The Effect of Antimony Additions on the Microstructure and Performance of Automotive Zn-Al-Mg Steel Coatings

Dan Britton

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Background and Aims

- Zinc-Aluminium-Magnesium (ZAM) alloys are applied to steel as an alternative to traditional GI coatings
- Main advantages come from the presence of eutectic phases
- Current uses include solar panel installations and air conditioning systems

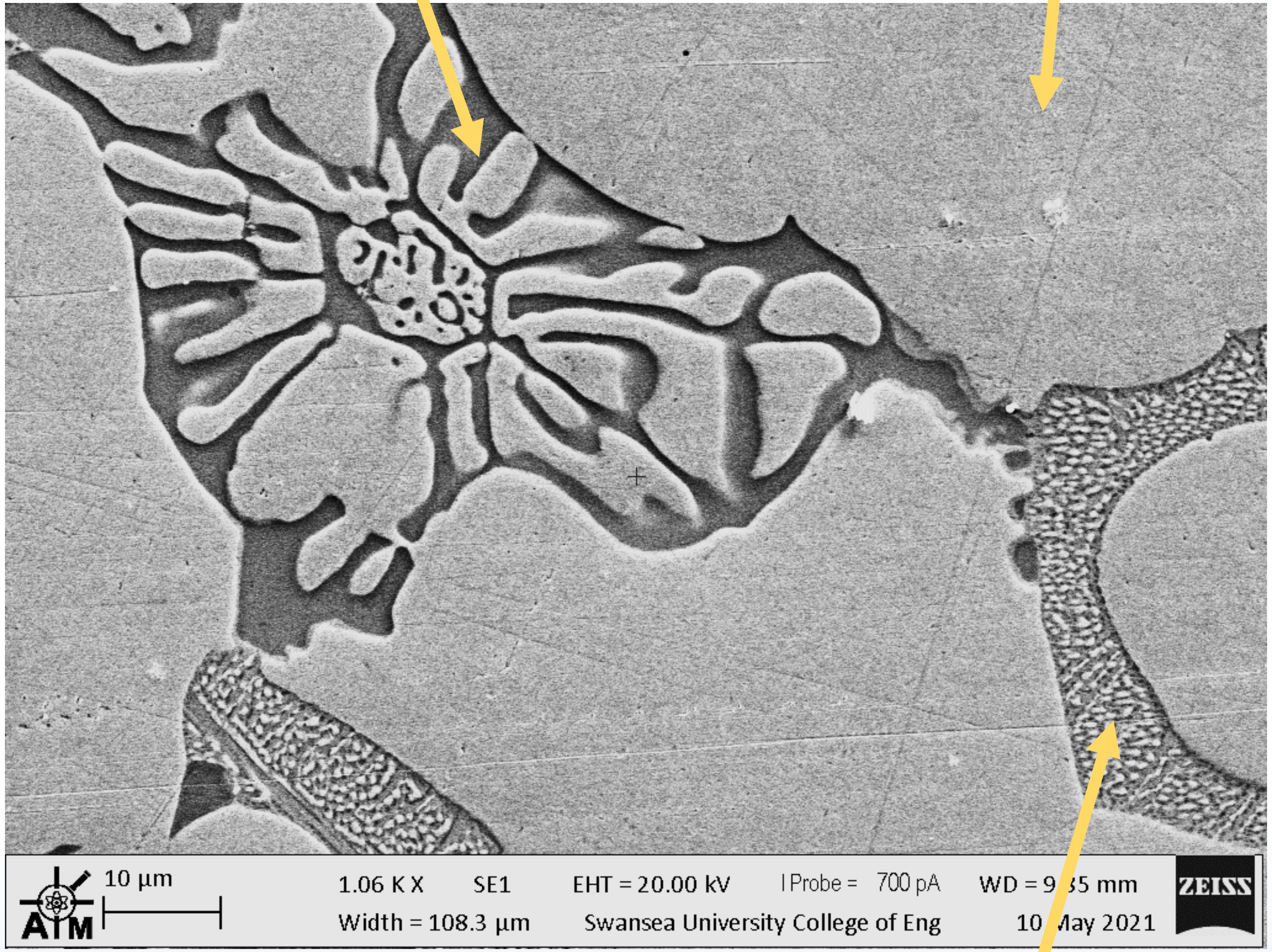

Figure 1 – Microstructure of ZAM Coating

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Background and Aims

+ Enhanced corrosion protection
+ Decreased tool pollution during sheet steel processing
+ Increase in manufacturing run-time

