Scratch Evolution during Chemical Mechanical Polishing

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Motivation

• Importance of scratch removal during CMP

• Scratching commonly caused by hard abrasives (e.g. diamond grits from conditioning pad) embedded in polishing pad or slurry agglomeration

• Incomplete removal of scratches may lead to circuit failure
Typical Sources of Scratching in CMP

Contamination from Pad Conditioner

- Diamond grits that are pulled out of the conditioning pad can embed themselves in the polishing pad and cause wafer scratching.

Agglomerated Slurry Particles

- Slurry particles can agglomerate and act as large contaminants that can scratch the wafer surface.
Experimental Procedures

- Scratches were created using a diamond tip tool
- Specimens polished for regular intervals on CMP machine
- AFM imaging measurements taken and analyzed
# Experimental Conditions

## Processing

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material</td>
<td>Silicon, Silicon Oxide</td>
</tr>
<tr>
<td>Down Pressure</td>
<td>5 psi</td>
</tr>
<tr>
<td>Table Rotation</td>
<td>75 rpm</td>
</tr>
<tr>
<td>Pad</td>
<td>IC 1000 stacked pad</td>
</tr>
<tr>
<td>Slurry</td>
<td>Nalco 2350 (Si), Cabot ILD 1300 (SiO2)</td>
</tr>
<tr>
<td>Tool</td>
<td>Toyoda Float Polishing Machine</td>
</tr>
</tbody>
</table>

## Metrology

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>AFM Instrument</td>
<td>Digital Instruments DI 5000 AFM with positioning stage,</td>
</tr>
<tr>
<td></td>
<td>Lawrence Livermore Laboratory</td>
</tr>
<tr>
<td>Scan Size</td>
<td>45 X 45 microns</td>
</tr>
<tr>
<td>Measurement Mode</td>
<td>Tapping Mode</td>
</tr>
<tr>
<td>Resolution</td>
<td>8 nm</td>
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<tr>
<td>Measurement Time</td>
<td>90 minutes per sample</td>
</tr>
</tbody>
</table>
• Subsurface damage caused during the initial scratch can propagate during subsequent polishing.
Silicon Oxide Scratch Evolution

- Initial state at $t = 0$ s
- Evolution at $t = 30$ s
- Progression to $t = 120$ s
- Conclusion at $t = 60$ s

The color scale indicates depth from 0 to 2000 nm.
Roughness & Depth

Scratch Bottom Roughness (Ra)

Scratch Depth

Top view of AFM image. Roughness measurements were made of the bottom (valley) of the scratches and monitored during the polishing.
2002 and 2003 Goals

The experimental results can be used to integrate a scheme for detecting scratching using sensor based process monitoring (e.g. acoustic emission) and determining the amount of polishing required to remove the defects.

Integrate initial chemical models into basic CMP model.
Validate predicted development by 9/30/2002.

Develop comprehensive chemical and mechanical model.
Perform experimental and metrological validation by 9/30/2003.