2019 CMPUG Meeting

“Low Particle Size Ceria STI Slurry Designed for High Performance Dishing and Nitride Loss”
Ferro’s Core Technologies

- Particle engineering
- Particle surface science and modification
- Materials characterization
- Formulation chemistry
Fast Oxide CMP

- Staircase CMP
- MEMS
- Inter-layer dielectric (ILD)

Polish oxide films as fast as possible while maintaining high planarization efficiency

Source: www.memx.com
We make our own particle to optimize size, shape, phase, and reactivity.

The formulation is then customized for the specific particle and application to accelerate removal rates, enhance uniformity, extend shelf-life, etc.
Ceria Polishing Mechanism

- As opposed to other abrasive types, ceria has a large surface chemical action during oxide polishing.

- Studies have shown that Ce$^{3+}$ sites on the surface of ceria particles are critical for SiO$_2$ removal rate.
  - Veera Dandu (Clarkson thesis, also presented at 17$^{th}$ Annual International Symposium on Chemical Mechanical Planarization, August 12$^{th}$-15$^{th}$, 2012, Lake Placid, NY)
Next Generation Ceria Particle

- Particle processing modified to optimize $\text{Ce}^{3+}$ stabilization
- Removal rates increase in parallel to $\text{Ce}^{3+}$ density*

*Unformulated “blank” particle
Further Particle Optimization

Ceria Particle A
Particle modified further to have more active surfaces to make contact with oxide substrate

Ceria Particle B
Ce$^{3+}$ Dense surface, more O vacancies on surface
1731: Ultra Fast Oxide Slurry

- Pairing the next gen. particle with complementary formulation chemistries yields an ultra fast oxide slurry

~50% Boost in pattern oxide rates!

3 PSI
IC1000 Pad
200mm Mirra

Ceria Particle A
Ceria Particle B

= Custom formulation
Ferro Calcinated Ceria STI Slurry

- Our Custom made low $D_{\text{mean}}$ solid state ceria particle is intended to minimize defects

- Employing know how for ceria particle engineering and formulations (accelerants, inhibitors...etc), we have developed a STI slurry with low $D_{\text{mean}}$, and is still able to maintain high RR and good selectivity in low abrasive concentrations

* Measured by Horiba LA-910
## SRS-2303 VS Competitor A

**Brief Summary**

<table>
<thead>
<tr>
<th></th>
<th>SRS-2303</th>
<th>Competitor A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solids</td>
<td>3%</td>
<td>4%</td>
</tr>
<tr>
<td>Solids at POU</td>
<td>0.3%</td>
<td>1-4%</td>
</tr>
<tr>
<td>pH</td>
<td>3.5-3.8</td>
<td>~5</td>
</tr>
<tr>
<td>Dilution Ratio</td>
<td>10X</td>
<td>3X~4X</td>
</tr>
<tr>
<td>$D_{mean}$</td>
<td>85nm</td>
<td>150nm</td>
</tr>
<tr>
<td>$D_0$</td>
<td>197nm</td>
<td>584nm</td>
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<tr>
<td>TEOS RR(A/min)**</td>
<td>3200</td>
<td>950</td>
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<tr>
<td>SiN RR(A/min)**</td>
<td>2</td>
<td>15</td>
</tr>
<tr>
<td>Selectivity</td>
<td>1600:1</td>
<td>60:1</td>
</tr>
</tbody>
</table>

*Measured on Horiba 910  
**Mirra 200mm, IC1000 2psi for SRS-2303 3psi for Competitor A Platen 77 rpm Head 73 rpm, SRS-2303 Combined with 8X diluted 2298
Ferro has developed a multi-component STI platform for our solid state ceria designed to be a mix-on-tool, either 1 or 2-Platen, STI solution.

- **Dilutable Ceria (SRS2303)**
  - A Pack
    - $A + H_2O$
  - B Pack (Platen 1)
    - Faster rates
  - C Pack (Platen 2)
    - Slightly slower rates
    - Excellent nitride hold
    - Low dishing
## SRS-2303 & SRS2303+2298

<table>
<thead>
<tr>
<th></th>
<th>Blanket TEOS (A/min.)</th>
<th>Oxide RR* (A/min.)</th>
<th>Nitride RR* (A/min.)</th>
<th>Selectivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>SRS-2303</td>
<td>5400</td>
<td>6000</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>SRS-2303+2298</td>
<td>3200</td>
<td>3600</td>
<td>2</td>
<td>1600:1</td>
</tr>
</tbody>
</table>

*50/50µm feature 2 PSI, 93 RPM, IC1000 pad 200mm Mirra*
SRS-2303: Polishing Stability

- Stable and predictable removal rates

**RR vs Polish Time**

<table>
<thead>
<tr>
<th>Removal Rates (A/min)</th>
<th>Polishing Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>5000</td>
<td>15</td>
</tr>
<tr>
<td>5500</td>
<td>30</td>
</tr>
<tr>
<td>6000</td>
<td>60</td>
</tr>
<tr>
<td>6500</td>
<td>120</td>
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</tbody>
</table>

