Investigation of Zinc Whisker Growth from Electrodeposits Produced Using an Alkaline Non-Cyanide Electroplating Bath

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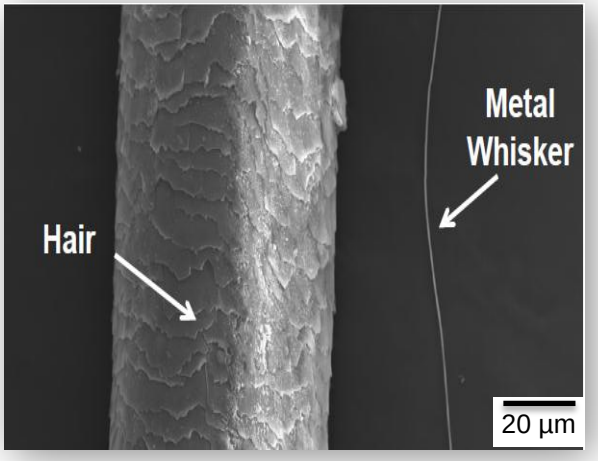
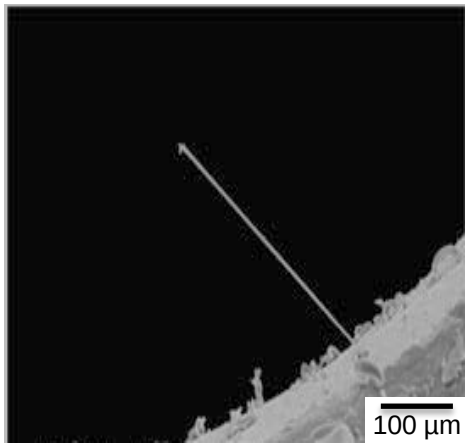
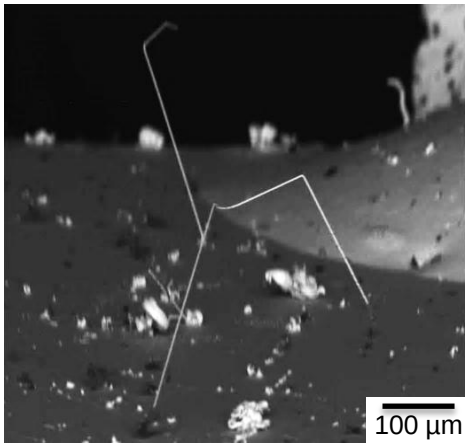
What is a metallic whisker?

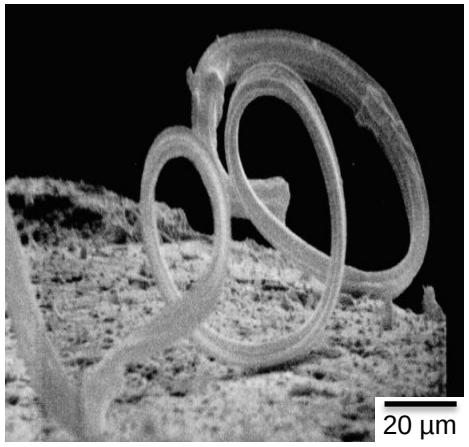
- Crystalline metallic crystals
- Spontaneously grow from metal surfaces (Sn, Zn and Cd)
- Reported average grow rate ~ 250 µm per year
- 1 µm in diameter and a few millimetres in length

