deprotection blur from MTF data

![Graph showing Aerial Image and Blurred contrast](image)

<table>
<thead>
<tr>
<th>Resist</th>
<th>Res. (nm)</th>
<th>Blur (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUV 2D</td>
<td>50</td>
<td>45</td>
</tr>
<tr>
<td>Supplier A</td>
<td>35</td>
<td>24</td>
</tr>
<tr>
<td>KRS</td>
<td>32.5</td>
<td>14</td>
</tr>
<tr>
<td>MET 1K</td>
<td>35</td>
<td>21</td>
</tr>
<tr>
<td>Supplier C</td>
<td>35</td>
<td>22</td>
</tr>
</tbody>
</table>
LER roll-off as a resolution metric

LER roll-off (correlation length) is NOT a good indicator of resolution

<table>
<thead>
<tr>
<th>Resist</th>
<th>Res. (nm)</th>
<th>$L_c$ (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EUV 2D</td>
<td>50</td>
<td>24</td>
</tr>
<tr>
<td>Supplier A</td>
<td>35</td>
<td>20</td>
</tr>
<tr>
<td>KRS</td>
<td>32.5</td>
<td>18</td>
</tr>
<tr>
<td>MET 1K</td>
<td>35</td>
<td>22</td>
</tr>
<tr>
<td>Supplier C</td>
<td>35</td>
<td>28</td>
</tr>
<tr>
<td>Supplier E</td>
<td>35</td>
<td>26</td>
</tr>
<tr>
<td>Supplier F</td>
<td>30</td>
<td>25</td>
</tr>
</tbody>
</table>

Spatial Frequency ($\mu$m$^{-1}$)

PSD (nm$^2$/um$^{-1}$)

EUV 2D
MET 1K
Comparing MTF and Correlation Length Metrics for Process Studies

Raw data courtesy of Tom Wallow, AMD

<table>
<thead>
<tr>
<th>PEB</th>
<th>Blur (nm)</th>
<th>L_c (nm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>90° C</td>
<td>22</td>
<td>20.7</td>
</tr>
<tr>
<td>100° C</td>
<td>29</td>
<td>23.8</td>
</tr>
<tr>
<td>110° C</td>
<td>32</td>
<td>22.6</td>
</tr>
</tbody>
</table>
Corner Rounding as a Resolution Metric

- Use fine-corner detail in large feature to determine resolution limit

Modeling data provided by Ryoung-han Kim, AMD
Corner-rounding appears to be a good predictor of resolution.
Corner-Rounding Analysis Showed Supplier F to be Best Sample: Printing Results

Coded 45-nm:90-nm
Actual 38-nm:90-nm
LER 3.0 nm: L = 403 nm

Dose to size (50-nm 1:1)
= 19 mJ/cm²

Coded 40-nm:80-nm
Actual 33-nm:80-nm
LER 3.1 nm: L = 403 nm

Coded 35-nm:70-nm
Actual 27-nm:70-nm
LER 3.0 nm: L = 366 nm

Opening Workshop of SANKEN US Branch, 12/15/06
More Supplier F Printing Results

Coded 32.5-nm:65-nm
Actual 28-nm:70-nm
LER 4.4 nm: L = 407 nm

Coded 30-nm:60-nm
Actual 24-nm:60-nm
LER 4.0 nm: L = 350 nm

Coded 30-nm:60-nm
Actual 21-nm:60-nm
LER 4.0 nm: L = 350 nm

Coded 22.5-nm:67.5-nm
Actual 22.7-nm:67.5-nm
LER 4.0 nm: L = 512 nm
EUV Resist LER & Sensitivity

LER versus Sensitivity for selection of known EUV resists

Status: Line Edge Roughness (HVM Spec): < 1.6 nm
Line Edge Roughness (Best Current): 2.5 nm
Summary

• The SEMATECH MET facility at Lawrence Berkeley National Lab provides ultrahigh resolution capabilities from a conventional projection EUV system
• EUV resolution is currently resist limited
• High sensitivity requirements places stringent constraints on resist resolution improvements
• Interface effects may require the use of more complex film stacks
• MTF and corner-rounding provide good metrics for intrinsic resolution
• A new resist outperforming KRS has been identified
  • 30-nm dense, 22.5-nm semi-isolated
Acknowldgments

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