Loughborough University

THE DEVELOPMENT OF A TIN-WHISKER MITIGATING CONFORMAL COATING

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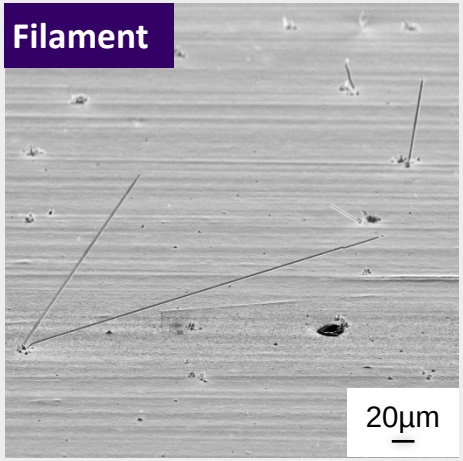
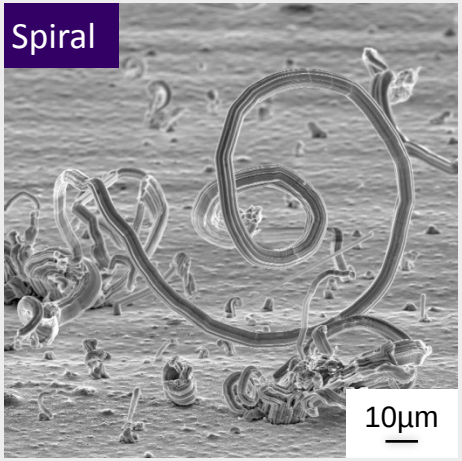
Outline of Presentation

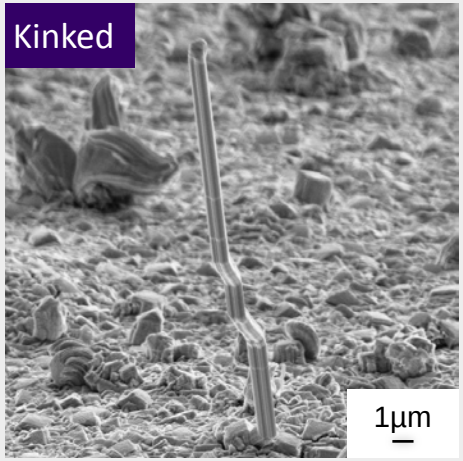
- Introduction to tin whiskers
- Aims and objectives
- Experimental approach
- Whisker growth studies
- Mechanical properties
- Conclusions

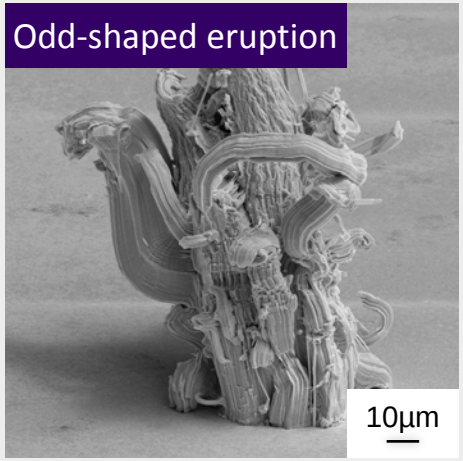
What are metal whiskers?

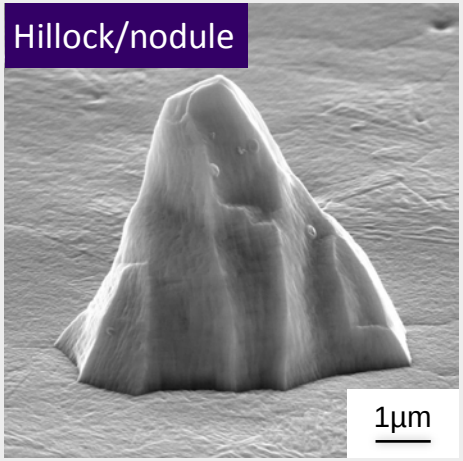
- Electrically conductive crystalline growths from a metal surface (e.g. **Sn**, Zn and Cd)
- Uncertain incubation period before growth
- Numerous growth morphologies possible
- A few micrometres in diameter and up to several millimetres in length