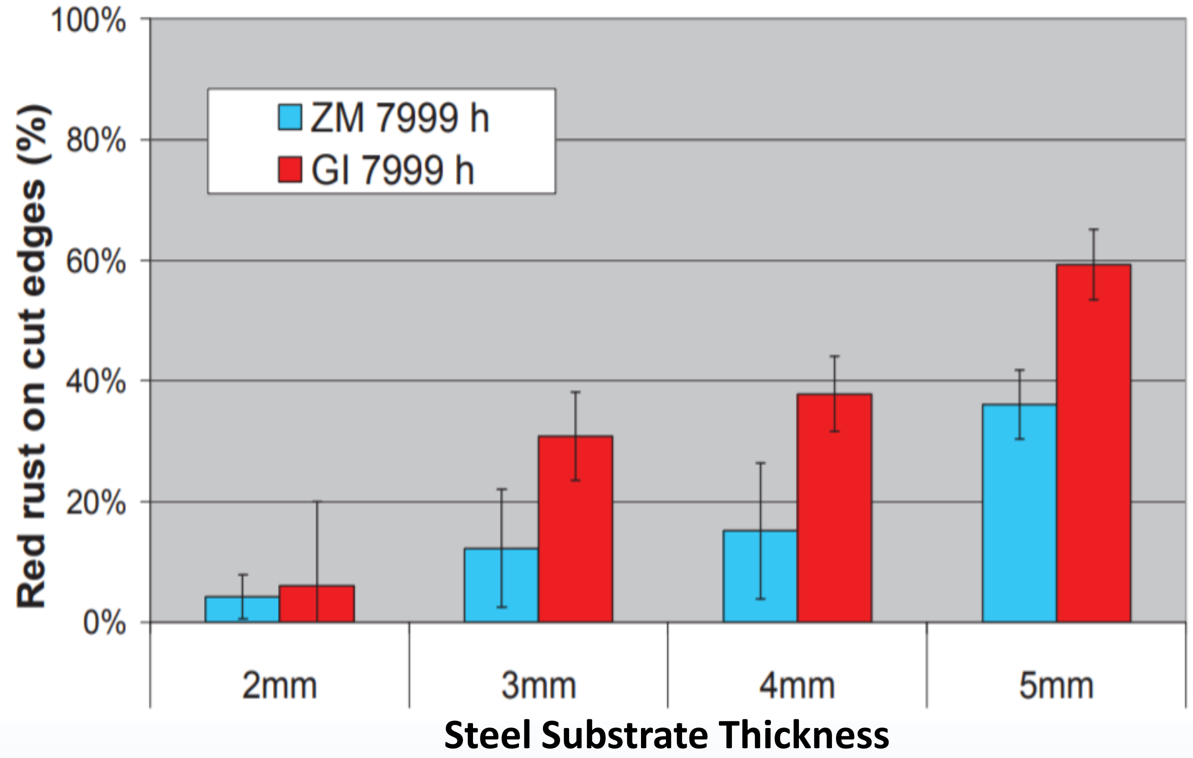

Figure 2 - Appearance of Red Rust on 25µm GI and ZAM Coatings After 7999 Hours in Accelerated SST [1]

[1] Monnoyer et al, Galvatech 2015

Background and Aims

+ Enhanced corrosion protection
+ Decreased tool pollution during sheet steel processing
+ Increase in manufacturing run-time
- Narrow process window for good surface finish

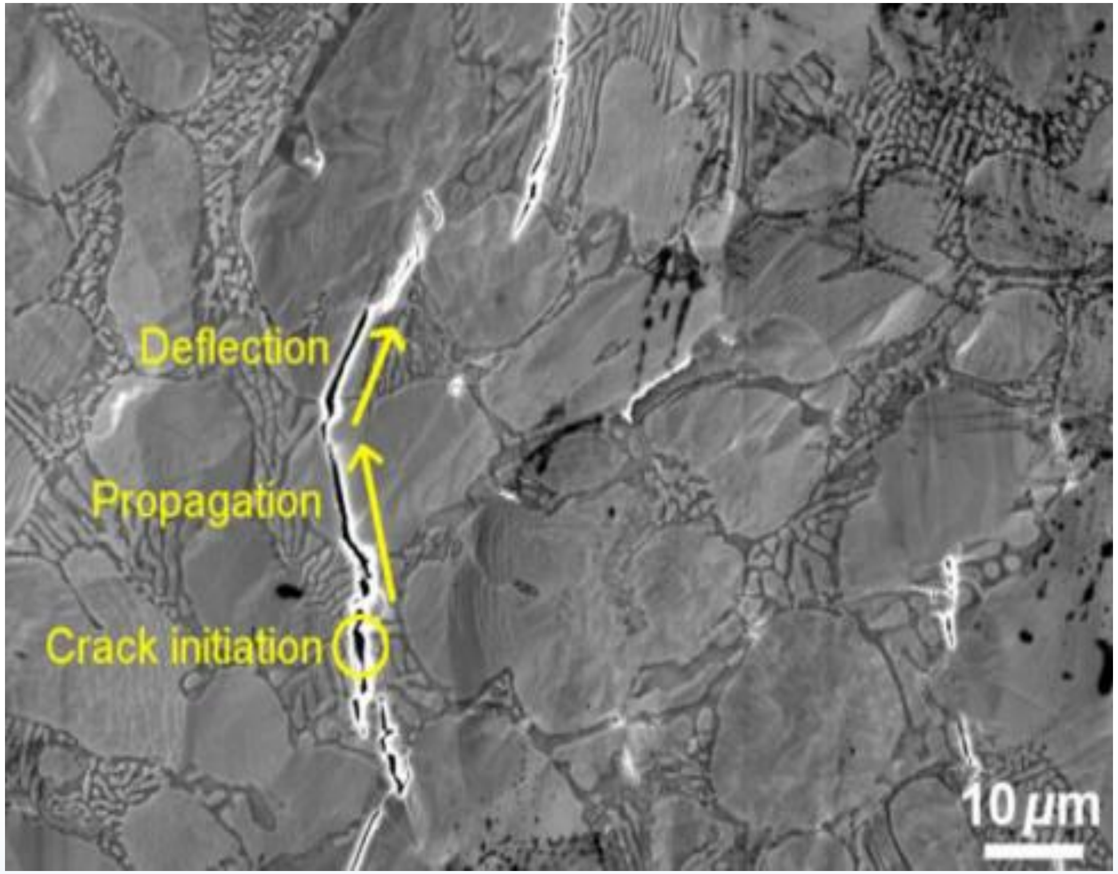

Figure 3 – Cracking in ZAM Coatings [2]

[2] Ahmadi et al, Materials and Design 186 (2020)

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Background and Aims

- Previous research has examined the use of germanium (Ge) additions in ZAM coatings which reduced the amount of brittle binary eutectic [3]
- As Ge is expensive and not commercially viable for continuous galvanizing, the effect of Sb additions to ZAM was investigated in this work
- Antimony has long been used as a spangle former in galvanized coatings, lowering surface tension and increasing fluidity and surface finish

[3] Wint et al, Corrosion Science 179(9) 2020.

