Recent trend of CMP equipment platform and its requirement of process and consumables: BEOL CMP

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CMP Process Development Team
Number of CMP layers & BEOL CMP

Advanced logic

BEOL CMP
Over 50% of all CMP layers
3 platen Cu CMP process

- Cu bulk and Cu clear in separate platens (Platen 1 and 2)
- Little attention to Cu polishing rate
- More options on platen 2 to reduce polishing defects
- High CoO due to lower run rate than 2 platen process tools
2 platen Cu CMP process

- Platen 1 and 2: Cu bulk + Cu clear
- Platen 3 and 4: Barrier/Oxide CMP
- 2 polishing units: Platen 1 and 3 & Platen 2 and 4

Pro: Higher run rate than 3 platen Cu CMP
Better tool availability

Con: 1 platen for Cu bulk + clear
### Endpoint in 2 platen Cu CMP

<table>
<thead>
<tr>
<th>Layers</th>
<th>Cu overburden</th>
<th>Cu polishing time</th>
<th>Barrier polishing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Layers</td>
<td>1X</td>
<td>1x</td>
<td>0.6x</td>
</tr>
<tr>
<td>Middle Layers</td>
<td>1.2x</td>
<td>1.2x</td>
<td>0.7x</td>
</tr>
<tr>
<td>High Layers (3 platens)</td>
<td>3.8x</td>
<td>1.1x</td>
<td>1.1x</td>
</tr>
</tbody>
</table>

- Longer Cu polishing time than Barrier polishing due to 1 platen Cu polishing
  - Run rate improvement restricted by Cu polishing time
  - Higher chance of defects due to longer Cu polishing time per platen
Scratch defect source – Cu blanket test

Cu polishing or Barrier polishing?

- Cu polishing
- Barrier Polishing (Alkaline Slurry)
- Cu polishing
- Barrier Polishing (Acidic slurry)
How to reduce Cu polishing time?

• Process
  – Pressure and RPM

• Incoming Cu overburden
  – Reduction of Cu plating thickness

• Consumable
  – Pad, Slurry and Conditioner
How to reduce Cu polishing time?

- **Process**
  - Pressure and RPM

- Incoming Cu overburden
  - Reduction of Cu plating thickness

- Consumable
  - Pad, Slurry and Conditioner
Process – Pressure or Velocity?

- **Removal Rate** = $K_p \times \text{Pressure} \times \text{Relative velocity}

- Pressure or Velocity?

  - Pressure is more dominant factor for removal rate increase

- What is maximum allowable Cu polishing pressure in your mind?
### Process – pressure increase

<table>
<thead>
<tr>
<th></th>
<th>POR</th>
<th>Higher pressure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure in Cu polishing</td>
<td>1x</td>
<td>1.4X</td>
</tr>
<tr>
<td>Pressure in Ba polishing</td>
<td>1x</td>
<td>1x</td>
</tr>
<tr>
<td>Defect map</td>
<td><img src="image1.png" alt="Defect map" /></td>
<td><img src="image2.png" alt="Defect map" /></td>
</tr>
<tr>
<td>Total Defect</td>
<td>1x</td>
<td>1.7X</td>
</tr>
<tr>
<td>Scratch</td>
<td>1x</td>
<td>3X</td>
</tr>
</tbody>
</table>

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How to reduce Cu polishing time?

• Process
  – Pressure and RPM

• **Incoming Cu overburden**
  – **Reduction of Cu plating thickness**

• **Consumable**
  – Pad, Slurry and Conditioner
Incoming Cu overburden

- Large Cu overburden resulting in longer Cu polishing
  - Due to height delta, more dishing and Rs variation

- Reduced Cu overburden resulting in shorter Cu polishing
  - Less dishing and better Rs uniformity
Reduced Cu overburden and Cu polishing time

Cu polishing time VS. Cu overburden

Normalized Cu overburden

- More than 30% Cu endpoint decrease
- Concern of under-fill

Within Die Uniformity post Plating

1.00X Cu overburden
- Optimization of Cu electroplating
- No degradation even 0.5X Cu overburden

0.50X Cu overburden with plating optimization
How to reduce Cu polishing time?

• **Process**
  – Pressure and RPM

• **Incoming Cu overburden**
  – Reduction of Cu plating thickness

• **Consumable**
  – Pad, Slurry and Conditioner
Consumable for higher Cu removal rate

- Slurry
  - High static etch rate
    - Risk of corrosion defects and over polishing
  - High abrasive content
    - Risk of scratch defects and severe dishing
- Pad
- Conditioner
Pad for Cu polishing

• Requirements
  – Planarization: Less dishing
  – Uniformity: Uniform E-test data across wafer
  – Low defects: Less scratch
  – Higher Cu removal rate: Without quality degradation
  – Longer life: Low cost of ownership
  – Conditionability: Consistent pad cut rate
Pad for Cu polishing

- Hard or Soft?
- Recent pad development trend
New pad test

- Higher removal rate than baseline (1.2X)
- Shorter polishing time than baseline (0.8X)
- Comparable defect to baseline
Conditioner & Pad surface

Defect

- Lower contact pressure
- Less scratch
- Better planarization

Planarization

Removal rate

(KINIK)
Conventional conditioner
Conditioner displacement VS. Down force

- Static penetration depth
- Load vs. static penetration depth
- Less than 30% of grits
- Less than 20% of grits
- Less than 10% of grits
- Common range

Conventional Conditioner

Pad

50-100µm
10-30µm
### Designed Surface Diamond Conditioner

#### CVD Diamond Conditioner

<table>
<thead>
<tr>
<th>Conditioner</th>
<th>Micro view</th>
<th>Side view</th>
<th>Pad surface height variation</th>
<th>Pad surface</th>
<th>Defect Scan</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>POR</strong></td>
<td><img src="image1.png" alt="Micro view" /></td>
<td><img src="image2.png" alt="Side view" /></td>
<td><img src="image3.png" alt="Pad surface height variation" /></td>
<td><img src="image4.png" alt="Pad surface" /></td>
<td><img src="image5.png" alt="Defect Scan" /></td>
</tr>
<tr>
<td><strong>CVD Diamond Conditioner</strong></td>
<td><img src="image6.png" alt="Micro view" /></td>
<td><img src="image7.png" alt="Side view" /></td>
<td><img src="image8.png" alt="Pad surface height variation" /></td>
<td><img src="image9.png" alt="Pad surface" /></td>
<td><img src="image10.png" alt="Defect Scan" /></td>
</tr>
</tbody>
</table>

- **Rough**
  - due to wide diamond tip height variation
  - Resulting in more defects

- **Smooth**
  - due to tight diamond tip height variation
  - Resulting in less defects
Pad Texture Histogram VS. Conditioners

- Tight pad asperity control with CVD diamond conditioner (0.6X)
Summary

• BEOL CMP equipment platform
  – From 3platen to 2 platen
  – 1 platen for Cu bulk and Cu clear CMP

• Critical Cu removal rate control
  – Process
    – Incoming Cu overburden
    – Consumable

• Forecast of Cu polishing