Mask Substrate/Blank Cleaning Progress Challenges
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Arun JohnKadaksham and Frank Goodwin
SEMATECH,
Albany, NY
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Outline

• EUV Substrate and Mask cleaning challenges
  – Current capability
  – Challenges in mask and substrate cleaning

• Steps taken by SEMATECH for addressing the challenges and closing the gaps in cleaning technology
  – Immediate focus
  – Long term
Substrate Cleaning Challenge: Quality of Substrates

- **Quality of substrates** is the primary challenge in substrate cleaning
  - Poor quality substrates have low cleaning yield and blank yield

M7360 inspection images of substrates with low quality

Cleaning yield is reduced by substrates of low quality
Overcoming Substrate Quality Issue with Cleaning

• Current solution is to introduce substrate etching to remove killer particles and defects
Issues with Current Substrate Cleaning Method

- Substrate roughness and pit counts increase by removal of killer particles, although not significant enough to impact blank properties and total defects
- **Ideal Solution:** Cleaning process that removes all particles without roughening or generating pits or a complementary process that will mitigate pits and roughness

Substrate roughness and pits post etch clean process

**EUV blank Spec**

Remaining pit dimensions

Particles before removal
Complete Substrate Cleaning Solution

Dressed Photon NanoPolishing (DPNP) has been identified as a potential technique for pit and surface smoothing.

Process integration into a cleaning tool is ongoing

DPNP Timeline

- 2012 Feasibility Evaluation
- Dec-2013 Test Chamber at CNSE
- June-2014 Optimized process and tool module design
- Dec-2014 Integrate to Mask Tool

Test chamber built at CNSE

Process Integration
- Cleaner 1: Organics clean and Particle Removal
- Cleaner 2: DPNP Pit smoothing
- Cleaner 3: Final Clean and Preparation for Deposition
- Inspection
- IBD: Blank Deposition
Particle Removal Technology

• **Megasonics** is still the primary particle removal technology
  – Pit damage from megasonics is a well known issue
• SEMATECH has **optimized** megasonics for no pit generation on substrates at defect sizes above 38nm and on blanks above 50 nm (SiO\textsubscript{2} equivalent size)
  – Frequency and power were used as optimization parameters
• Megasonics can be further optimized by the gas and medium properties
• Other particle removal technologies with better PRE might exist
  – Binary spray, ion beam, plasma etc.

\[ \ddot{R} + \frac{3}{2} \dot{R}^2 + \frac{2\sigma}{\rho R} + \frac{4\mu \dot{R}}{\rho R} + \frac{1}{\rho} \left[ P_0 - \left( P_0 + \frac{2\sigma}{R_0} \right) \left( \frac{R_0}{R} \right)^{3\gamma} - P_A \sin \omega t \right] = 0 \]
Chemicals for Cleaning

- Industry still relies on harsh acids and bases for cleaning
  - Effect of these chemistries on EUV mask degradation, outgassing, and molecular and progressive contamination is well known
- **Alternative chemicals** and advanced cleaning techniques need to be investigated and implemented

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<th>Current Technology</th>
<th>Purpose</th>
<th>Issues</th>
<th>Alternative</th>
<th>Advantage</th>
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<tr>
<td>SPM (H2SO4/H2O2)</td>
<td>Organic removal, metallic particle removal</td>
<td>Oxidation, outgassing, progressive contamination</td>
<td>Insitu-UV, Plasma</td>
<td>No residues, dry cleaning</td>
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<tr>
<td>APM (NH4OH/H2O2)</td>
<td>Particle removal</td>
<td>Oxidation, Etching, pitting, residual contamination</td>
<td>TMAH, dilute Ammonia</td>
<td>No pit generation and residues</td>
</tr>
<tr>
<td>Ozone Process</td>
<td>Organic removal, particle removal</td>
<td>Oxidation, particle adders</td>
<td>H2 water, In- situ UV</td>
<td>No oxidation and residues, recovery of blanks from oxidized state</td>
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Backside Cleaning

• A cleaning process for removing large particles from EUV mask backside without affecting front surface does not exist
  – Primarily due to spin-spray technique currently used for cleaning
• An alternative process for backside cleaning needs to be developed

Images from Suss-microtec

Spin spray clean with backside rinse is not the ideal solution for cleaning backside of mask
EUV Mask Cleaning for Lifetime

- **SPM/APM** chemistries have known issues with lifetime cleaning of EUV masks
- **Insitu-UV cleaning** developed for EUV mask cleaning needs to be optimized for damage free lifetime cleaning
- **Plasma/dry cleaning** need to be characterized/optimized and incorporated into mask cleaning

How to improve mask lifetime by improving mask material?

“Understanding the Mechanism of Capping Layer Damage and Development of a Robust Capping Material for 16 nm HP EUV Mask”, Il-Yong Jang et. al., SEMATECH, Oct 7, Session 2 EUV Symposium
Collaborate and Innovate

Concepts are not going to materialize into products without partnerships
SEMATECH/Suss-Microtech Projects for Near Future

• Integrated tool for substrate cleaning with pit smoothing
  – DPNP integrated with mask cleaning tools

• Insitu-UV process optimization
  – Status: New lamp installed and Mask cleaning tests ongoing

• Backside cleaning without impacting front side
  – Status: Working on concepts and supplier/literature search

• Development of plasma module for dry cleaning and mask lifetime cleaning
  – Status: Fully functional feasibility test module at CNSE
  – Third party tool supplied to SEMATECH from Suss-Microtech
  – Tool installation and cleaning tests start this year

• Alternate particle removal methods and chemicals
  – Status: Alternate particle removal methods identified
  – Status: TMAH delivered
Summary

• SEMATECH has entered into a partnership with Suss-Microtech to address the gaps in advanced mask cleaning technology
  – Together with the partnership with CNSE, SEMATECH is enabled to do rapid product and process development from concepts

• Immediate needs and gaps have been identified and SEMATECH and Suss-Microtech is working in closing the gaps

• Any further requirements and suggestions from member companies can be addressed and incorporated into plans