The Changing Needs of CMP: How to Design for Technology Shifts

B. Small, L. Yao, R. Jee, H. Tran, B. Scott, C. Shang, M. Yu, P. Chelle, D. Frey, F. McClung

August 7, 2002

EKC Technology, Inc.
A ChemFirst Company

Solutions for Wafer Cleaning, Surface Preparation and CMP Processes

© 2002 EKC Technology, Inc.
# EKC CMP Products

## CMP Products

<table>
<thead>
<tr>
<th>Product Description</th>
<th>pH</th>
<th>Abrasive</th>
</tr>
</thead>
<tbody>
<tr>
<td>MicroPlanar™ CMP1000™ former generation oxide slurries</td>
<td>10-11</td>
<td>Silica</td>
</tr>
<tr>
<td>MicroPlanar™ CMP2000™ Advanced Planarization Slurries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Including STI2100™, IMD2400™ and PMD2700™</td>
<td>4-6</td>
<td>Ceria</td>
</tr>
<tr>
<td>MicroPlanar™ CMP3000™ series Tungsten Slurries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Ferric nitrate based slurries</td>
<td>1-2</td>
<td>Alumina</td>
</tr>
<tr>
<td>• Non ferric nitrate based slurries</td>
<td>2-8</td>
<td>Alumina/ SiO₂</td>
</tr>
<tr>
<td>MicroPlanar™ CMP9000™ series Copper Slurries</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Phase I : Nitrogen based slurries</td>
<td>3-5</td>
<td>Alumina/ SiO₂</td>
</tr>
<tr>
<td>• Phase II : Nitrogen based slurries</td>
<td>4-9</td>
<td>Silica</td>
</tr>
</tbody>
</table>

## Post CMP Cleaning Products

<table>
<thead>
<tr>
<th>Product Description</th>
<th>pH</th>
</tr>
</thead>
<tbody>
<tr>
<td>MicroPlanar™ PCMP5000™ series Post-CMP Cleaning Solutions</td>
<td>2-9</td>
</tr>
</tbody>
</table>

## CMP Tool Cleaning Products

<table>
<thead>
<tr>
<th>Product Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MicroPlanar™ PCMP100™ series products</td>
</tr>
</tbody>
</table>
Different metals, different depositions...

- Copper, Aluminum
- Barrier material
  - Ti
  - Ta
  - W
  - and why not WN?
  - What about TiSiN?, TaSiN?
- Thinner layers
...and different dielectric options...

<table>
<thead>
<tr>
<th>Material</th>
<th>Supplier</th>
<th>k value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CVD OSG Dielectrics</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black Diamond I &amp; II</td>
<td>Applied Materials</td>
<td>2.4 - 3.1</td>
</tr>
<tr>
<td>Coral</td>
<td>Novellus Systems</td>
<td>2.4 - 2.8</td>
</tr>
<tr>
<td>Flowfill CVD, Orion low k</td>
<td>Trikon Technologies</td>
<td>2.8, &lt;=2.2</td>
</tr>
<tr>
<td>Aurora 2.7</td>
<td>ASM International</td>
<td>&lt;=2.7</td>
</tr>
<tr>
<td><strong>CVD etch stop/hard mask</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BLOk</td>
<td>Applied Materials</td>
<td>4.5</td>
</tr>
<tr>
<td>Low-k SiC</td>
<td>ASM International</td>
<td>3.8</td>
</tr>
<tr>
<td><strong>Spin-On Dielectrics (SODs)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Polyaromatic (SiLK)</td>
<td>Dow Chemical</td>
<td>2.65</td>
</tr>
<tr>
<td>HSQ (Fox), Porous HSQ (XLK)</td>
<td>Dow Corning</td>
<td>2.9, 2.0</td>
</tr>
<tr>
<td>MSQ, Porous MSQ</td>
<td>JSR</td>
<td>2.7, 2.0-2.2</td>
</tr>
<tr>
<td>Porous silica (MesoELK)</td>
<td>Air Products/Schumacher</td>
<td>1.9</td>
</tr>
<tr>
<td>OSG (HOSP), OSG etch stop (HOSP BEST)</td>
<td>Honeywell</td>
<td>2.5, 2.6</td>
</tr>
<tr>
<td>Organic (GX-3) &amp; porous organic (GX-3p)</td>
<td>Honeywell</td>
<td>2.6, 1.9</td>
</tr>
<tr>
<td>Porous silica (NANOGLASS)</td>
<td>Honeywell Elec. Materials</td>
<td>1.3, 2.2</td>
</tr>
</tbody>
</table>
Mechanical Properties of SiO$_2$ vs low-k Films