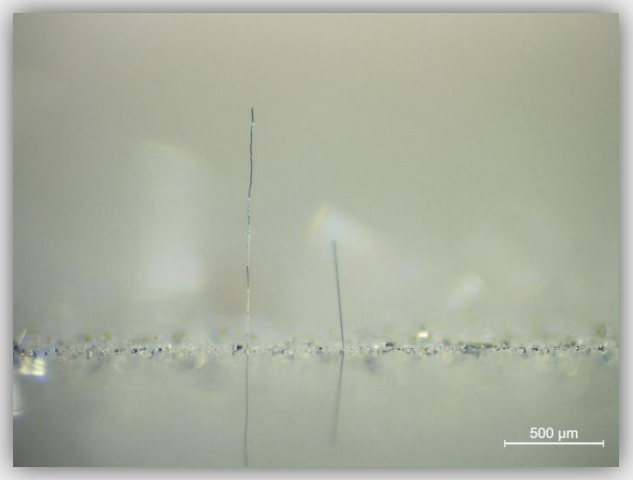


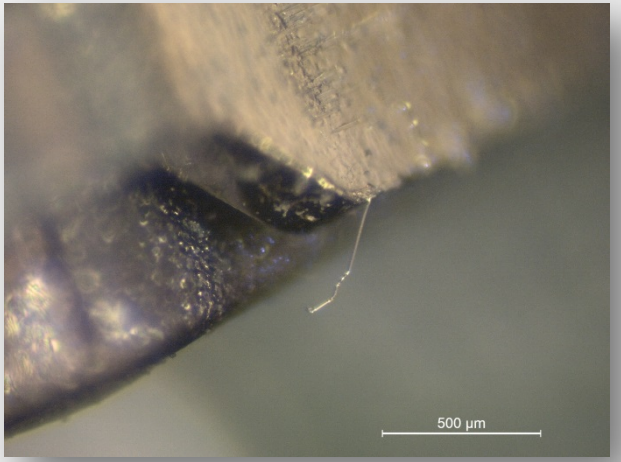




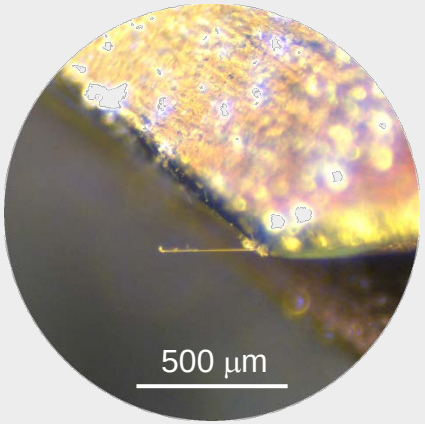
Tin whisker related problems

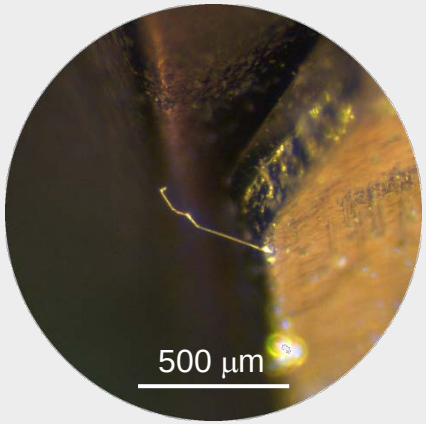
- *Filament type* whiskers present the greatest threat to the reliability of electronics components
- Grow to sufficient lengths to cause electrical short circuits
- Although investigated for over 70 years, whisker related problems are increasing due to environmental legislation and device miniaturisation

