High-Volume Manufacturing of EUV Mask Blanks
*Status and Roadmap*

**Katrina Rook, Meng Lee, Sandeep Kohli, Adrian Devasahayam, Frank Cerio**

Veeco Instruments Inc.
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Veeco Ion Beam Technology Background

- Ion beam is a ‘core’ technology for Veeco
- Over 30 years experience in advanced etch and deposition
- Veeco developed & built several successful product lines based on ion beam technology
- Veeco has adapted ion beam technology and developed the IBD-LDD for EUV mask blanks
  - Development began with LLNL in late 90s
  - Collaboration with Sematech and major mask companies in the 2000s
- The Veeco IBD-LDD is the tool-of-record for Mo/Si multilayer deposition
  - Committed to ongoing IBD-LDD development
  - Actively validating roadmap to support EUV market
Ion Beam Deposition for Low Defect Deposition

Cap layer
(2.5 nm Ru)

~ 40 bilayers
Mo3nm/Si4nm
(~7nm)

Substrate Fixture

Cross-section of EUV mask blank

Ion Beam Deposition Advantages

<table>
<thead>
<tr>
<th>Defects</th>
<th>Plasma remote from substrate</th>
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<tbody>
<tr>
<td></td>
<td>Electronic shutter =&gt; continuous plasma</td>
</tr>
<tr>
<td></td>
<td>Controlled rate minimizes decoration</td>
</tr>
<tr>
<td></td>
<td>0 defects at &gt;70nm</td>
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</table>

<table>
<thead>
<tr>
<th>CWL Uniformity</th>
<th>Fixture tilt &amp; rotate</th>
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<tbody>
<tr>
<td></td>
<td>~ 0.2% 3σ</td>
</tr>
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</table>

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<tr>
<th>Reflectivity</th>
<th>Controlled rate for layer smoothness &amp; repetition</th>
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<tbody>
<tr>
<td></td>
<td>&gt; 67%</td>
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Veeco History of EUV Mask Blank Deposition

1996
First EUV Multilayer R&D System
LLNL RD 100 Award 1997

1999
New Ion Source Configuration
Self-Aligned Grids

2003
SEATECH JDA
ESC Development
Rotating Targets
Shield Treatment
Ion Assist
PAM Module
Neutralizer Development
Particle Trap

2010
Odyssey Upgrade
Elliptical Grid
Target Extension
Neutralizer Improvement

2014
Zero >70nm Defect Masks
→ Qualified for 7nm Node
Broader Veeco Involvement in EUV Mask Blank Manufacturing

- Multilayer/capping deposition – improvement required for 5nm technology node
- Absorber deposition and etch – new material (Ni, Co, ..) required for future technology node
Roadmap for IBD-LDD Multilayer Deposition

1996
First EUV Multilayer R&D System

1999
New Source Configuration

2003
SEMAPTECH JDA - System Optimization

2014
Odyssey Upgrade
Defect Reduction

2019 – 2020
Trailblazer Upgrade
End Point for Thickness Control

2021
NEXT GEN HVM Platform
Higher Throughput and Reflectivity Improvement
Ion Beam Etch for Next Gen EUV Absorber Materials
IBE for Etch of Novel Materials for EUV Absorber

Problem:

> Shadowing effect to print smaller features
> Increased incident angle for High NA scanner

Current Situation:

> TaN layer thickness cannot be reduced
> Ni, Co and alloy under development as substitute for TaN
> RIE chemistry challenged to etch ferromagnetic and atypical semi materials (due to low volatility)

Solution:

> IBE can be used to etch thin layers of Ni and Co

Ref: Appl. Sci. 2018, 8, 521; doi:10.3390/app8040521
# Veeco Ion Beam Etch for Next Gen Absorber Layer

## IBE Feature vs Selected Benefits

<table>
<thead>
<tr>
<th>IBE Feature</th>
<th>Selected Benefits</th>
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<tbody>
<tr>
<td><strong>Physical etch</strong></td>
<td>✓ Any material - no chemistry dependence</td>
</tr>
<tr>
<td></td>
<td>✓ Complex materials and structures</td>
</tr>
<tr>
<td></td>
<td>✓ No chemical damage</td>
</tr>
<tr>
<td></td>
<td>✓ No chemical residues</td>
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<tr>
<td></td>
<td>✓ No chamber conditioning, memory effects</td>
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<tr>
<td></td>
<td>✓ Dense and isolated features etch at same rate</td>
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<tr>
<td><strong>Directional ion beam</strong></td>
<td>✓ Anisotropic etch</td>
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<td></td>
<td>✓ Device shape &amp; sidewall angle control</td>
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<tr>
<td></td>
<td>✓ Eliminate re-deposition</td>
</tr>
<tr>
<td><strong>Ion source isolated from</strong></td>
<td>✓ Low pressure operation: low contamination &amp; re-deposition</td>
</tr>
<tr>
<td><strong>substrate</strong></td>
<td>✓ Process flexibility: Independent beam and voltage control</td>
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<tr>
<td></td>
<td>✓ Low energy capability, down to 50V</td>
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<tr>
<td></td>
<td>✓ Low ion damage</td>
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<td></td>
<td>✓ Low temperature operation</td>
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**Industry standard for magnetic and novel material etch**
Ion-Beam Etch & Endpoint for Patterning of Ni/Ru Absorber

- Ni ER 200 ~ 1000A/min
- Ni : PR 0.7-1.5 => resist mask > 80nm

- Ni/Ru endpoint by OES or SIMS
- Ni : Ru < 1 : 1 => Ru Thickness

www.SRIM.org
Ion-beam Deposition of Uniform Ni Absorber Layers

- Ni uniformity $\sim 0.6\%$ 3σ
- Deposition rate up to $\sim 125$ A/min
- Density and surface roughness not impacted at optimized angle
Summary

> 20 years of involvement in EUV market

> Veeco IBD-LDD is the tool-of-record for EUV mask blanks multilayer (ML) deposition
  » Tool meet requirements for 7nm technology node
  » Actively working to improve for future node

> Ion beam etch is a viable option to pattern near future absorber materials

> Ion beam deposition can be extended for highly uniform absorber layer