Microstructure

- Phase compositions were confirmed using EDX, DSC and previous literature [4]

Table 1 – Sample compositions, ICP-OES

Sample ID	Sb wt.% Addition
ZAM-0Sb	<0.01
ZAM-0.5Sb	0.45
ZAM-1Sb	0.83
ZAM-2Sb	1.80

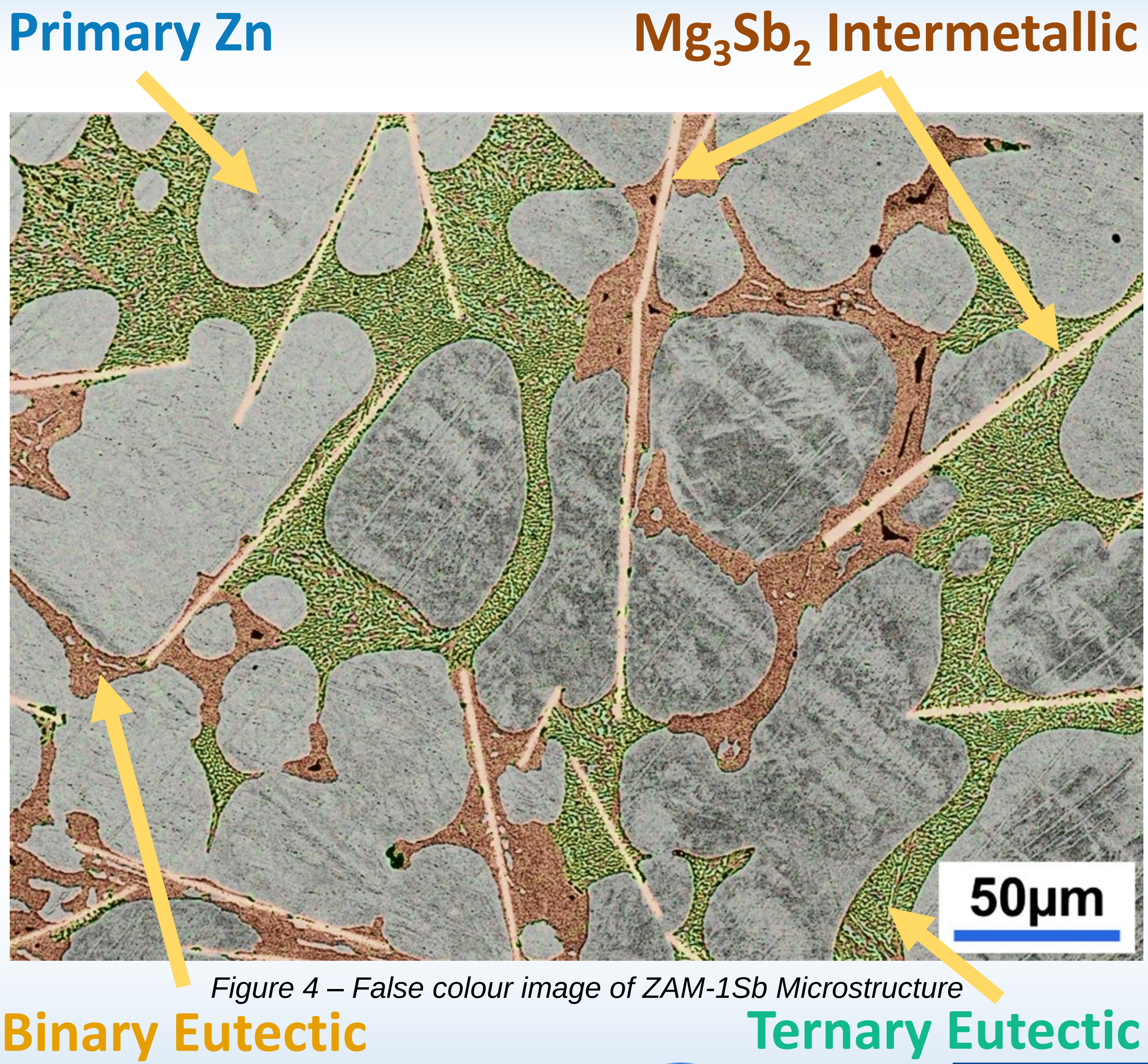

Figure 4 – False colour image of ZAM-1Sb Microstructure

[4] Dong et al, Materials 980(10), 2017

Microstructure