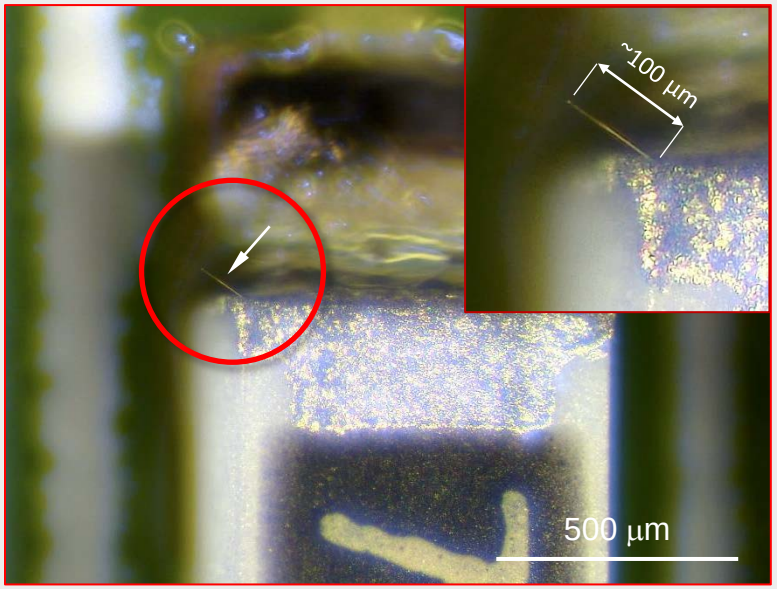


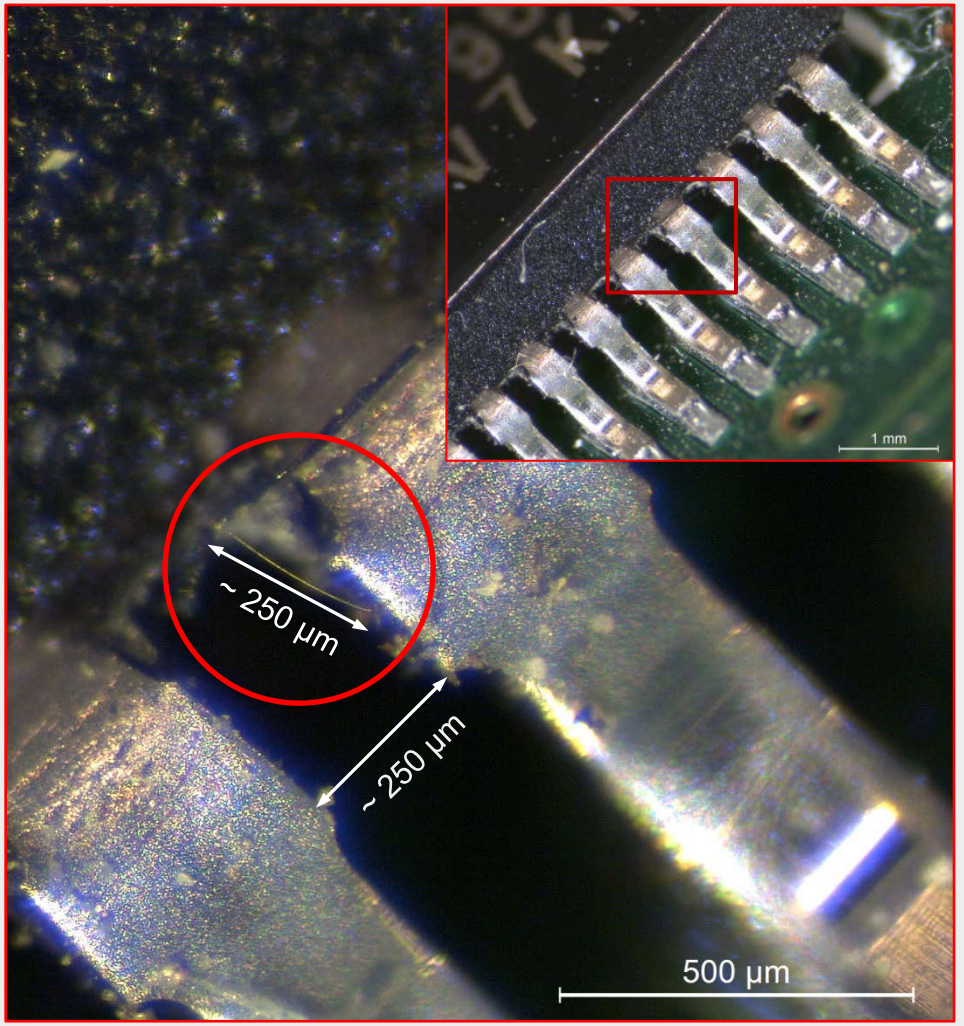


Examples of whiskers on consumer electronics



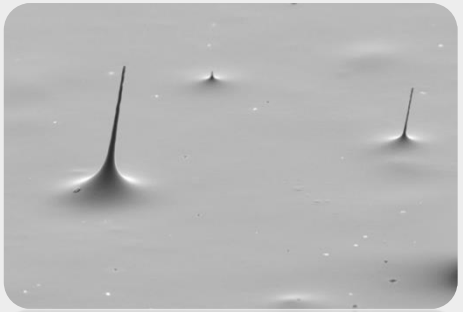






Tin whiskers and conformal coatings

- 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 ➲ incorporation of nanoparticles

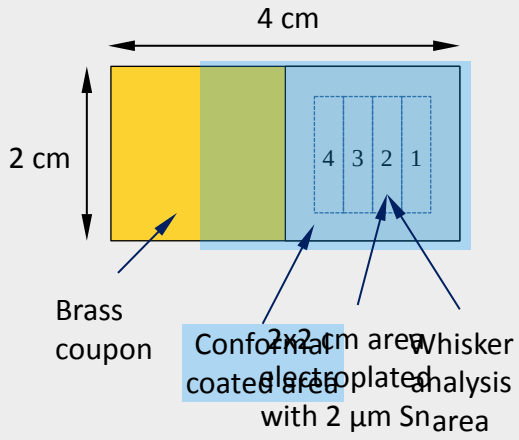


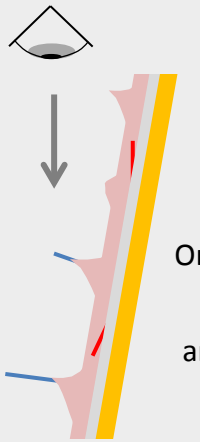
Research Aims and Objectives

- 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

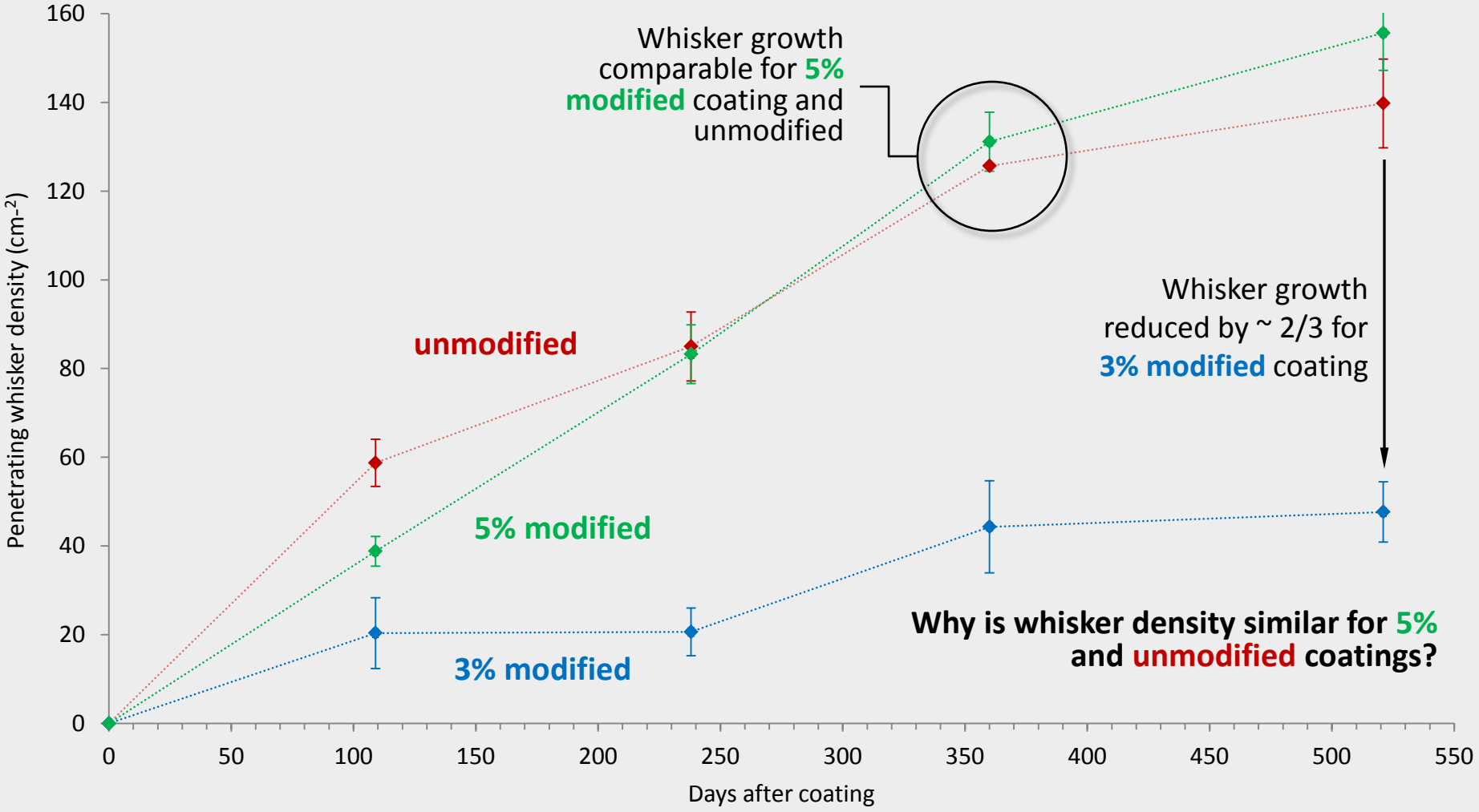
- Whisker growth has been investigated using brass coupons electroplated with 2 µm of bright tin at 10 mA cm^{-2}
- Apply modified conformal coatings based on HumiSeal formulations
- All conformal coatings applied by spraying
- Samples stored in an environmental chamber at **55˚C/85%** humidity to accelerate whisker growth
- Whisker growth evaluated at periodic intervals using a stereo microscope and SEM