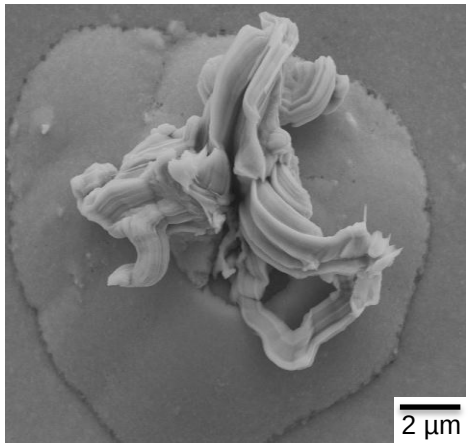


Able to form various shapes







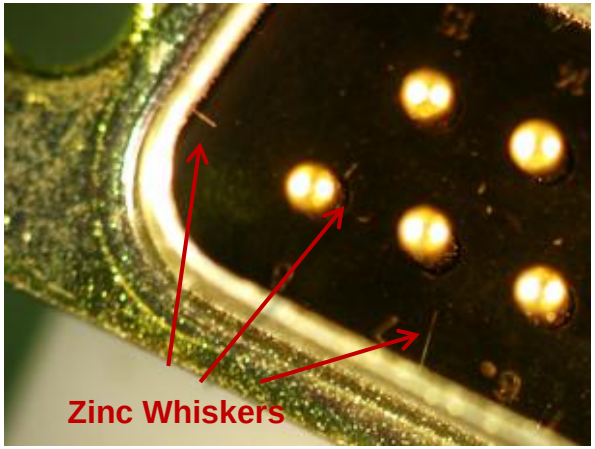


NASA Photo Gallery; nepp.nasa.gov/whisker/photos/index.html

Electronic failures caused by Zn whiskers

Year	Whiskers on	Applications
1987	Local Power Range Monitoring Detectors	Dresden nuclear Power Station
1990	Rotary Switch	Apnea Monitors
1990	Local Power Range Monitoring Detectors	Duane Arnold Nuclear Power Station
1995	Framework	Telecom Equipment
1996	Chassis	Computer Routers
1998	Chassis	Computer Hardware
1999	Xsistor Package +Standoff	Missiles
1999	Chassis	Computer Routers
2001	Bus Rail	Space Ground Test Equipment
2003	Floor Tiles	Computer Data Centre in Canada
2004	**Floor Tiles**	**Computer Data Centre in Colorado**
2004	Floor Tiles	Computer Data Centre in Australia
2012	Floor Tiles	Computer Data Centre in North East England

Many long zinc whiskers on zinc coated steel [1]

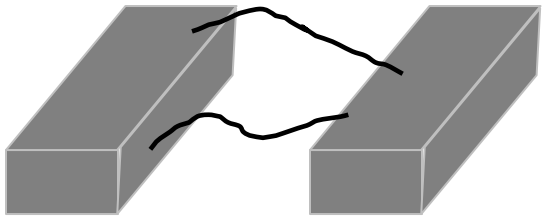


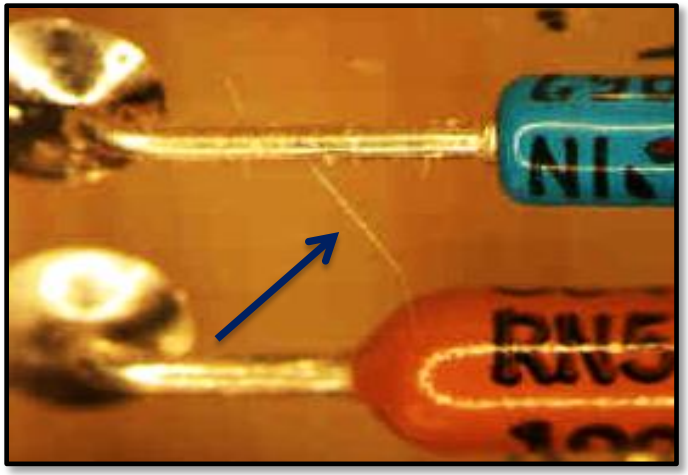
Zinc-electroplated connector shell [2]

1. http://commons.wikimedia.org/wiki/File:Zinc_whiskers.jpg 2. http://nepp.nasa.gov/whisker/photos/index.html

Electronic failure mechanisms

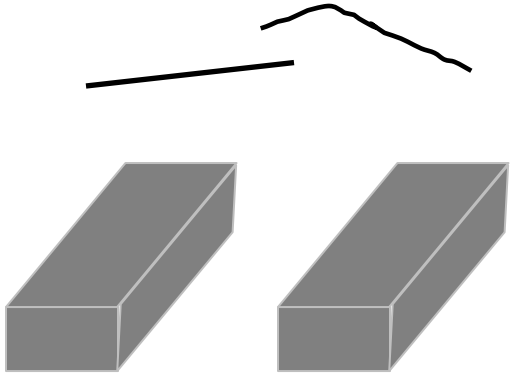
Type 1: Grown whiskers to bridge components

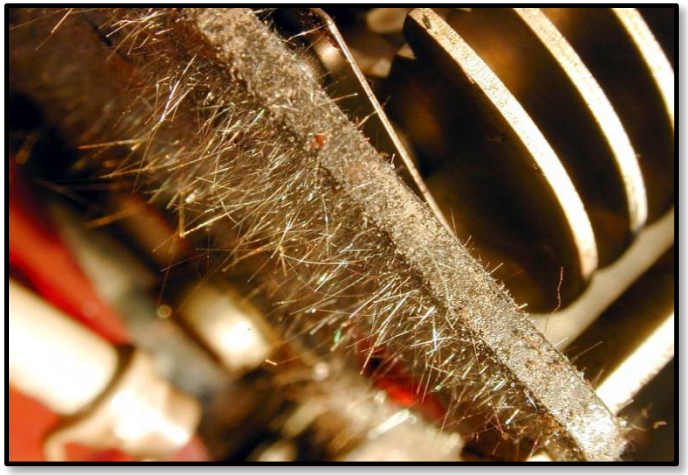




Type 1: A whisker grew and connected two diodes used in a nuclear power plant

Type 2: Airborne whiskers settle on components





Type 2: Whiskers formed inside an air-spaced capacitor and became airborne whiskers