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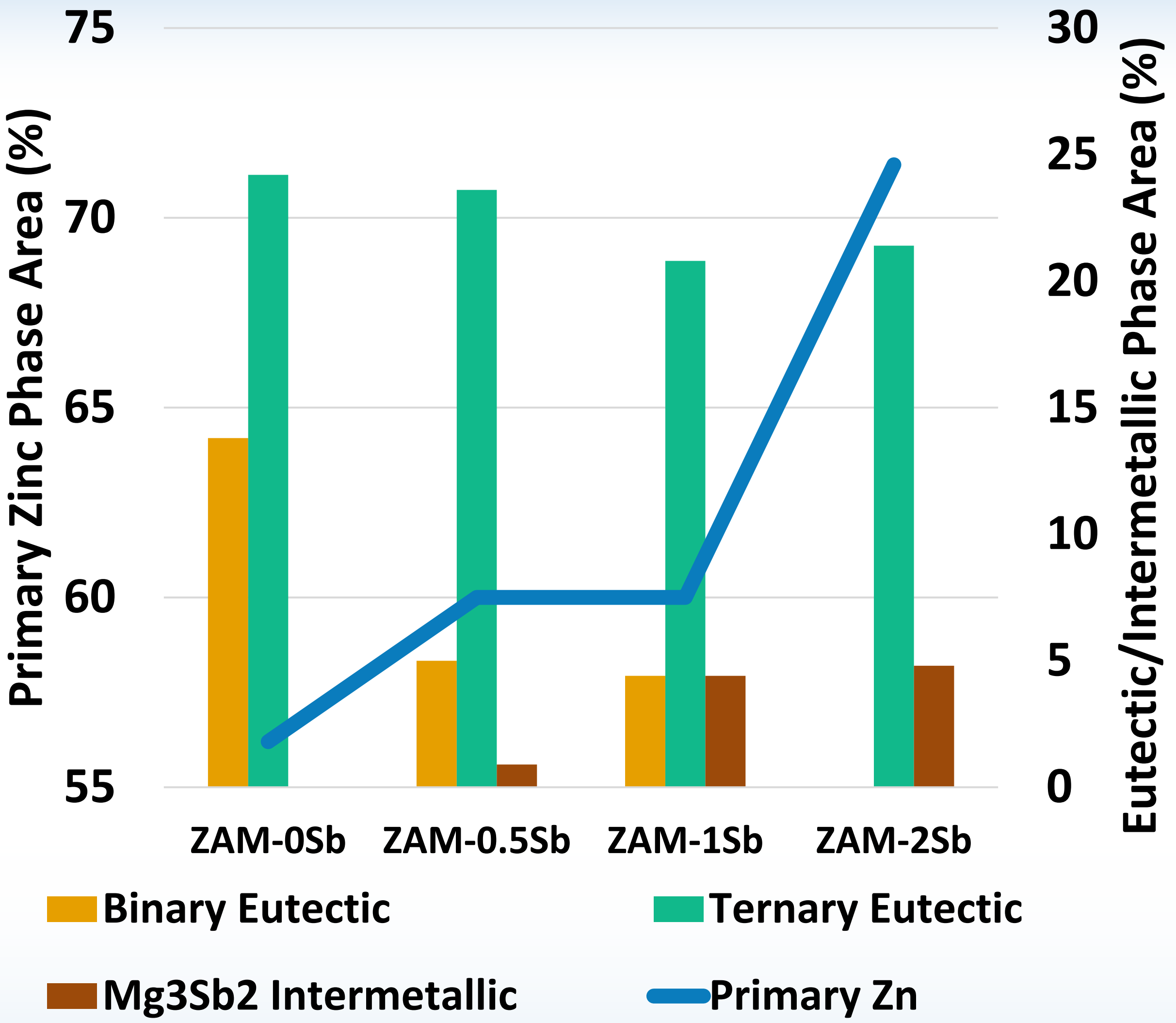

Figure 5 – Phase Area Percentage for All Samples

[4] Dong et al, Materials 980(10), 2017

Phase Formation

- Phase compositions were confirmed using EDX, DSC and previous literature [4]

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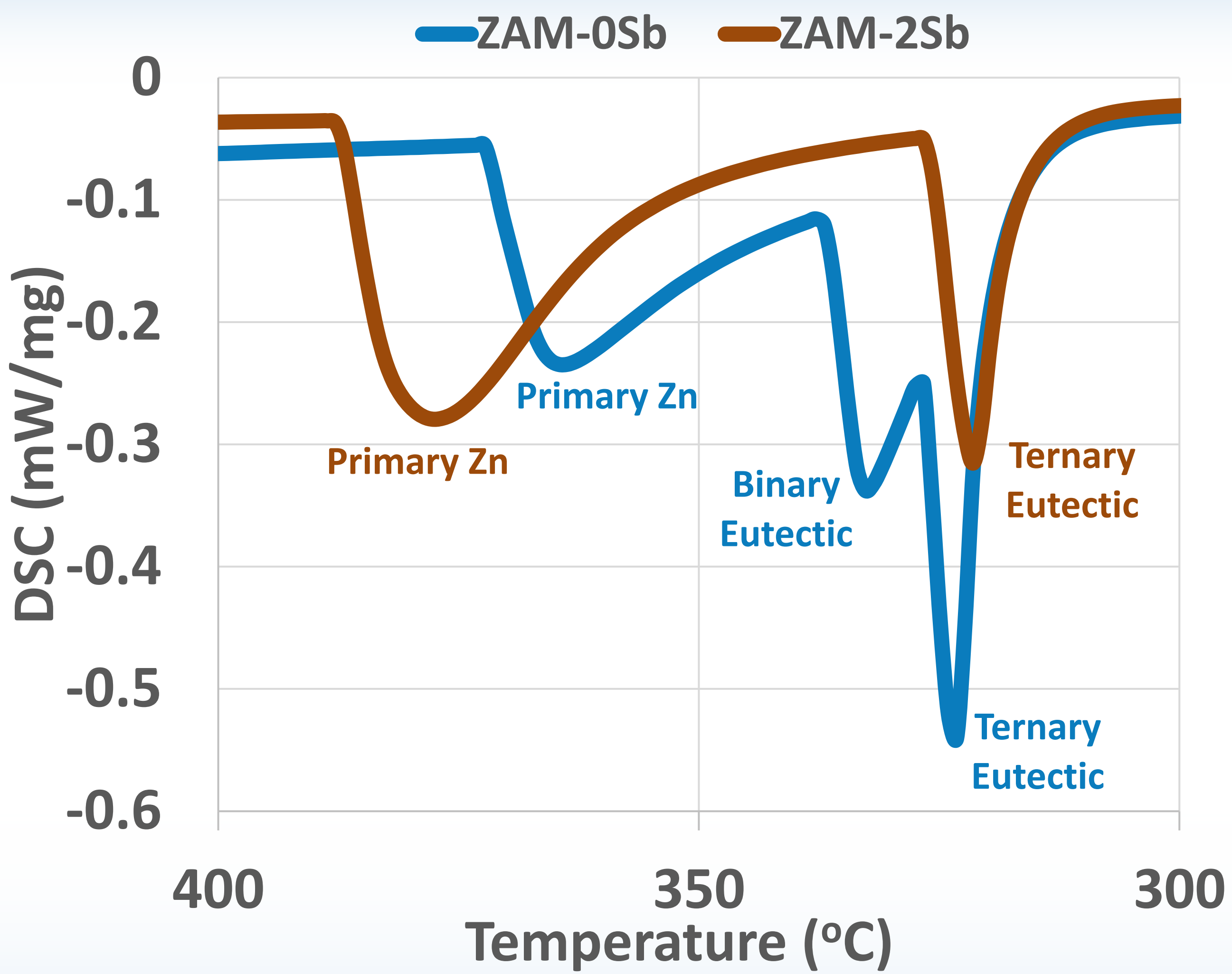