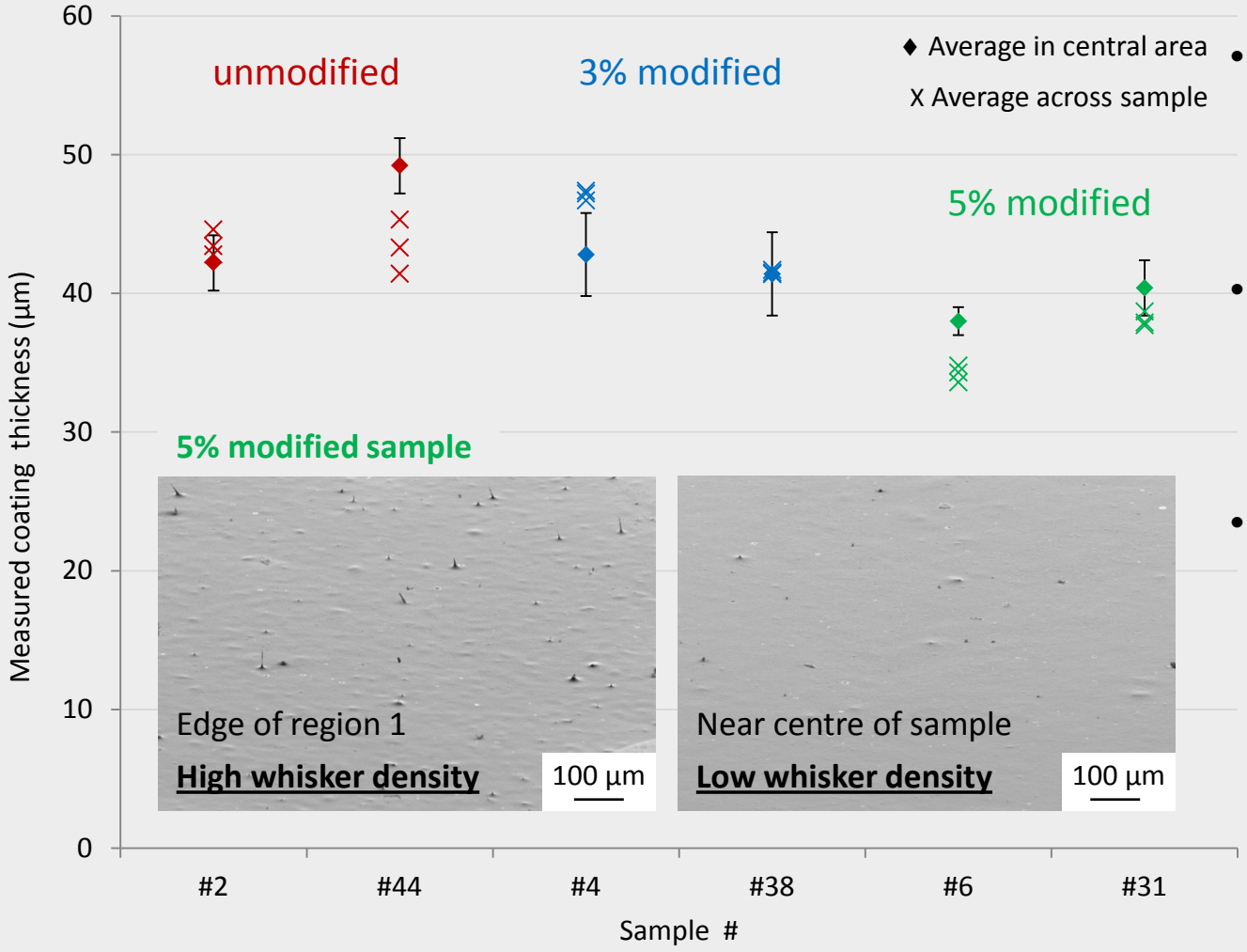


Only view/count whiskers that are growing out of the coating

Modified acrylic coating: Batch 1 (9-10-15)

