The development of a tin whisker mitigating conformal coating

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THE DEVELOPMENT OF A TIN-WHISKER MITIGATING CONFORMAL COATING

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Outline of Presentation

• Introduction to tin whiskers
• Aims and objectives
• Experimental approach
• Whisker growth studies
• Mechanical properties
• Conclusions
What are metal whiskers?

- Electrically conductive crystalline growths from a metal surface (e.g. Sn, Zn and Cd)
- Uncertain incubation period before growth
- Numerous growth morphologies possible
- A few micrometres in diameter and up to several millimetres in length

Spiral | Kinked | Odd-shaped eruption | Hillock/nodule
10µm | 1µm | 10µm | 1µm
Tin whisker related problems

- *Filament type* whiskers present the greatest threat to the reliability of electronics components
- Grow to sufficient lengths to cause electrical short circuits
- Although investigated for over 70 years, whisker related problems are increasing due to environmental legislation and device miniaturisation
Examples of whiskers on consumer electronics

500 µm

~100 µm

~250 µm
Tin whiskers and conformal coatings

- Conformal coatings are routinely applied to provide environmental protection to printed circuit boards and associated electronic components.

- Currently, tin whisker mitigation is attempted with conformal coatings that have not been designed to prevent whisker growth.

- Develop a coating that is specifically formulated to mitigate whisker growth through incorporation of nanoparticles.
Research Aims and Objectives

• Engender polymers with physical barriers to whisker growth through the inclusion of nano-fillers in the conformal coating polymer formulation.

• Apply concept to commercial conformal coatings that are currently used for environmental protection in electronic components.

• Evaluate the microstructure, mechanical properties and whisker resistance of the modified coating formulations.
Evaluation of whisker mitigation

• Whisker growth has been investigated using brass coupons electroplated with 2 µm of bright tin at 10 mA cm$^{-2}$

• Apply modified conformal coatings based on HumiSeal formulations

• All conformal coatings applied by spraying

• Samples stored in an environmental chamber at 55°C/85% humidity to accelerate whisker growth

• Whisker growth evaluated at periodic intervals using a stereo microscope and SEM
Modified acrylic coating: Batch 1 (9-10-15)

Whisker growth comparable for 5% modified coating and unmodified.

Whisker growth reduced by ~ 2/3 for 3% modified coating.

Why is whisker density similar for 5% and unmodified coatings?
Evaluation of coating thickness

Coating thickness evaluated using an eddy current technique

- 3% modified and unmodified coatings are comparable in thickness
- 5% modified coatings are not uniform in thickness
  - no improvement in average whisker density compared with unmodified
Modified acrylic coating: Batch 2 (11-5-16)

- Whisker growth for 3% modified coating is reduced by ~40%, compared with unmodified.
- Whisker growth reduced by an order of magnitude for both 5% modified and 7% modified coatings.
- Greatest reduction in whisker growth observed for 5% coating.
Coating thickness vs. whisker density

- Modified acrylic based coatings demonstrate an enhanced resistance to whisker growth
- Further improvements in whisker mitigation are achieved at higher loadings
- Whisker growth reduced by an order of magnitude for coatings with higher loading
Summary of whisker growth

(a) uncoated sample

(b) unmodified coating

(c) 7% modified coating

In the absence of a conformal coating, long filament whiskers may be produced.

‘Conventional’ coating will retard whisker growth compared with an uncoated surface.

WHISKERMIT conformal coatings result in further, very significant, reductions in whisker growth.
Improved mechanical properties

- Improved resistance to whisker growth is derived from enhanced mechanical properties compared with the unmodified acrylic polymer.
- Mechanical properties increase with increased nanomaterial content.
- Importantly, modified coatings retain a high level of ductility.

<table>
<thead>
<tr>
<th>Material</th>
<th>Yield stress (MPa)</th>
<th>% stain at break</th>
<th>Young's modulus (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>unmodified</td>
<td>2.63±0.15</td>
<td>422±8.4</td>
<td>149±17</td>
</tr>
<tr>
<td>3%</td>
<td>3.02±0.14</td>
<td>417±15.6</td>
<td>165±31</td>
</tr>
<tr>
<td>5%</td>
<td>3.45±0.14</td>
<td>425±4.6</td>
<td>187±30</td>
</tr>
<tr>
<td>7%</td>
<td>4.03±0.17</td>
<td>399±6.1</td>
<td>216±13</td>
</tr>
<tr>
<td>10%</td>
<td>4.8±0.4</td>
<td>368±34</td>
<td>247±43</td>
</tr>
</tbody>
</table>
SEM analysis of fracture surface

Unmodified acrylic

3% loading

5% loading

7% loading

10% loading

Large pores present on fracture surface for 10% modified coatings ➔ reduced ductility
Nanomaterial modified coatings provide improved whisker mitigation for a given coating thickness. Comparable whisker mitigation can be achieved for nanomaterial modified coatings of reduced thickness. Improved protection at corners and edges where coating thickness may be reduced.
Whisker growth: synthetic rubber

- Reduced whisker growth for 3% modified coating
- Further reduction in whisker growth as loading is increased to 5%
Conclusions

• We have demonstrated that the resistance to whisker growth of conventional conformal coatings may be enhanced by incorporating nanoparticles into their formulation.

• Improved whisker mitigation has been demonstrated for both acrylic and synthetic rubber based conformal coatings.

• The coating’s ability to mitigate whisker growth improves as the nanoparticle content is increased.

• Significant increases in Young’s modulus and yield stress are achieved with only limited reduction in ductility observed at the highest nanoparticle loading.
Any questions?

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