Produce a bridge between components

↓

Short circuiting, voltage variance and other signal disturbance

↓

Electrical equipment failure

NASA Photo Gallery; nepp.nasa.gov/whisker/photos/index.html

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Objectives

- Observe whisker growth
  - Growth rate
  - Growth morphology
- Investigate the growth mechanism
- Mitigate Whisker growth

Experimental approaches

- Electroplating bath

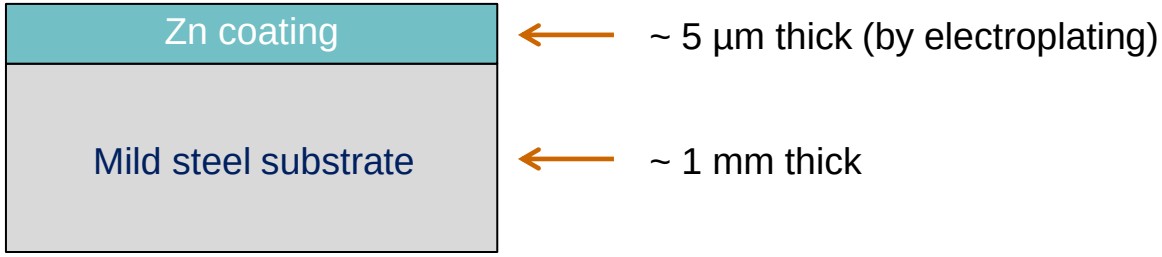
Alkaline cyanide-free zinc plating solution

pH ~ 10

Chemicals	Amount
Zinc	11 g/l
Sodium hydroxide	130 g/l
Conditioner	30 ml/l
Brightener	1.5 ml/l
Purifier	1 ml/l
Initial additive	7 ml/l

- Sample geometry

Current density:
25 mA/cm^2

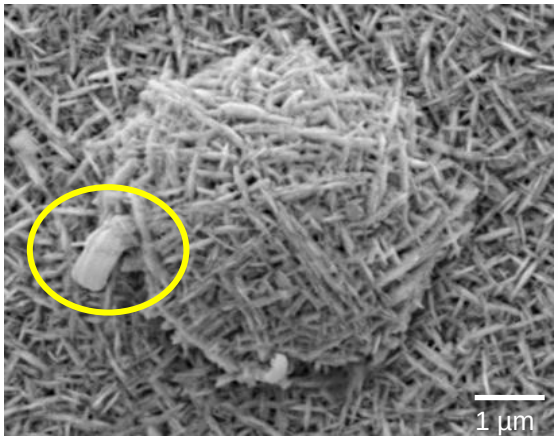


- Sample storage:

Room temperature (~ 20ºC)

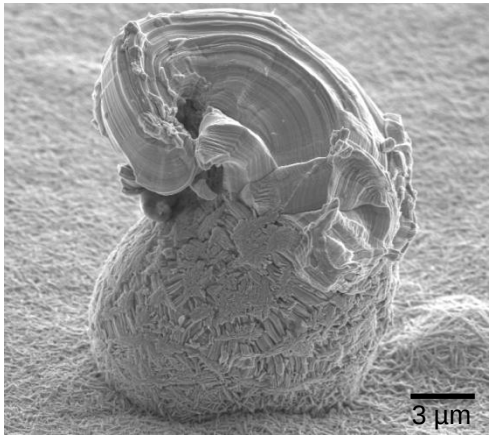
Observation of whisker growth at room temperature