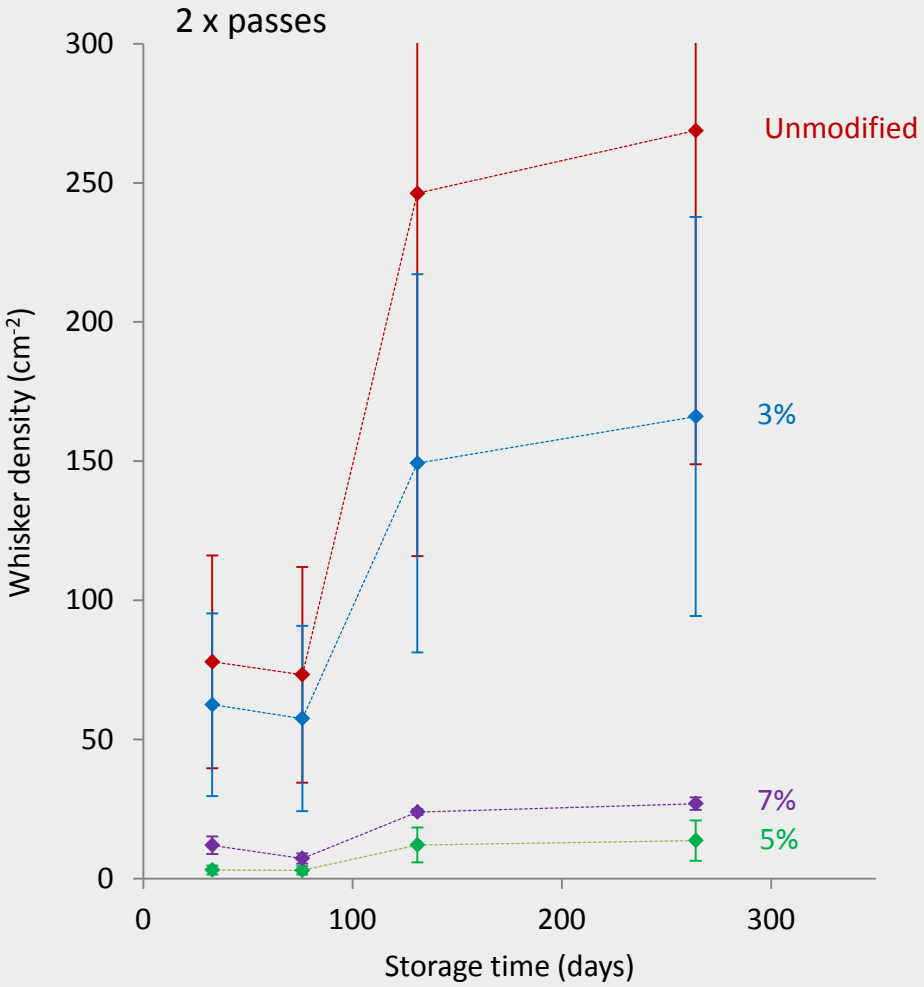


Evaluation of coating thickness



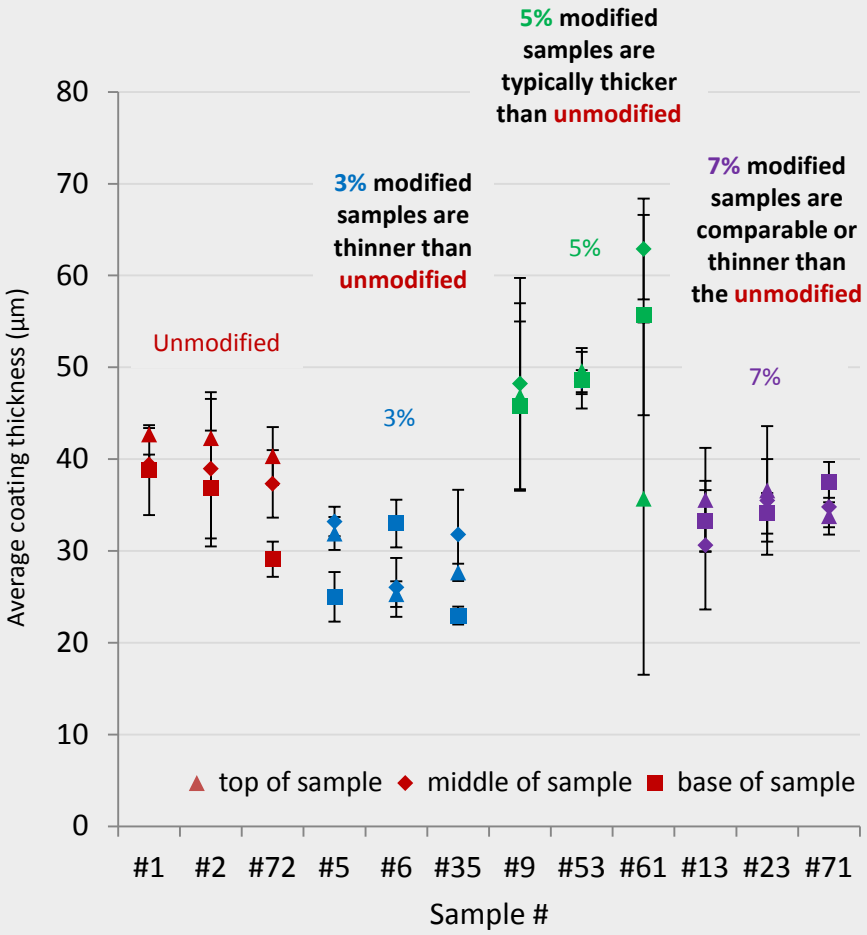
- Coating thickness evaluated using an eddy current technique
- 3% modified and unmodified coatings are comparable in thickness
- 5% modified coatings are not uniform in thickness
  ➲ no improvement in average whisker density compared with unmodified

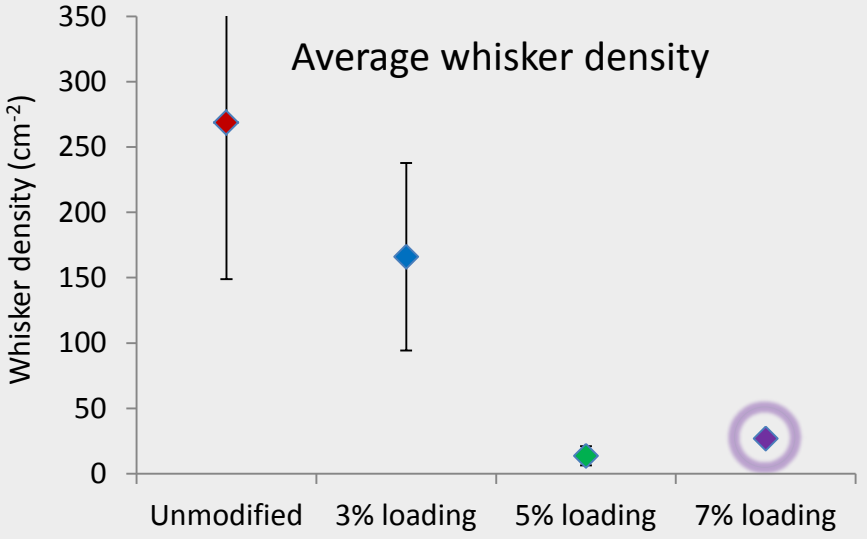
Modified acrylic coating: Batch 2 (11-5-16)



