Microelectronic Packaging: The Rough of It

OR

Improvement of Adhesion between Dielectric and Seed Layer for Next Generation System-on-Package (SOP)

Will Stoll

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Moore’s Law

- exponential rise in performance coupled with an exponential drop in price
- integrated circuit innovations
Microelectronic Packaging

- **Printed Circuit Boards**
  - Multiple paths to individual components
- **System-On-A-Package (SOP)**
  - Embedded electronic components in a high density multilayered substrate
SOP Substrate Formation

- **Core Formation**
  - Laminate core (stability) dielectric material
  - Hot pressed

- **Dielectric**
  - Epoxy materials
    - Good bonding, poor dielectric properties at high frequencies
  - Resin Material RXP-4
    - Superior dielectric properties
SOP Substrate Formation

- Photolithography
  - transfer images with UV light onto photosensitive material (photo resist)
  - Lamination of photoresist
  - Photolithography
  - Development
Metallization – Subtractive Etching

- Laminate
- Photolithography – exposure
- Photolithography – development
- Etching and Stripping of Photoresist
Metallization – Subadditive Etching

1. Seed Layer deposition
2. Photolithography - exposure
3. Photolithography - Development
4. Electroplating and Stripping of Photoresist
5. Etching of seed layer
RXP-4 Challenge

- Delamination between RXP-4 dielectric and electroless copper.

- Improved Bonding
  - Mechanical bonding
    - Greater surface roughness $\rightarrow$ greater contact area $\rightarrow$ better bonding
    - Anchoring – irregular cavities creates interference fit
  - Chemical Bonding
Plasma Etching

- High energy gas ions bombard surface in a heated vacuum chamber.
- Process not characterized on RXP-4
Chemical Desmear

- Harsh chemical bath that roughens the surface
  - Swell
  - Etching
  - Conditioning
- Effect not known on RXP-4
Experimental Work

Increase the surface roughness of RXP-4

- Plasma Etching
  - Gas Flow Rate
  - Gas Composition
  - Gas Time Exposure

- Chemical Desmear
  - Swell and Etching Times
Surface Roughness Measurements

DekTak 3030 Surface Profiler Measuring System.

- Diamond-tipped stylus
- Measures the surface electromechanically
RXP-4 Samples

- Plasma Treated
- Untreated
Plasma Flow Rate Results

Roughness Difference vs Plasma Treatment
Cu etched RXP-4B

Average Roughness Difference Between Untreated and Treated Sample (micrometers)

Flow Rate of CF4 & O2 (sccm)

\[ y = -4E-05x^2 + 0.0117x + 0.0159 \]
Plasma Gas Composition Results

![Graph showing the plasma concentration effect on surface roughness. The x-axis represents the ratio of O2 to CF4, and the y-axis represents the average roughness difference between untreated and treated sample (micrometers). The graph indicates that the roughness difference increases with higher ratios of O2 to CF4.]
Plasma Gas Time Exposure Results

Surface Roughness vs Plasma Time

Average Surface Roughness Difference between Treated and Untreated Samples (micrometers)

Plasma Time (minutes)

Legend:
- Blue: Plasma to Prior
- Maroon: Plasma to Untreated (glass)
## Plasma Gas Time Exposure Results

<table>
<thead>
<tr>
<th>Time (minutes)</th>
<th>Average Roughness Difference (µm) ±0.2µm</th>
<th>Etched Thickness (µm)±1µm</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>0.73</td>
<td>0.83</td>
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<tr>
<td>15</td>
<td>0.64</td>
<td>0.7</td>
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<tr>
<td>12</td>
<td>0.21</td>
<td>0.27</td>
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<tr>
<td>10</td>
<td>0.6</td>
<td>0.49</td>
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<tr>
<td>8</td>
<td>0.23</td>
<td>0.22</td>
</tr>
<tr>
<td>5</td>
<td>0.07</td>
<td>0.22</td>
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</table>
## Chemical Desmearing Results

<table>
<thead>
<tr>
<th>Sample</th>
<th>Time (minutes)</th>
<th>Before</th>
<th>Plasma</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Swell</td>
<td>Etching</td>
<td>µm</td>
<td>µm</td>
</tr>
<tr>
<td>R1</td>
<td>5</td>
<td>10</td>
<td>0.51</td>
<td>0.58</td>
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<tr>
<td>R2</td>
<td>10</td>
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<tr>
<td>R3</td>
<td>15</td>
<td>30</td>
<td>0.46</td>
<td>0.55</td>
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<tr>
<td>R0</td>
<td>0</td>
<td>0</td>
<td>0.47</td>
<td></td>
</tr>
<tr>
<td>GT1</td>
<td>5</td>
<td>10</td>
<td></td>
<td>0.36</td>
</tr>
<tr>
<td>GT2</td>
<td>10</td>
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<tr>
<td>GT3</td>
<td>30</td>
<td>30</td>
<td></td>
<td>0.57</td>
</tr>
</tbody>
</table>
Chemical Desmearing Results
Conclusions

- Plasma Etching increased surface roughness or RXP-4 consistently to 1µm.
  - Optimal parameters (100 C, 400 W Rf Power)
    100/25 cc/min 02/CF4 flow rate
    10-15 minutes
- No increase in surface roughness with Chemical Desmear
- Final conclusion awaiting industry adhesion test results
Research Link to Classroom

- Great stories (real-life research examples)
- Professional contacts

Lesson Plan & Modern Physics Education
Basis of Quantum Theory

- Uncertainty Principle
  - If the velocity (momentum) is known, the position is unknown
  - If the position is known, the velocity (momentum) is unknown

- Quantized
  - Only discrete wavelength’s can fit in the boundary conditions of a standing wave.
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