4 weeks after deposition

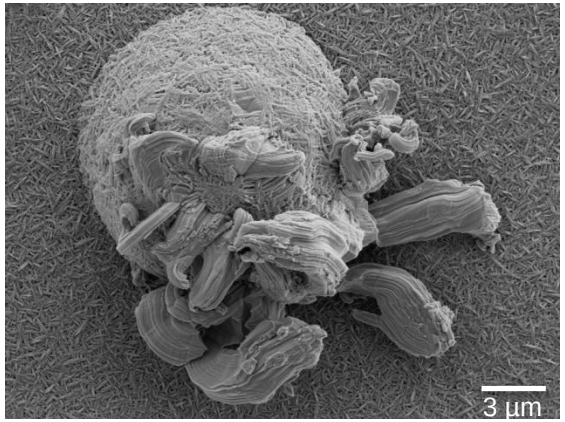


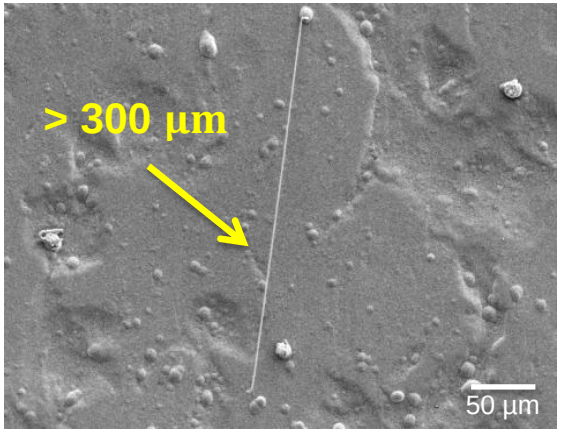
- Whiskers were present 4 weeks after deposition;
- 4 months after deposition, all the whiskers were growing associated with “nodules”.

Many larger eruptions and longer whisker filaments present!



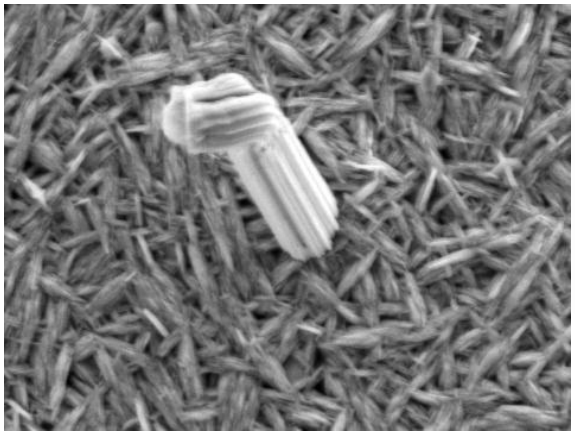
4 months after deposition





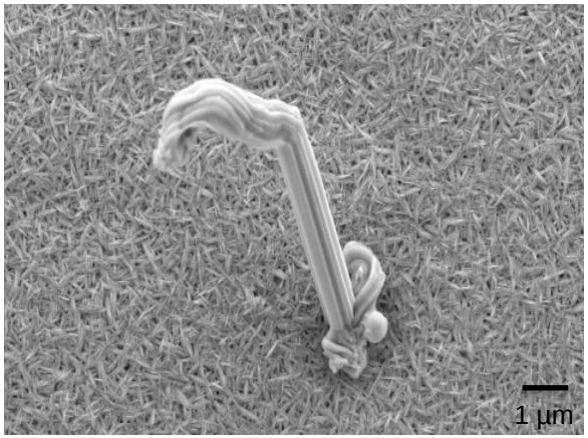
Observation of whisker growth at room temperature

5 months after deposition

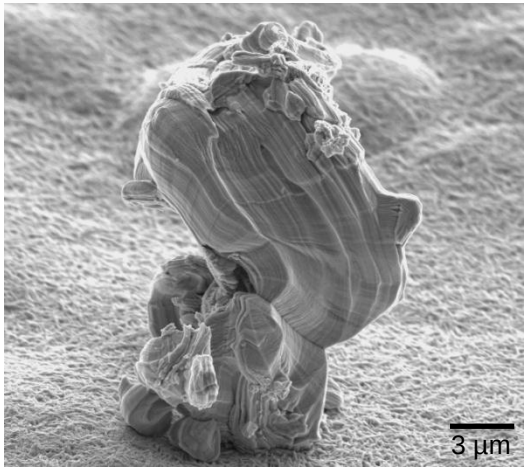


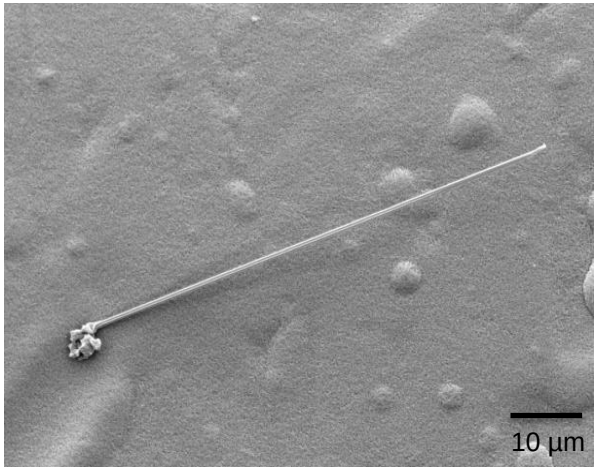
Many larger eruptions and longer whisker filaments present!