Figure 6 – Differential Scanning Calorimetry (Cooling) Results Comparison for ZAM-0Sb and ZAM-2Sb

[4] Dong et al, Materials 980(10), 2017

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Corrosion Testing

- Linear Polarisation Resistance (LPR) and Open Circuit Potential (OCP) were both performed using a three-electrode setup, attached to a *Gamry Interface* potentiostat

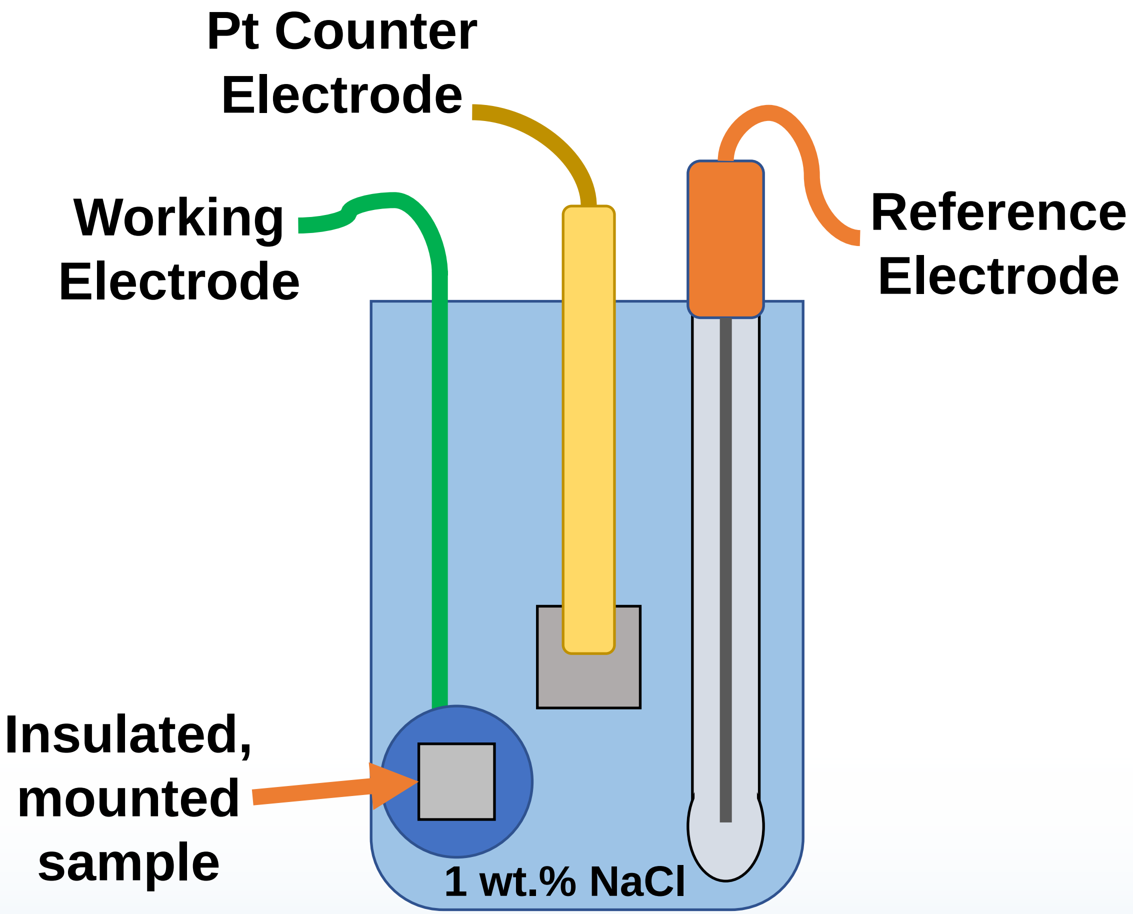

Figure 7 – Corrosion Testing Schematic

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Corrosion Behaviour

- Open Circuit Potential (OCP) gives information about the thermodynamic properties of corrosion
- More negativity of open circuit potential signifies an increased likelihood of corrosion
- All Sb additions show increased likelihood of corrosion compared to the control