- 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

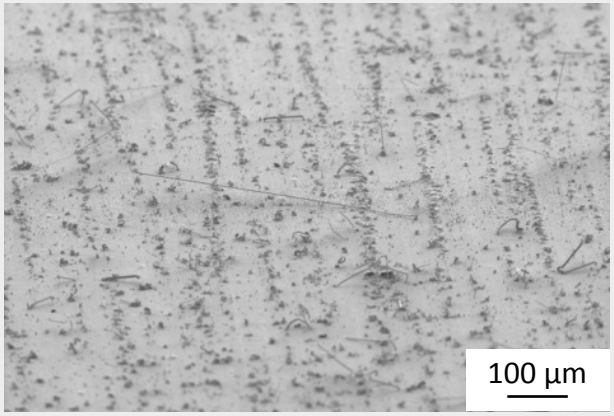




- Modified acrylic based coatings demonstrate an enhanced resistance to whisker growth
- Further improvements in whisker mitigation are achieved at higher loadings
- Whisker growth reduced by an order of magnitude for coatings with higher loading

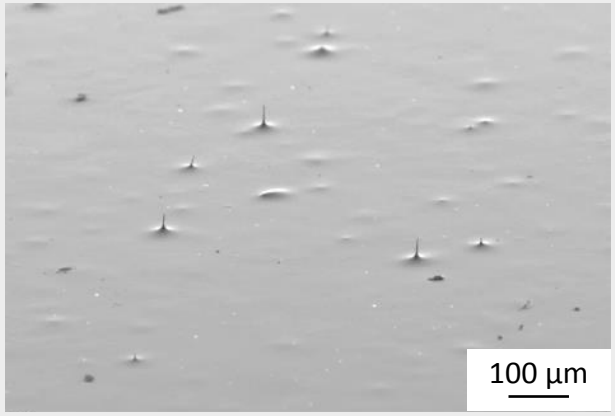
Summary of whisker growth

(a) uncoated sample



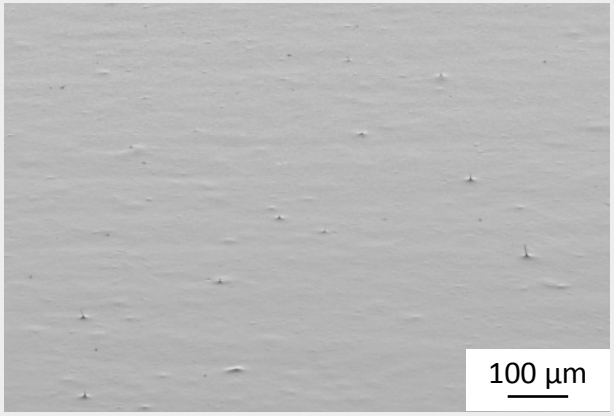
In the absence of a conformal coating, long filament whiskers may be produced

(b) unmodified coating



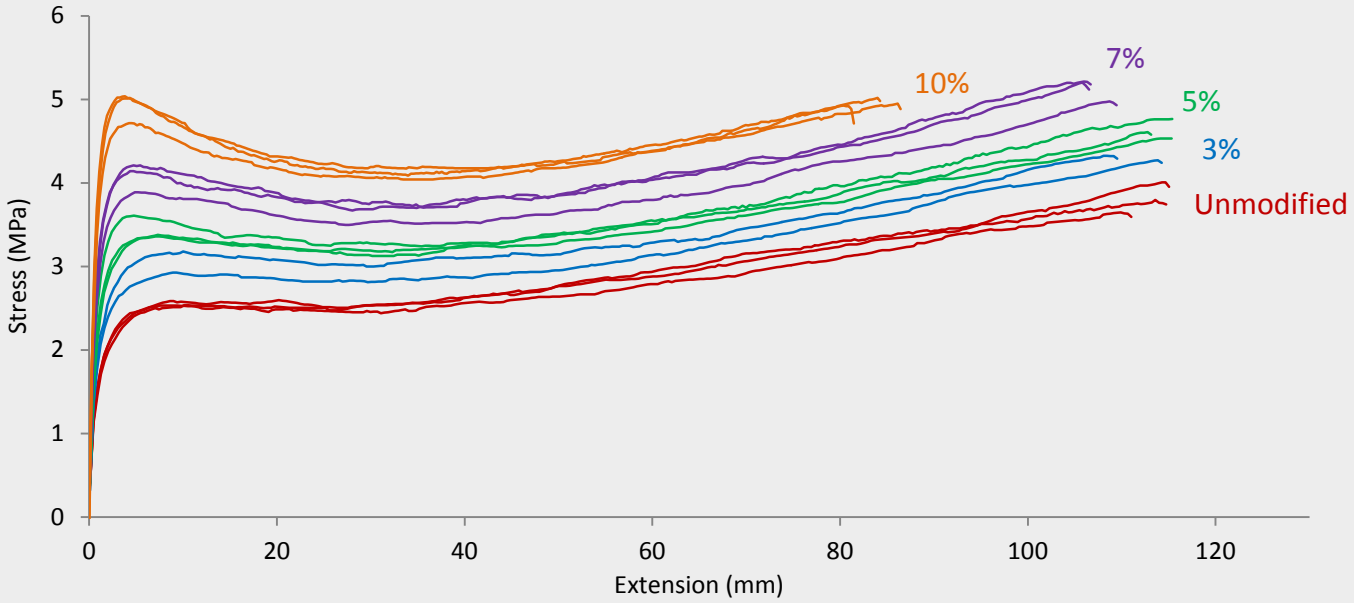
'Conventional' coating will retard whisker growth compared with an uncoated surface

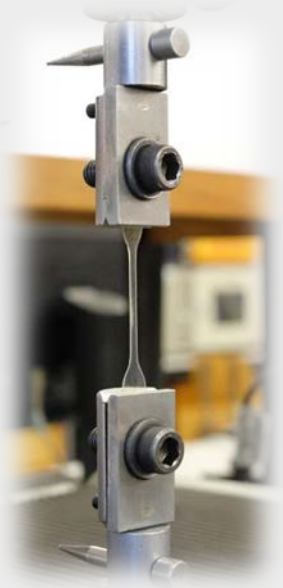
(c) 7% modified coating



WHISKERMIT conformal coatings result in further, very significant, reductions in whisker growth