8 months after deposition

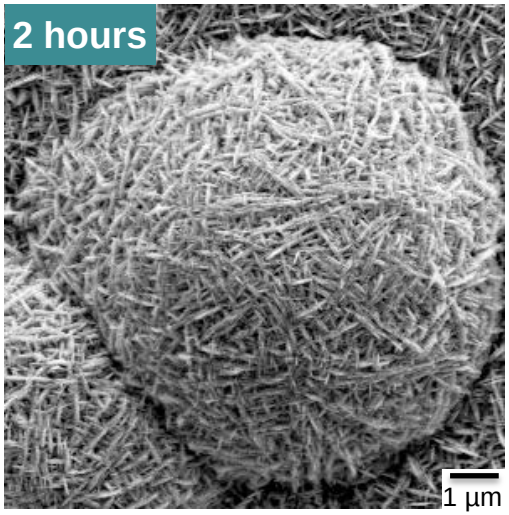


- Whiskers growing from the flat deposit surface were present 5 months after deposition;
- The presence of nodules markedly **shortens the incubation time.**

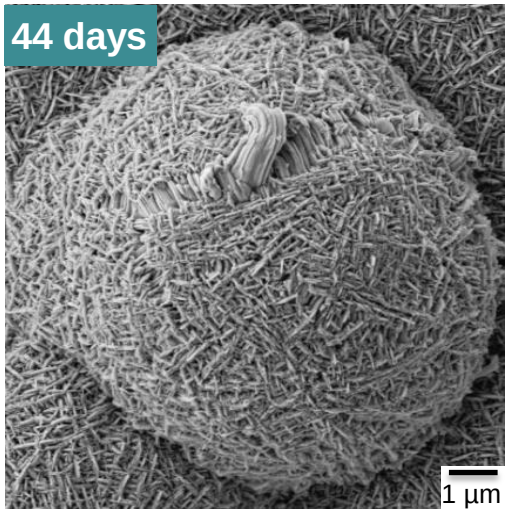




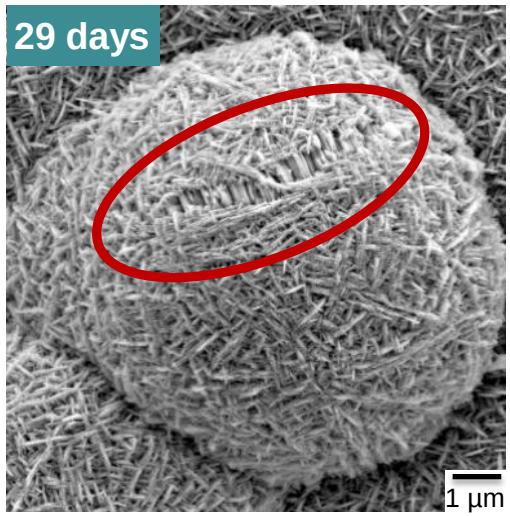
Periodic analysis of whisker growth associated with nodules