**Mini Marathon**

<table>
<thead>
<tr>
<th>Removal Rates (A/min)</th>
<th>Wafer Counts</th>
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</thead>
<tbody>
<tr>
<td>5000</td>
<td>5</td>
</tr>
<tr>
<td>5500</td>
<td>10</td>
</tr>
<tr>
<td>6000</td>
<td>15</td>
</tr>
<tr>
<td>6500</td>
<td>20</td>
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</tbody>
</table>

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SRS-2303: PV Response

- Prestonian polishing behavior with a predictable response to PV

93 RPM, 150 mL/min.
200mm Mirra, TEOS Blanket

3 PSI, 150 mL/min.
200mm Mirra, TEOS Blanket
Experimental Setup

- Pattern wafers (MIT864 mask), 1\textsuperscript{st} step polished to active oxide THK=1150~1250A (10\% feature density) is used for comparison

- Polish 2\textsuperscript{nd} step with SRS-2303 and Competitor A slurry

- Polished on AMAT Mirra 200mm polisher, 2 psi DF, 77 rpm platen, 73 rpm head and 150ml/min slurry flow for SRS-2303, 3 psi DF, 77 rpm platen, 73 rpm head and 150ml/min slurry flow for Competitor A

- End Point is determined when 500um pitch feature cleared
SRS-2303+2298 (SON additive) VS Competitor A Slurry

- Platen 2 Active Oxide THK (10%-90% features, 100um size)
- SRS-2303 polished at lower DF, but still clears wafer within 30s

100µm feature size 2 PSI, 77 RPM, IC1000 pad 200mm Mirra

100µm feature size 3 PSI, 77 RPM, IC1000 pad 200mm Mirra
SRS-2303+2298 (SON additive) VS Competitor A Slurry

- Platen 2 Trench Loss (10%-90% features, 100um size)
- Lower Trench Loss across all features with SRS-2303

### Trench Loss

- **SRS-2303**: 100um feature size 2 PSI, 77 RPM, IC1000 pad 200mm Mirra
- **Competitor A**: 100um feature size 3 PSI, 77 RPM, IC1000 pad 200mm Mirra

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SRS-2303+2298(SON additive) VS Competitor A Slurry

- Platen 2 Nitride Loss (10%-90% features, 100um size)
- Lower Nitride Loss across all features with SRS-2303

Nitride Loss

Polish Time Relative to EP

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SRS-2303: 50% feature density 2 PSI, 77 RPM, IC1000 pad 200mm Mirra

Competitor A: 50% feature density 3 PSI, 77 RPM, IC1000 pad 200mm Mirra

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Profilometry Methods

- **EndPoint (EP) is defined when 500um-50% feature cleared**
- **Profilometry done with KLA HRP-220**
- **We pick 5 peaks/valleys in the middle that is leveled and average**
- SRS-2303 shows superior resistance to dishing with extended overpolishing
- SRS-2303 has tighter grouping across all density ranges, better planarity
Profile Comparison

10% Profilometry Comparison

- Angstroms vs. um
- SRS2303 EP, SRS2303 25% OP, SRS2303 100% OP, Competitor EP, Competitor 25% OP, Competitor 100% OP
Profile Comparison

30% Profilometry Comparison

Profile Comparison

- Angstroms
- um

- SRS2303 EP
- SRS2303 25% OP
- SRS2303 100% OP
- Competitor EP
- Competitor 25% OP
- Competitor 100% OP
Profile Comparison

50% Profilometry Comparison

- SRS2303 EP
- SRS2303 25% OP
- SRS2303 100% OP
- Competitor EP
- Competitor 25% OP
- Competitor 100% OP
864 Pattern wafer with KLA-2139 scan
Defect Comparison

### Competitor

<table>
<thead>
<tr>
<th></th>
<th>Small particle</th>
<th>Big particle</th>
<th>Other</th>
<th>False</th>
<th>Total</th>
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<tbody>
<tr>
<td>Review count</td>
<td>87</td>
<td>24</td>
<td>18</td>
<td>12</td>
<td>141</td>
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<tr>
<td>Defect count%</td>
<td>61.7%</td>
<td>17.0%</td>
<td>12.8%</td>
<td>8.5%</td>
<td></td>
</tr>
</tbody>
</table>

### SRS2303

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<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review count</td>
<td>69</td>
<td>4</td>
<td>9</td>
<td>12</td>
<td>94</td>
</tr>
<tr>
<td>Defect count%</td>
<td>73.4%</td>
<td>4.3%</td>
<td>9.6%</td>
<td>12.8%</td>
<td></td>
</tr>
</tbody>
</table>
Defect type

- Small particle
- Big particle
Defect type

Other
Ferro SRS-2303 Advantage

- Low $D_{\text{mean}}$ particles have been made to minimize defect concerns associated with larger particle size
- Superior defects
- Lower $D_{\text{mean}}$ particles, lower polishing down force
- Faster removal rate (3X) to achieve high throughput and lower costs
- High dilution ratio (0.3% ceria POU) lowers cost
- Excellent stop on nitride performance and low trench loss enables customers more processing window
- Custom slurries can be developed upon request