...and different mechanical and chemical properties of these different materials...

<table>
<thead>
<tr>
<th>Materials Properties</th>
<th>PECVD TEOS SiO$_2$</th>
<th>Zircon</th>
<th>SiLK</th>
<th>SiLK film (v7)</th>
<th>Fox</th>
<th>XLK</th>
<th>SiCOH</th>
<th>a-SiC:H</th>
</tr>
</thead>
<tbody>
<tr>
<td>k value (Pre-CMP)</td>
<td>4</td>
<td>2.25</td>
<td>2.65</td>
<td>&lt;2.4</td>
<td>2.9</td>
<td>2</td>
<td>2.7+/0.1</td>
<td>5.1</td>
</tr>
<tr>
<td>Hardness (GPa)</td>
<td>8</td>
<td>0.45</td>
<td>0.2</td>
<td>0.16</td>
<td>0.6</td>
<td>0.2</td>
<td>0.25</td>
<td>NA</td>
</tr>
<tr>
<td>Modulus (GPa)</td>
<td>71.7</td>
<td>3.1</td>
<td>3.2</td>
<td>2.5</td>
<td>6</td>
<td>2</td>
<td>3.2</td>
<td>NA</td>
</tr>
<tr>
<td>CTE (ppm/°C)</td>
<td>0.94</td>
<td>16</td>
<td>66</td>
<td>NA</td>
<td>20</td>
<td>&lt;10</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>k value (Post CMP)</td>
<td>NA</td>
<td>NA</td>
<td>2.7+/0.04</td>
<td>2.44+/0.04</td>
<td>NA</td>
<td>&gt;4.1+/1.26</td>
<td>3.05+/0.24</td>
<td>5+/0.16</td>
</tr>
</tbody>
</table>

© 2002 EKC Technology, Inc.
...and different Integration Schemes...

Hybrid Integration

Low-k with etch stop

Low-k with timed etch

Dow Chemical Co.

© 2002 EKC Technology, Inc.
...and different selectivity strategies...

Direct contact between metal & low-κ is unavoidable
...and different challenges...
…requires:

• Supplier Flexibility and ability to tune Product
• Tighter Cu and Oxide loss, better planarization, lower defects or higher yields, no corrosion, compatible PCMP solutions
• Lots of communications are needed:
  – Fab / Supplier:
    » TELL US WHAT YOU DO
    » TELL US WHAT YOU WANT
    » TELL US WHEN YOU CHANGE DIRECTION
  – Supplier / Supplier:
    » Equipment vendor / consumable vendor
    » Pad vendor / slurry vendor (or pad vendor / conditioning disk vendor, …)
• Technology extension
  » Product / Process
  » Alternative technology ??
MicroPlanar™ CMP3550™

- CMP3550™ abrasive
- Alumina and PIA based slurry (low plug recess and etch rate)
- pH range = ~2 (after mixed with oxidizer)
- Oxidizer = PIA (H₅IO₆) (CMP3510™
- Stable process, no titration required
- Blanket wafers
  - W removal rate = ~3600 Å/min
  - Ti removal rate = ~ 800 to 900 Å/min
  - TEOS removal rate = 350-450 Å/min
RJX-Series - Summary of Work