Several specific nodules were monitored periodically

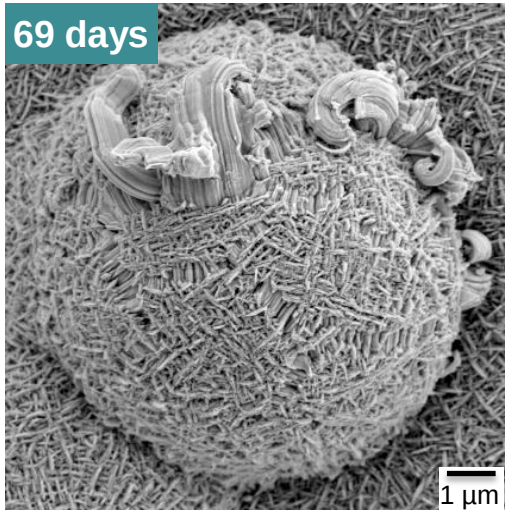


A whisker grew associated with the staircase structure



"Staircase structure" first appeared

More whiskers grew associated with the staircase structure



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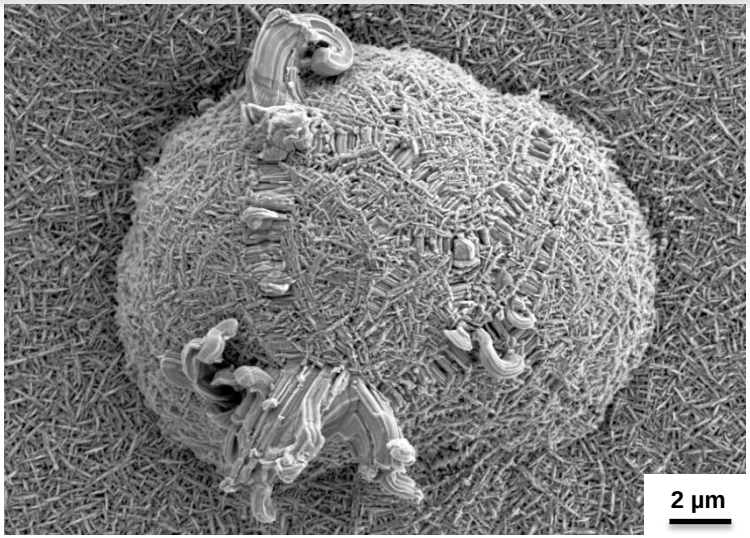
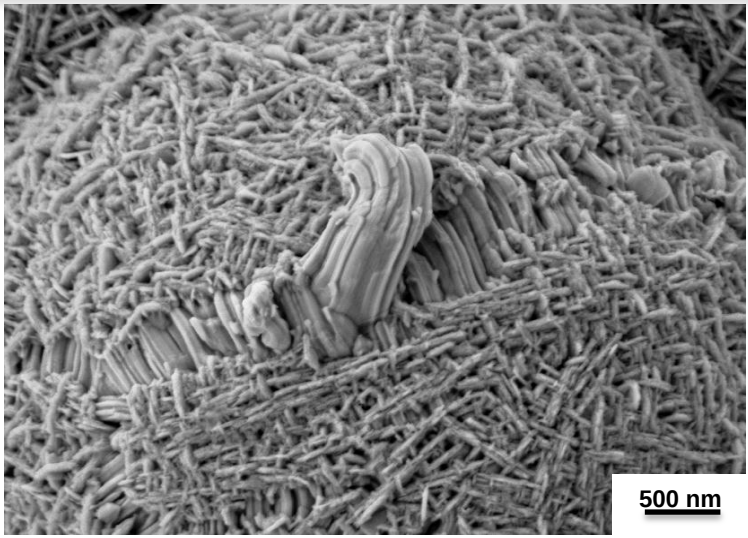
Staircase structures

