Mask Considerations for Next Node

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Role of Mask/Scanner Signatures on Device Yield
“Does the Flap of a Butterfly’s wings in Brazil Set Off a Tornado in Texas?”

–Edward Lorenz    Dec. 29, 1972
“Does the Topple of a Mask SRAF in Taiwan Set Off A Crisis in Cupertino?”

– Anonymous  Feb 24, 2015
Layout Complexity

Joseph Tainter, 1988
The Collapse of Complex Societies
Level Count Complexity

Mask Counts Per Node

Degree of Multi-Pattern
Critical process characterization items
- Min Resolution
- PEC (thru-pitch) and global positional dose correction
- CDU, global and local
- LWR thru density and dose
- CD linearity
- CD thru-pitch
- Corner Rounding

Process B vs. A:
33% reticle local CDU improvement translated to 35% on-wafer LCDU improvement and reduction of undersized contacts.
Corner Rounding
- 22% improvement in corner rounding radius (Process B vs. Process A)

LWR Improvement (Line/Space):

Process A

Process B

Increasing Dose →

Increasing Dose →
Hunting for Hot Spots

Mask Sensitivity Matrix

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>Avg</th>
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<tr>
<td>Roughness</td>
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<td>0.022</td>
<td>0.155</td>
<td>0.076</td>
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<td>Rounding</td>
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<td>0.008</td>
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<td>Transparency</td>
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<td>Resize</td>
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<td>0.091</td>
<td>0.317</td>
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<td>PhaseShift</td>
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<td>Shift</td>
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<td>0.119</td>
<td>0.331</td>
<td>0.113</td>
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Hunting for Nanometers

- **Extraction of Periodic Registration Effect**
- **Isolation and Modeling of CD Systematics**

- **Writer/resist interaction**
- **Supplements higher order polynomial fitting**

We know both signature magnitude and shape are important.
Applying Multiple Sensors to Characterize Masks

- Data Preparation
  - Secondary Data Collection
    - Metrology
  - Direct - Analysis
    - Indirect - Simulation
  - Defect Analysis
    - Defect Disposition
      - Pass
      - Fail/Repair

- EUV ADC
- Simulation to Aerial Defect Printability Simulation

<table>
<thead>
<tr>
<th>Defect</th>
<th>AFM image</th>
<th>3D AFM image</th>
<th>SEM image</th>
<th>GDS Clip</th>
<th>DPS Image</th>
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</table>
2D/3D mask process correction
Feed forward models

Temporal mask behavior
Mask maintenance

Enables cycle time
Drives cost down

Pattern fidelity and speed
Global/local corrections

Matching

Multi-sensor integration
Deep data analysis and model building

Data

Lifecycle

Yield

Validation

Pattern