- Slurry Information
  - Oxidizer: MicroPlanar™ CMP 3510™ (PIA based)
  - Abrasive: Alumina or Silica
  - After mixing: pH=5.0, solids: 1-3%
- Process: 5.5psi/0psi/120rpm/110rpm/175ml, Ex-situ conditioning
- Pad: IC1000/SubaIV
- Blanket wafer
  - W removal rate = 4840Å/min
  - Ti removal rate = 1230Å/min
  - TEOS removal rate = 395Å/min
Effect of Additives with RJX Slurries

Effect of Additive A Concentration on Tungsten Removal Rate
pH=5.0

Rate (A/min)

Concentration of Additive A (%)

© 2002 EKC Technology, Inc.
CSX-Series- Summary of Work

- Slurry Information
  - Oxidizer: CSX291 (PIA based)
  - Abrasive: Silica
  - After mixing: pH=3.5, solids: 3%
- Process: 6psi/0psi/90rpm/90rpm/175ml, Ex-situ condition.
- Pad: IC1000/SubaIV
- Blanket wafer
  - W removal rate = 4910Å/min ± 7.6%
  - Ti removal rate = 1020Å/min ± 6.1%
  - TEOS removal rate = ~400Å/min
BSSX-Series- Summary of Work

• Slurry Information
  – Abrasive: BSSX-180 or 200 (Silica)
  – After mixing: pH=3.0, solids: 2.5%
• Process: 5psi/0psi/110rpm/90rpm/175ml, Ex-situ condition.
• Pad: IC1000/Suba IV
• Blanket wafer
  – W removal rate = 4750-5200Å/min
  – Ti removal rate = >2000Å/min
  – TEOS removal rate = 250-300Å/min
## Customer Evaluation of BSSX-200

<table>
<thead>
<tr>
<th>Feature</th>
<th>Slurry A</th>
<th>BSSX-200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downforce</td>
<td>1</td>
<td>1.11</td>
</tr>
<tr>
<td>Tablespeed</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Flow (ml/min)</td>
<td>300</td>
<td>400</td>
</tr>
<tr>
<td>Pad</td>
<td>IC1000 Perf</td>
<td>IC 1000 Perf</td>
</tr>
<tr>
<td>Tungsten Removal</td>
<td>4011 - 4105Å</td>
<td>4011 - 4052Å</td>
</tr>
<tr>
<td>Uniformity</td>
<td>1.64 - 3.64</td>
<td>1.61 - 3.00</td>
</tr>
<tr>
<td>Oxide Loss</td>
<td>150 - 250Å</td>
<td>200 - 300Å</td>
</tr>
<tr>
<td>Defectivity (total)</td>
<td>&lt;50 @ 0.19μm</td>
<td>&lt;50 @ 0.19μm</td>
</tr>
</tbody>
</table>

© 2002 EKC Technology, Inc.
EKC Cu Barrier Slurry Summary

EKC Cu Barrier (TaN) Slurry Summary

Chemistry - Colloidal Silica with Hydroxylamine Chemistry
            pH 3.0 - 10.0
            SiO₂: 0 - 15% solids

Process - Polishing pressure: 1.5psi - 3.0psi
          - Platen speed: 35 rpm - 95 rpm
          - Slurry flow: 150 ml/min - 250 ml/min

Performance - Films (Cu, TaN. Oxide, Low-k, etc) selectivities
               can be tuned
EKC Product Flexibility for Copper

Selectivities can be adapted with simple chemistry and/or mixing ratio adjustments
Nitrogen-Based Slurry Development for Copper/Low-k (SiLK™) Integration
Silica Based Slurry for High Selectivity Application, 2 PSI

Target: Lower SiLK Film MRR

* Original high selectivity slurry (Type A, Cu:TaN:Oxide = 1:5:1) shows a higher porous SiLK MRR
* Slurry Type E reduced porous SiLK MRR efficiently.