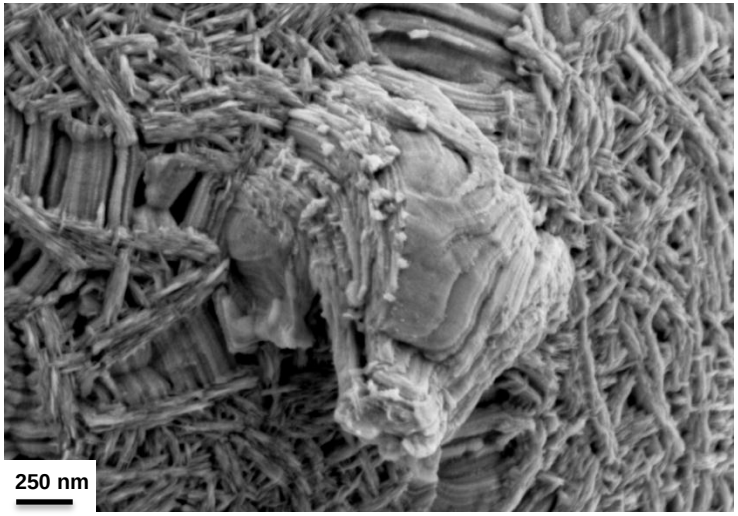
Appear ~ 1 month after deposition

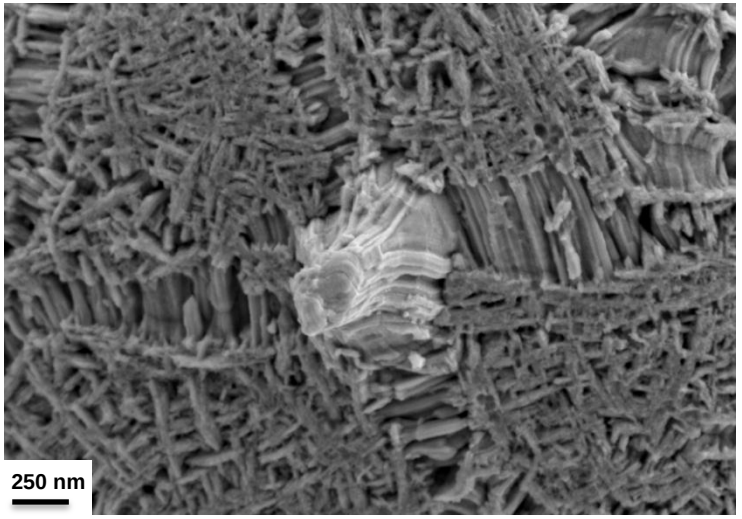
only present on the surface of nodules

Staircase structures are pre-cursors to whisker growth associated with nodules





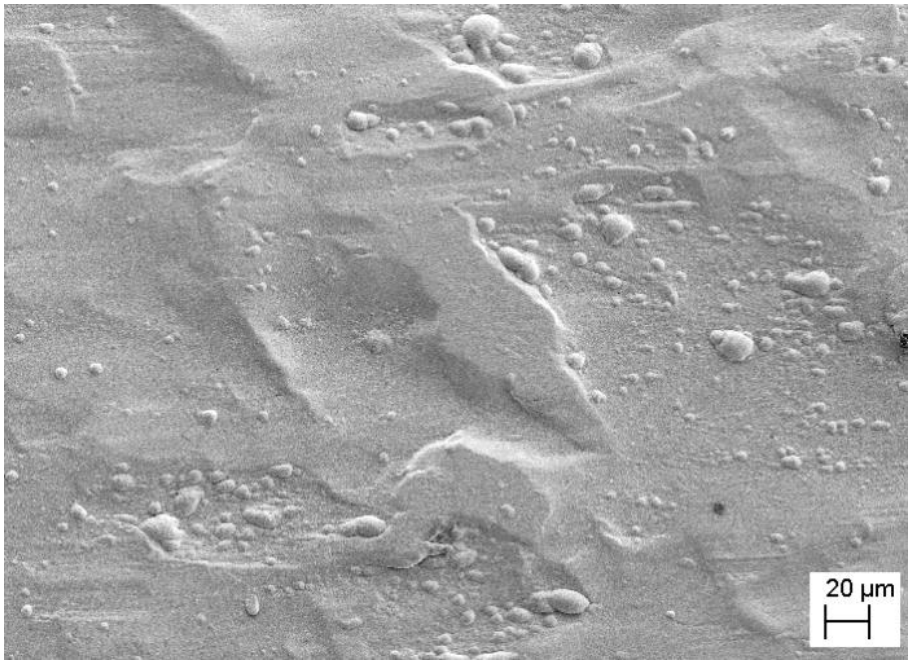




Mitigation method --- preventing nodule formation

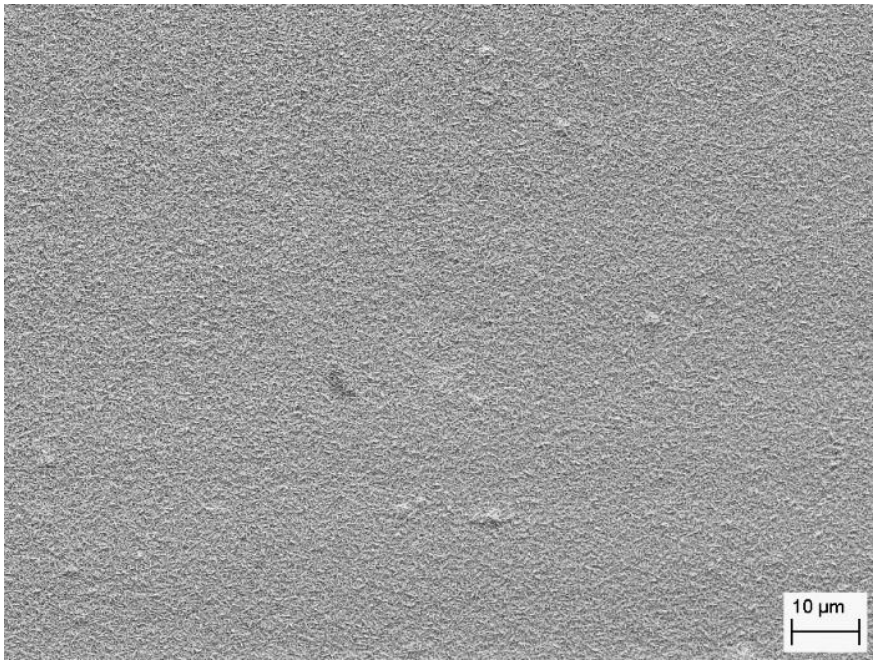
- No nodules and staircase structures present on zinc electroplated Hull cell panels
- The surface finish of substrates plays a key role in nodule formation?

Zinc coatings onto an as-received mild steel substrate



Uneven surface with
many nodules

Zinc coatings on a ground mild steel substrate (SiC paper from 240 to 1200)