Improved mechanical properties

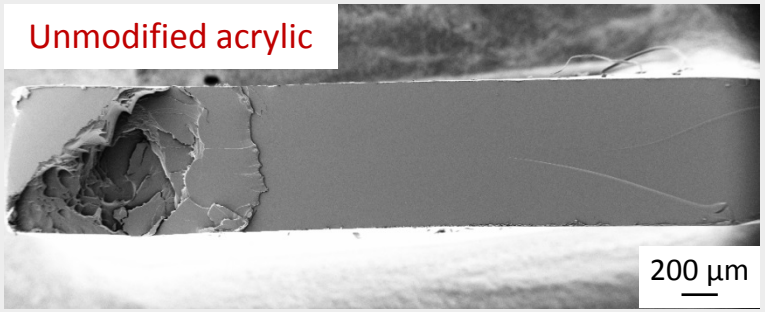


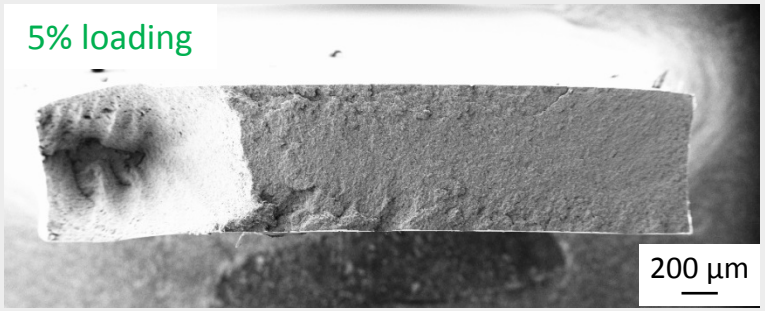


- Improved resistance to whisker growth is derived from enhanced mechanical properties compared with the unmodified acrylic polymer
- Mechanical properties increase with increased nanomaterial content
- Importantly, modified coatings retain a high level of ductility

Material	Yield stress (MPa)	% stain at break	Young's modulus (MPa)
unmodified	2.63±0.15	422±8.4	149±17
3%	3.02±0.14	417±15.6	165±31
5%	3.45±.14	425±4.6	187±30
7%	4.03±0.17	399±6.1	216±13
10%	4.8±0.4	368±34	247±43