Process Set up: IPEC 472 Polisher / Politex Embossed Pad
Process: 2 psi polishing pressure, 70 rpm platen speed, 75 rpm carrier speed, 200 ml/min slurry flow.
Technology Extension: Compatibility with low-k for direct contact with slurries

1) SiLK Porous and SiLK (ES) Film have no changes on FTIR before and after CMP with EKC slurry

2) SiCN Film has no changes on FTIR before and after CMP with EKC slurry
STI2100™ STI Slurry

- EKC Exclusive High Purity Ceria
- Low Abrasive Concentration
- Mean Diameter Particle Control: 150 nm
- pH : 5 (desirable pH range)
- Formulated with cAiP™
  (chemical Activator, inhibitor, Planarizer)

Advantages
- Enables Excellent Planarization
- Reasonable Cost for Advanced STI Slurry
- Single Component

Ceria, Horiba LA-920 data

© 2002 EKC Technology, Inc.
STI2100™ Performance

<table>
<thead>
<tr>
<th>Slurry</th>
<th>pH</th>
<th>Abrasive %</th>
<th>Blanket Wafer Removal Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Colloidal silica</td>
<td>10.5</td>
<td>20</td>
<td>3400 Å/min</td>
</tr>
<tr>
<td>Fumed silica</td>
<td>10.5</td>
<td>12.5</td>
<td>3400 Å/min</td>
</tr>
<tr>
<td>Ceria (abrasive only)</td>
<td>9</td>
<td>1</td>
<td>6500 Å/min</td>
</tr>
<tr>
<td>STI2100™</td>
<td>5</td>
<td>1.5</td>
<td>200 Å/min</td>
</tr>
</tbody>
</table>

Process on EBARA EPO-222D:
5.5psi downforce, 100 rpm platen, 107 rpm carrier, IC1000/Suba 400 perf. Thermal Oxide wafers

On MIT mask patterned wafer:
• Excellent planarity
• Minimum dishing on various densities and pitch sides

Process on IPEC472: 4psi DF, 100 rpm platen, 107 rpm carrier, IC1000/Suba 400 perf. SKIL-2 wafers

© 2002 EKC Technology, Inc.
<table>
<thead>
<tr>
<th>Slurry</th>
<th>Defect #</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>STI2100™</strong></td>
<td>SP1-TBI</td>
</tr>
</tbody>
</table>
|                              | > 0.14 μm| 185
| **STI2100™ + H₂O₂ Brush**    |          |
|                              | 40       |

**Process**: Ebara EPO-222D. 30s rinse followed by DI brush scrub 60s and pencil cleaner. No buffing. 15s polishing.

* 30s brush + 40s H₂O₂ 1% + 30s brush.

- No buffing, Low defectivity
- H₂O₂ is efficient for cleaning remaining Ceria particles
Noble Metals

- Oxidizer and Chemistries currently being evaluated at customer site with great promises.

**SEM images of polished Ir/TEOS pattern wafer**

Left: Top view of 0.6 micron size Ir plug.
Right: Cross-section of a 150nm deep, 0.6 micron-via size Ir plug.
LPX-100 Post CMP chemistry

- **Aqueous** (pH 7.5)
- Additional chelation agents and anions
- Good for post CMP copper
- LPX-100 peroxide can clean CeO$_2$ residues.
- Will not corrode sensitive metal films
- Broad process window
- Environmentally safe and aqueous drain compatible
- Will not corrode equipment
- No sign of bacteria growth (standard plate count CFU/ml)
- **No ammonium hydroxide, No Fluorides**
Conclusion

• Rapid Technology Shifts and New Challenges Require:
  – Flexible products and processes
  – Close communication with Fabs. More Joint Development Projects.
  – Close communications with Suppliers for a fully integrated supply chain

• EKC and its suppliers are addressing new technologies to answer the needs of the industry
Technology Extension

• Technology Extension: low down force, gentle process
  • Have I heard < 0.5 PSI? Is my tool capable of this?

• Technology Extension: low shear, lubricity
  • Evaluations on multi layer stacks required. No single layer demo!!

• Technology Extension: lower solids, or no particle (“reactive liquid”)
  • Still Chemical Mechanical Planarization
    – Conventional Pads
    – Fixed Abrasive Pads

• Technology Extension: next generation chemistries to modify metal oxide surface for improved removal.
  • More chemical, less mechanical
  • High planarization agents / Topography correction path