Tungsten CMP
Working Under Pressure

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29TH EUROPEAN CMP USERS MEETING
APRIL 12TH – 13TH ZURICH
Introduction

- CMP: synergical balance **Chemical** transformation/ **Mechanical** abrasion
- CMP: high n° interdependent Inputs
  - Pad
  - Slurry
  - Process Parameters ➔ CMP Engineer
- Miniaturization: surface properties > bulk material properties

- **Chemical/Mechanical** by Tuning P Ring & Head
- Dependence of surface quality = f(polishing pressures) in W CMP
Experimental Details

- Applied Materials Mirra
  - 1-3 PSI Head@cst Ring Pressure
  - 1-9 PSI Ring@cst Head Pressure
  - V Platen & Head = cst
  - IC1010 Dow
  - Polyether Ether Ketone (PEEK) Ring

- W commercial slurry (selective on SiO₂)

- T°Max: IR pyrometer

- Roughness Investigation: 1x1 µm scans AFM Veeco Dimension 3100 DI
  - Root Mean Square values
  - Power Spectra Density graphs

- W CVD wafers
  - Blanket
  - Patterned
RESULTS:
BLANKET WAFERS CHARACTERIZATION
W Blanket Surface Quality: Haze & RMS

- Surface quality improved for both
  - Ring pressure ↗
  - Head pressure ↗

Pad softening and Contact area increase through Pad $T^\circ C$: Low RMS
W Blanket Surface Quality: PSD

Head & Ring Pressure Influence

- Surface quality improvement
  - P Head ➔: @all spatial frequencies
  - P Ring ➔: @lower frequencies

Ring = 6.5 PSI, cst

Spatial Frequency [1/µm]

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Head Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>54.8°C</td>
<td>1 PSI</td>
</tr>
<tr>
<td>63.3°C</td>
<td>2 PSI</td>
</tr>
<tr>
<td>66.5°C</td>
<td>3 PSI</td>
</tr>
</tbody>
</table>

Head = 2 PSI, cst

Spatial Frequency [1/µm]

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>54.9°C</td>
<td>4 PSI</td>
</tr>
<tr>
<td>63.3°C</td>
<td>6.5 PSI</td>
</tr>
<tr>
<td>68.9°C</td>
<td>9 PSI</td>
</tr>
</tbody>
</table>

RMS
RESULTS:
PATTERNED WAFERS CHARACTERIZATION
Patterned Wafers: W Trench Evolution

- CMP 15% OVP by time
- AFM 1x1µm scans on 5µm W trench:
  - M = 3 PSI
  - M = 2 PSI
  - M = 1 PSI

![Graph showing W trench evolution with pressure levels and temperatures](image)

- Important W trench consumption & surface degradation @low pressure
Patterned W Trench Surface Quality: PSD

Head Pressure Influence

- Ring cst = 6.5 PSI
- 59.9°C
- 57.1°C
- 64.8°C

- P Head↑ and T°↑: Pattern roughness improvement
- Similar effect as Blanket
Patterned W Trench Surface Quality: PSD

Ring Pressure Influence

- P Ring ➔: Pattern roughness degradation
- Opposite to Blanket

Spatial Frequency [1/µm] vs. PSD [nm^4]

- M = 2 PSI, cst
- M = 3 PSI, cst

High Ring Pressure

Ring=4 PSI
Ring=6.5 PSI
Ring=9 PSI

RMS degradation

Z Scale 20 nm

@ M=3 PSI
W Patterned Wafer: RMS Line Roughness
Head & Ring Pressure Influence

- **P Head** @ Ring = cst: RMS ↓  →  Pattern ~ blanket
- **P Ring** @ Head = cst: RMS ↑  →  Pattern ≠ blanket

Why?
W Patterned Wafer: RMS Line Roughness Temperature

- Pad T°C Range: Blanket ~ Patterned
- Slurry transport effect?

Fullsheet Roughness = f(T°C)
- Head=1 PSI
- Head=2 PSI
- Head=3 PSI

Patterned Roughness = f(T°C)
- Head=1 PSI
- Head=2 PSI
- Head=3 PSI
Patterned W Trench Surface Quality: RMS ΔP Influence

- Higher ΔP = poor surface quality
- Increase ΔP = ↗ slurry mean residence time

Patterned Roughness = f(T°)

- Low ΔP
  - Retaining Ring
  - Head

- High ΔP
  - Retaining Ring
  - Head

Slurry transport (mass & heat) impact pattern surface quality
Conclusions

- Post-CMP W Surface quality = f (P, T°C) on blanket & patterned

<table>
<thead>
<tr>
<th>Blanket Wafers</th>
<th>Patterned Wafers</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Better surface quality</td>
<td>• Better surface quality</td>
</tr>
<tr>
<td>• P Head↗</td>
<td>• P Head↗</td>
</tr>
<tr>
<td>• P Ring↗</td>
<td>• P Ring↘</td>
</tr>
<tr>
<td><strong>Higher P &amp; Pad T°C: Synergy</strong></td>
<td><strong>Chemical / mechanical</strong></td>
</tr>
<tr>
<td><strong>balance between chemical</strong></td>
<td><strong>equilibrium shifted by slurry</strong></td>
</tr>
<tr>
<td><strong>action &amp; mechanical abrasion of</strong></td>
<td><strong>transport @ interface with</strong></td>
</tr>
<tr>
<td><strong>softened pad</strong></td>
<td><strong>patterned wafers</strong></td>
</tr>
<tr>
<td>➔ reduce roughness</td>
<td></td>
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- Further investigation of slurry flow, abrasive & oxidant concentration
Merci de votre attention
RMS = f(W Post-CMP Thickness)

![Graph showing RMS (nm) against Remaining W Thickness (a.u.) for different pressures (M=1PSI, M=2PSI, M=3PSI)]