Determination of pre/post process surface roughness and comparison with copper film adhesion on multiple polymer substrates

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Work supported by the Packaging Research Center at Georgia Tech
Motivation

- EU Directive
  - Restrict lead-based solder by July 1, 2006
    - Companies given exceptions

- Effect on manufacturing
  - Higher solder temperatures
  - CTE consideration
  - Layer adhesion
Scope of Project

- Board polymer research
  - Boards provided by Company A for chemical copper coating
  - Boards returned to Company A for adhesion testing (Peel Strength Test)

- Board surface roughness
  - Tested before copper coating allowing comparison to peel strength
Scope of Project

- Two types of roughness:
  - Micro-roughness (~100 Å)
  - Macro-roughness (>1000 Å)

- Examine which type of roughness is most affected by chemical roughening process

- Correlation between types of roughness for each board and peel strength
  - To determine which, if either, is the dominant mode for adhesion
Adhesion Theory

- Two main modes of adhesion
  - Chemical
    - Based on oxide formation
  - Mechanical
    - Based on surface energy reduction
Adhesion Theory

- Epoxy chemical structure
  - Oxygen group allows for oxide formation and chemical bond
  - Adhesion is based on surface area

Generic epoxy

Copper film
Adhesion Theory

- Mechanical Adhesion
  - Surface Energy
    - Asymmetry of chemical bonds
    - Additional layer relieves surface energy (bonding)

- Adhesion is based on surface roughness and area
**Expected Results**

- Chemical process is expected to increase micro-roughness more due to scale of reaction.

- Both types of adhesion depend on surface area:
  - Boards with a higher surface roughness will have a higher peel strength.

- Both types of roughness increase surface area:
  - It is unclear which type of roughness will correlate with peel strength better.
Methods: Sample Preparation

- 4 types of 5x5” boards (2 per type)
  - 1 board of each type set aside

- Placed in Atotech Permanganate Etch

- 1x5” section cut
  - Set aside as post process
  - 1x4” section set to Company A

- 4x5” boards were plated with electroless copper film (~1µm)

- Boards were plated with electrolytic copper (~18µm)
Methods: Sample Preparation

- Dupont photoresist film was applied and developed according to peel test pattern
- Copper was etched off and samples were sent back to Company A for testing
Methods: Sample Testing

- All un-plated board surface roughness measurements made with Veeco DekTak 3030
- Surfaces were taped to platform and leveled
- DekTak function used to determine surface roughness
  - Deviation from a linear approximation between two selected points
**Methods: Sample Testing**

- Micro-roughness was determined over a 5 micron range

- Macro-roughness was determined over a 315 micron range

- 5 locations were averaged to determine the board roughness
  - 7 trials were performed at each location
**Methods: Peel Test**

- Samples of plated board and post-process boards were sent to Company A
  - Peel Strength Tests were performed
  - Macro-scale surface roughness was performed over a 215x315 micron area using AFM

- Company A returned data for analysis
Results: Effect on macro-roughness

- Roughness increases by a varied amount
- Polymer 91-51 shows a lack of significant increase in macro-roughness
- Polymer 120-2 has greatest end macro-roughness
Results: Effect on micro-roughness

- Smaller percentage in micro-roughness
- Similar increases across polymers
- Polymer 120-2 has greatest end micro-roughness

<table>
<thead>
<tr>
<th>Polymer</th>
<th>Pre-Process</th>
<th>Post-Process</th>
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<tbody>
<tr>
<td>91-51</td>
<td>88.56</td>
<td>93.54</td>
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<tr>
<td>91-50</td>
<td>102.96</td>
<td>180.08</td>
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<tr>
<td>120-1</td>
<td>109.18</td>
<td>138.9</td>
</tr>
<tr>
<td>120-2</td>
<td>147.48</td>
<td>238.18</td>
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</tbody>
</table>

Percent Change:
- 66.5%
- 48.5%
- 74.9%
- 118.2%
Results: Correlation to Peel Strength

- Peel strength shows a stronger correlation with macro-roughness than micro-roughness.
- Polymer 91-51 shows significantly smaller peel strength.
- Polymers 120-1 & 2 have greatest peel strength.

<table>
<thead>
<tr>
<th></th>
<th>Macro (A)</th>
<th>Micro (A)</th>
<th>Peel Strength (lbf/in)</th>
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<tbody>
<tr>
<td>120-2</td>
<td>8990</td>
<td>238.18</td>
<td>1.908</td>
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<tr>
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<tr>
<td>91-51</td>
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<td>147.48</td>
<td>0.469</td>
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</table>
Board 91-51
- Deciding board for results
- Originally had a decrease in macro-roughness with etching
- Contained two distinct roughness sections

Measuring techniques
- AFM vs. DekTak
- Surface roughness vs. surface area
Future Work

- Six more samples are being tested in the next few weeks
- Improvement of micro/macro definitions to line up with current theory
- Investigate whether micro or macro-roughness has a larger effect on surface area
Effect on Classroom: Lesson

- Lesson based on understanding statistical significance of data
  - Students will learn statistical concepts
    - Standard Deviation
    - Confidence Intervals
    - Sample Sizing
  - Students will learn to use Excel
Effect on Classroom: Lesson

- Data collected as a class will be used to establish formulae and procedures
  - Measuring height using a 12” ruler
  - Use varying values to motivate question of how we know when to stop taking data
Effect on Classroom: Lesson

- In class lab
  - Students collect data
  - Students hand calculate values for small set of data
  - Students use Excel to calculate values for a larger set of data from lab

- Two assessments
  - Small worksheet with questions after classroom work
  - Excel spreadsheet with data to evaluate and electronic submission
References


Questions