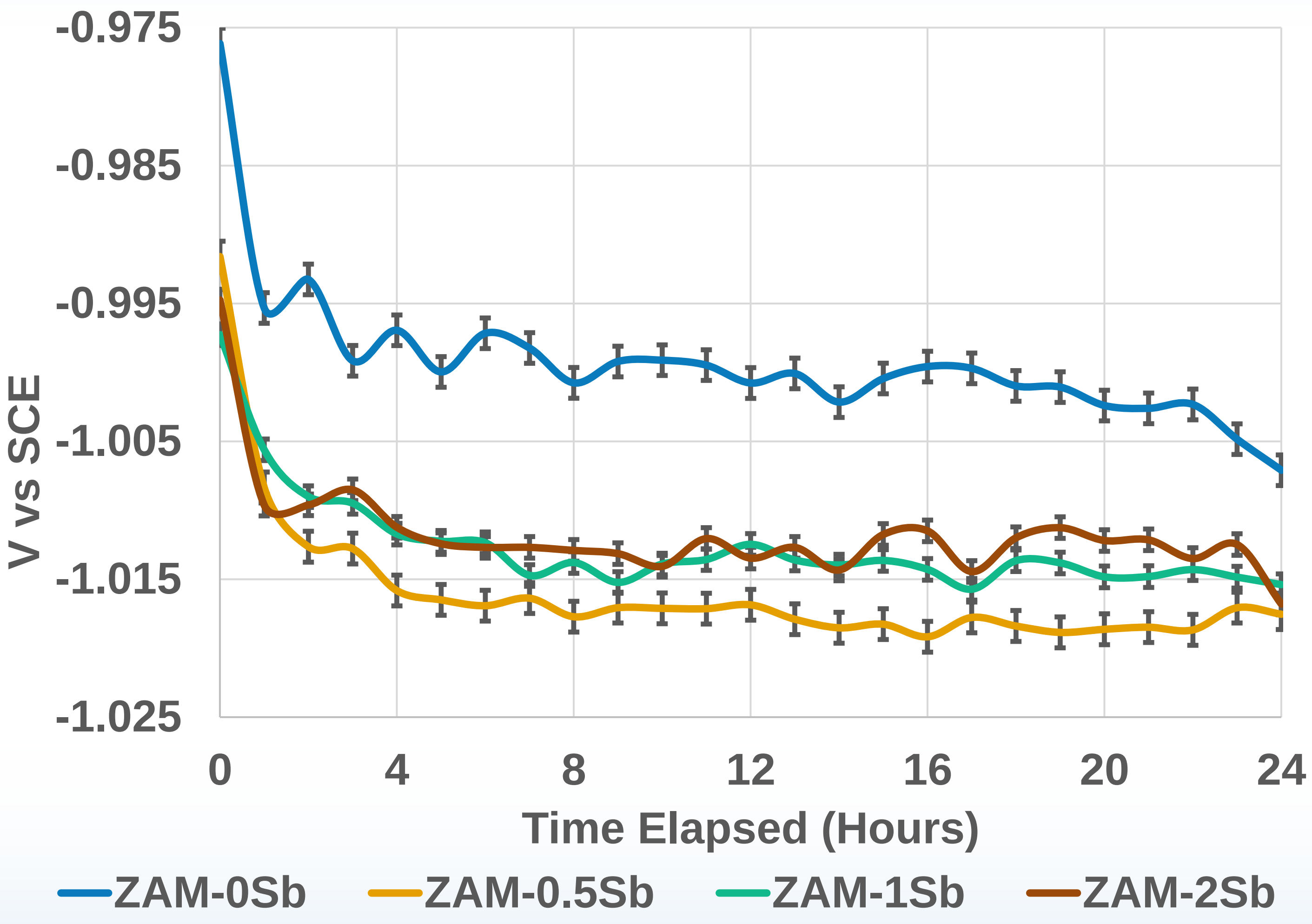

Figure 8 – Open Circuit Potential Results

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Corrosion Behaviour

- Linear Polarisation Resistance (LPR) shows the kinetic behaviour of a sample's corrosion
- An increase in 1/Rp indicates a rising rate of corrosion
- ZAM-2Sb consistently performs better than other samples.
- Data suggests greater additions of Sb slow corrosion rates in ZAM coatings