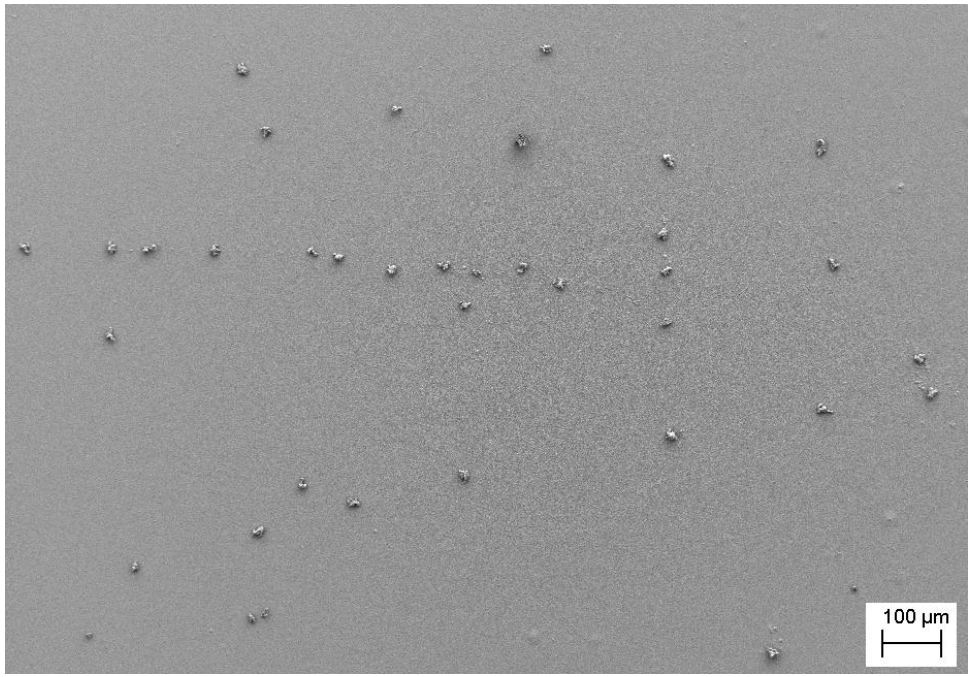


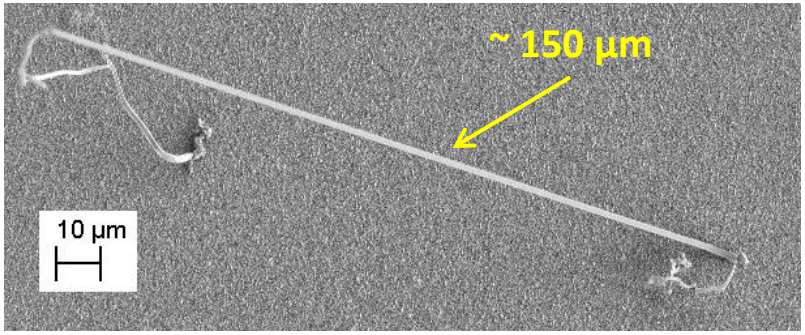
Smooth surface with
NO nodules

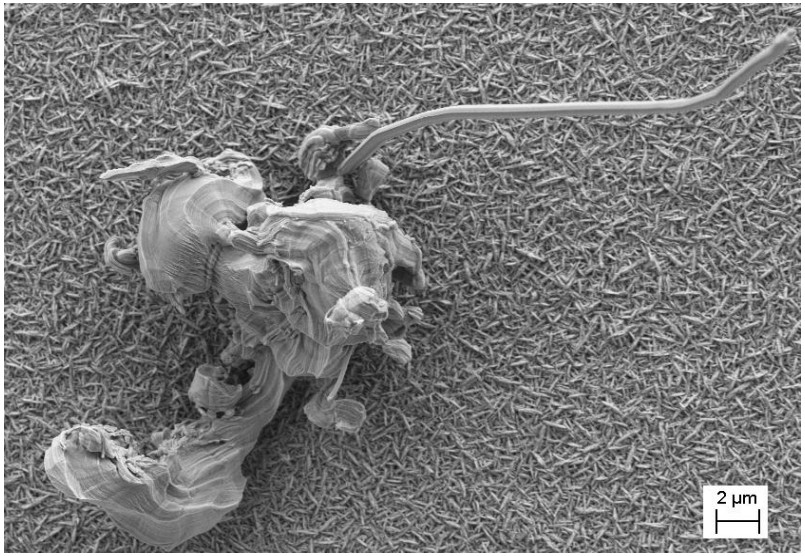
Accelerated whisker growth on the ground samples

Ground mild steel, 18 days after deposition

Many long whisker filaments and large eruptions were present







Whisker growth initiated much earlier on the ground sampls with no nodules present!

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Summary

- Whisker growth from nodules was observed only 4 weeks after deposition; whilst whisker growth from the flat deposit surface was not observed until 5 months after deposition

- The presence of nodules and subsequent development of staircase structures markedly reduced the incubation time for whisker growth

- Improving the surface finish of the mild steel sheet prior to deposition prevents the formation of nodules but results in accelerated whisker growth

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Questions

- Thank you for listening!
- Any questions or comments?

'Question mark' tin whisker from Dr Mark Ashworth