Colloidal Properties of Alumina Abrasives for Copper CMP Slurries

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Introduction
Chemical mechanical planarization (CMP) is used in integrated circuit manufacturing to remove excess material and provide a globally planarized wafer surface. The process requires slurry containing nanometer-sized abrasive particles and chemical additives to produce a mechanical and chemical synergistic effect that is responsible for the material removal rate (MRR). Because copper has become the interconnect of choice, the focus of our research is on copper CMP. The influence of common slurry additives on the colloidal behavior of alumina suspensions is investigated. The alumina suspensions are characterized using zeta potential and particle size distribution measurements with various chemical additives and in the presence of nanometer-sized copper particles. The results are compared to the colloidal behavior of the same slurries without the addition of copper.

2005 Main Objectives
- Develop basic understanding of agglomeration/dispersion effects on CMP
  - Characterize colloidal behavior of alumina slurries containing common CMP additives by measurement of zeta potential and particle size and compare data to the same slurries in the presence of copper particles.
  - Study particle size distribution to determine when a standard distribution assumption is applicable and when bimodal distributions occur.
- Basic material removal model development
  - Determine the effects of chemical additives on material removal rate (MRR) using the Luo and Dornfeld model with measured particle sizes and distributions.

Experimental CMP Slurry
- Abrasives
  - 40 wt% α-alumina slurry from Cabot Corporation
  - 180 nm average diameter
  - all samples were diluted to 0.1 wt% in a 1 mM KNO3 solution.
- Common copper CMP additives
  - glycine (complexing agent)
  - hydrogen peroxide (H2O2) (oxidizing agent)
  - sodium-dodecyl-sulfate (SDS) (surfactant)
  - benzo triazole (BTA) (corrosion inhibitor)
- Copper nano-particles
  - <100 nm in diameter from Aldrich

Experimental Copper CMP MRR

<table>
<thead>
<tr>
<th>pH</th>
<th>MRR (nm/min)</th>
<th>pH value</th>
<th>Chemical Additives</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2</td>
<td>0.1 M Glycine, 0.1 wt% H2O2</td>
<td>0.3</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>0.01 wt% BTA, 0.1 wt% H2O2, 0.1 mM SDS, 1 mM KNO3</td>
<td>0.3</td>
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<tr>
<td>5</td>
<td>4</td>
<td>0.1 M Glycine, 0.1 wt% H2O2</td>
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<td>6</td>
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</tr>
<tr>
<td>7</td>
<td>6</td>
<td>0.1 M Glycine, 0.1 wt% H2O2</td>
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<tr>
<td>8</td>
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<td>0.01 wt% BTA, 0.1 wt% H2O2, 0.1 mM SDS, 1 mM KNO3</td>
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<tr>
<td>9</td>
<td>8</td>
<td>0.1 M Glycine, 0.1 wt% H2O2</td>
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<tr>
<td>11</td>
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<td>0.3</td>
</tr>
</tbody>
</table>

Future Work
- Basic material removal model development
  - Incorporate bimodal distribution effects into Luo and Dornfeld mechanical model
  - Use data from CMP experiments to develop chemical component of Luo and Dornfeld model.
- Further develop basic understanding of agglomeration/dispersion effects
  - Investigate the effects of additives (glycine, H2O2, etc.) on the hardness of the copper surface.
  - Colloidal effects of additives on silica suspensions should also be studied, since silica is often used in copper CMP slurries.
- Determine polishing experiments need to be done to determine when particle size begins to dominate MRR as down pressure increases.

Acknowledgment