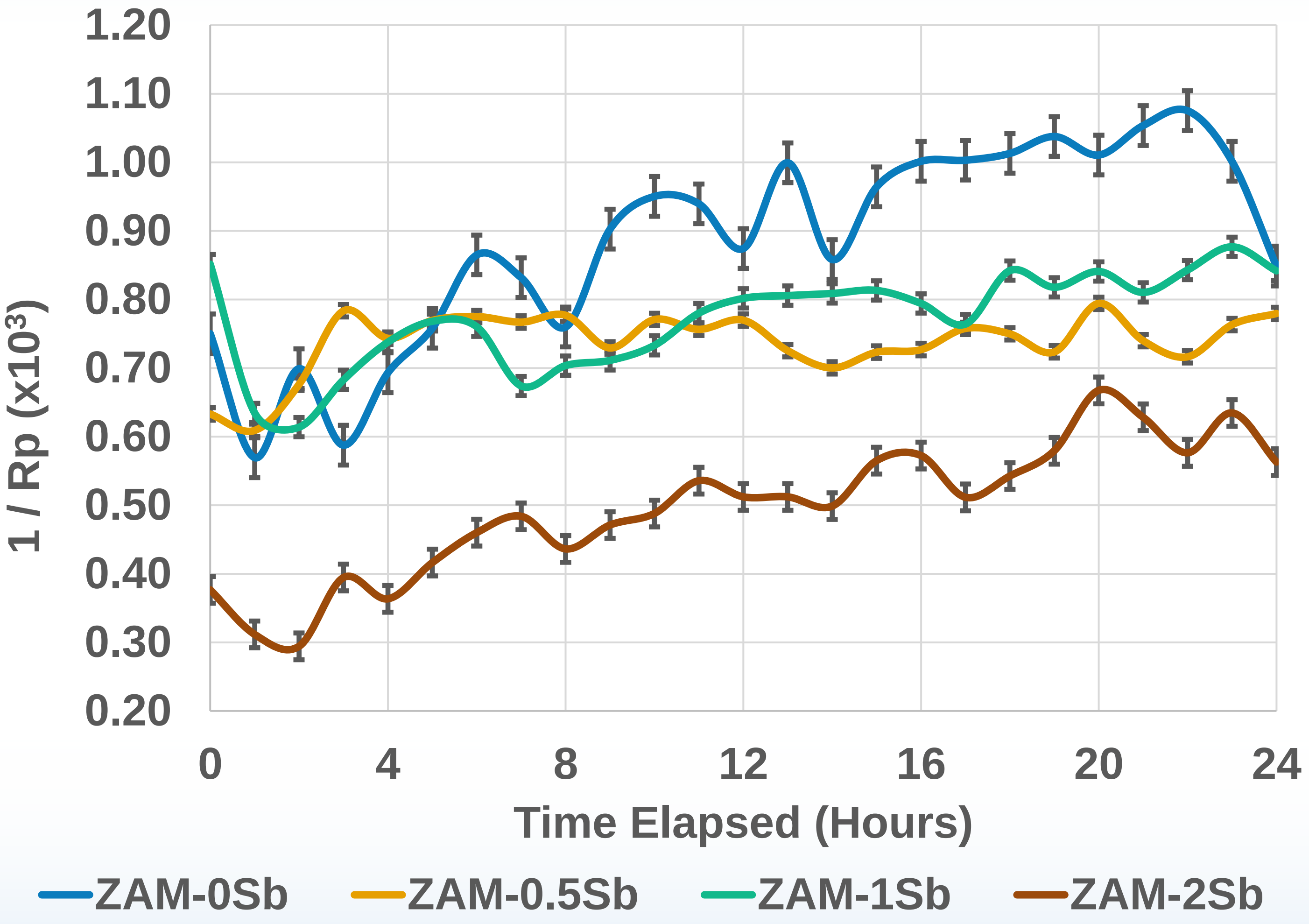

Figure 9 – Linear Polarisation Resistance Results

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Corrosion Behaviour

- Scanning Vibrating Electrode Technique is a semi-quantitative method for viewing current flux above a sample surface
- Red areas are anodic, metal dissolution takes place
- Blue areas are cathodic, oxygen reduction takes place
- Higher additions of Sb cause more anodic sites, but the intensity is more gentle