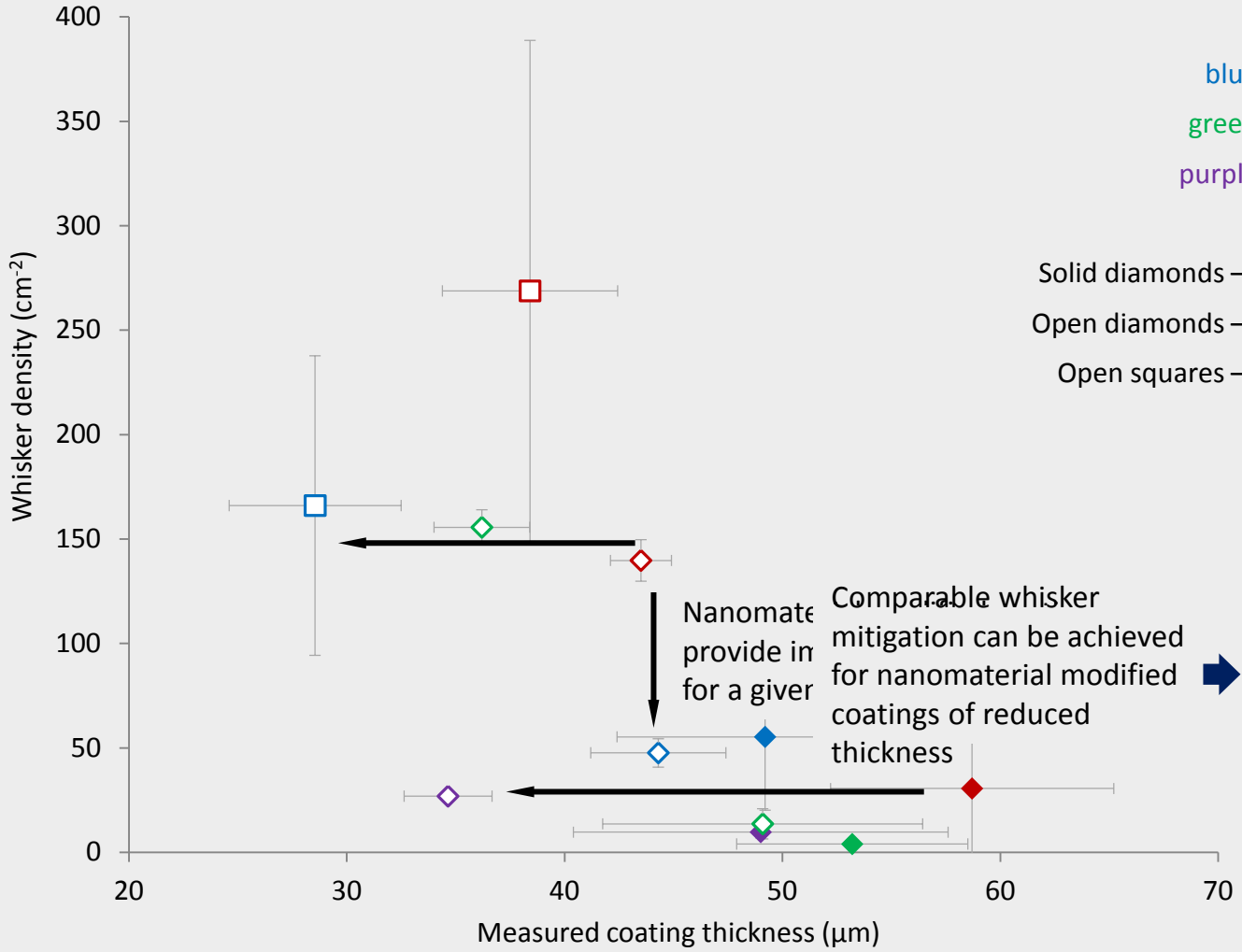
SEM analysis of fracture surface



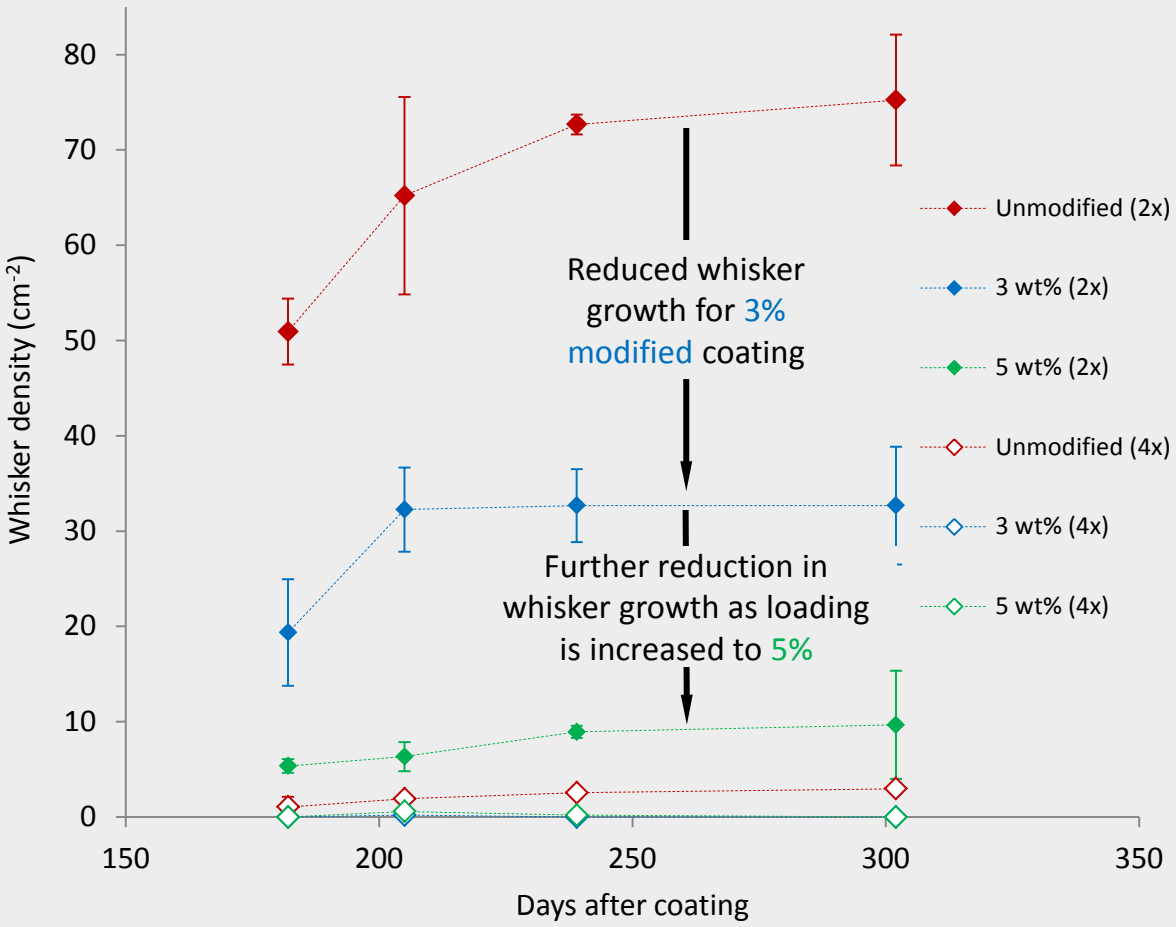


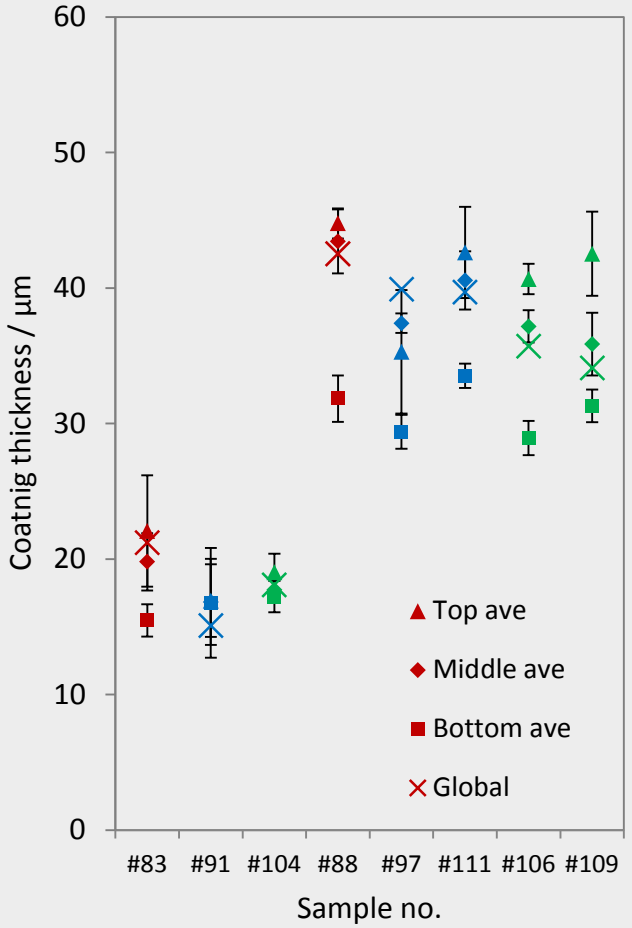
Large pores present on fracture surface for 10% modified coatings ➲ reduced ductility

Whisker growth vs. coating thickness



Whisker growth: synthetic rubber





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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