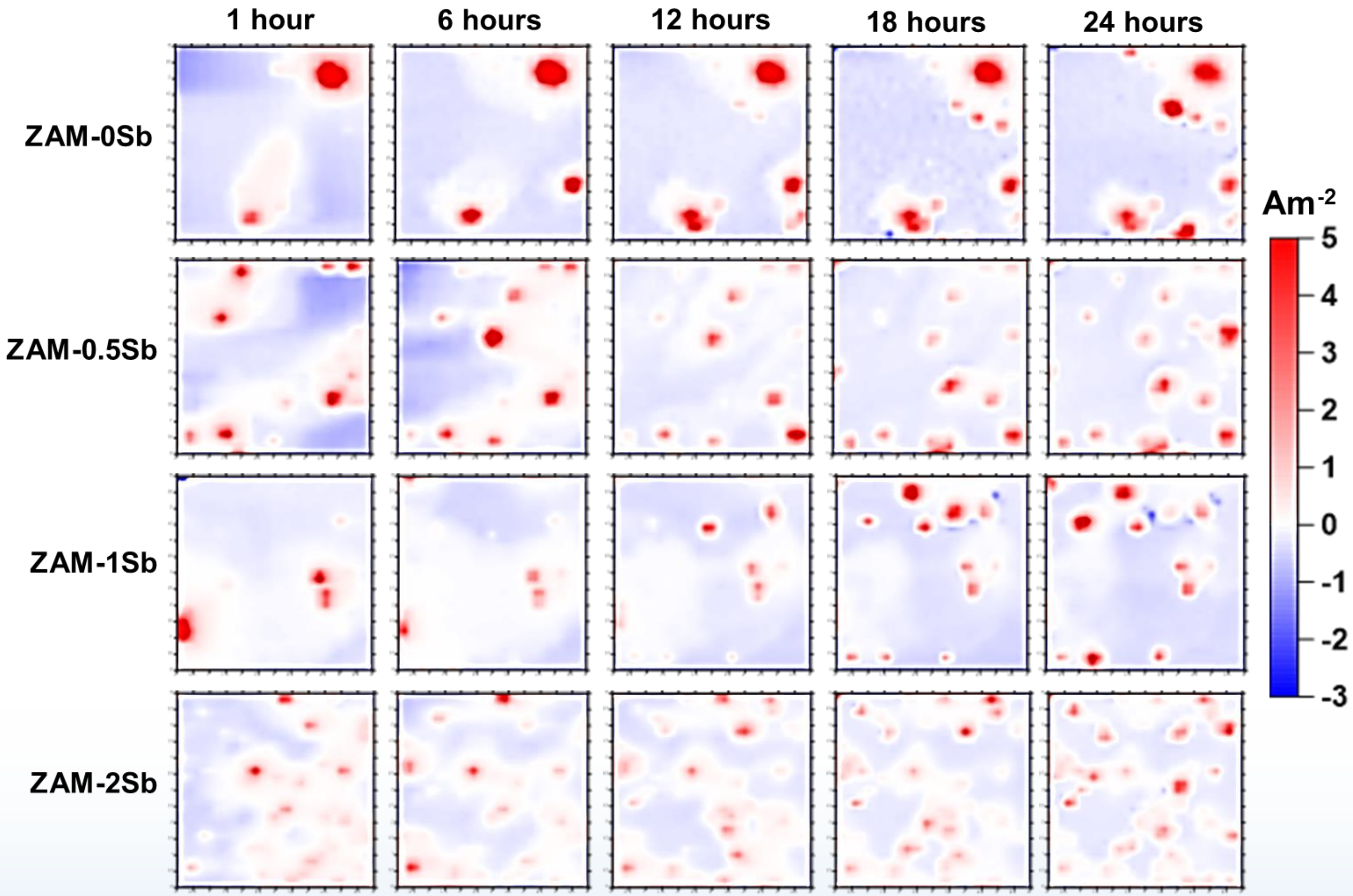

Figure 10 – SVET Maps for all Samples

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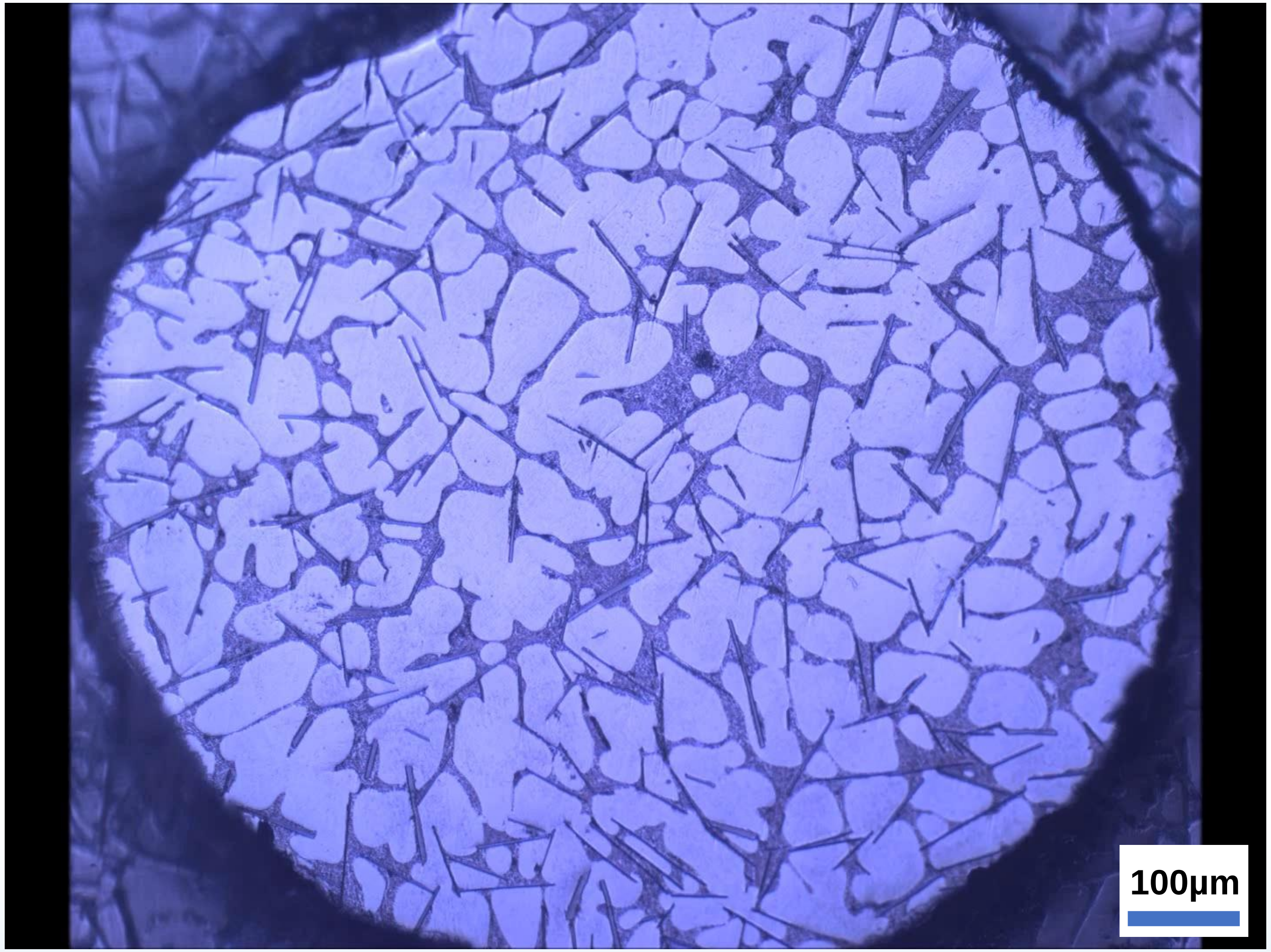
Corrosion Behaviour

- Time Lapse Microscopy (TLM) is a useful tool for observing corrosion behaviour on a micro scale
- Still images are taken every 2 minutes over a 24-hour period and stitched together to form a video at 2,400x speed



Media 1 – Time Lapse Microscopy video showing 8 hours of ZAM-Sb corrosion over 12 seconds

Corrosion Behaviour

- Larger Sb intermetallics appear to stop growth of the anode
- This behaviour would explain the decrease in metal dissolution seen during SVET testing

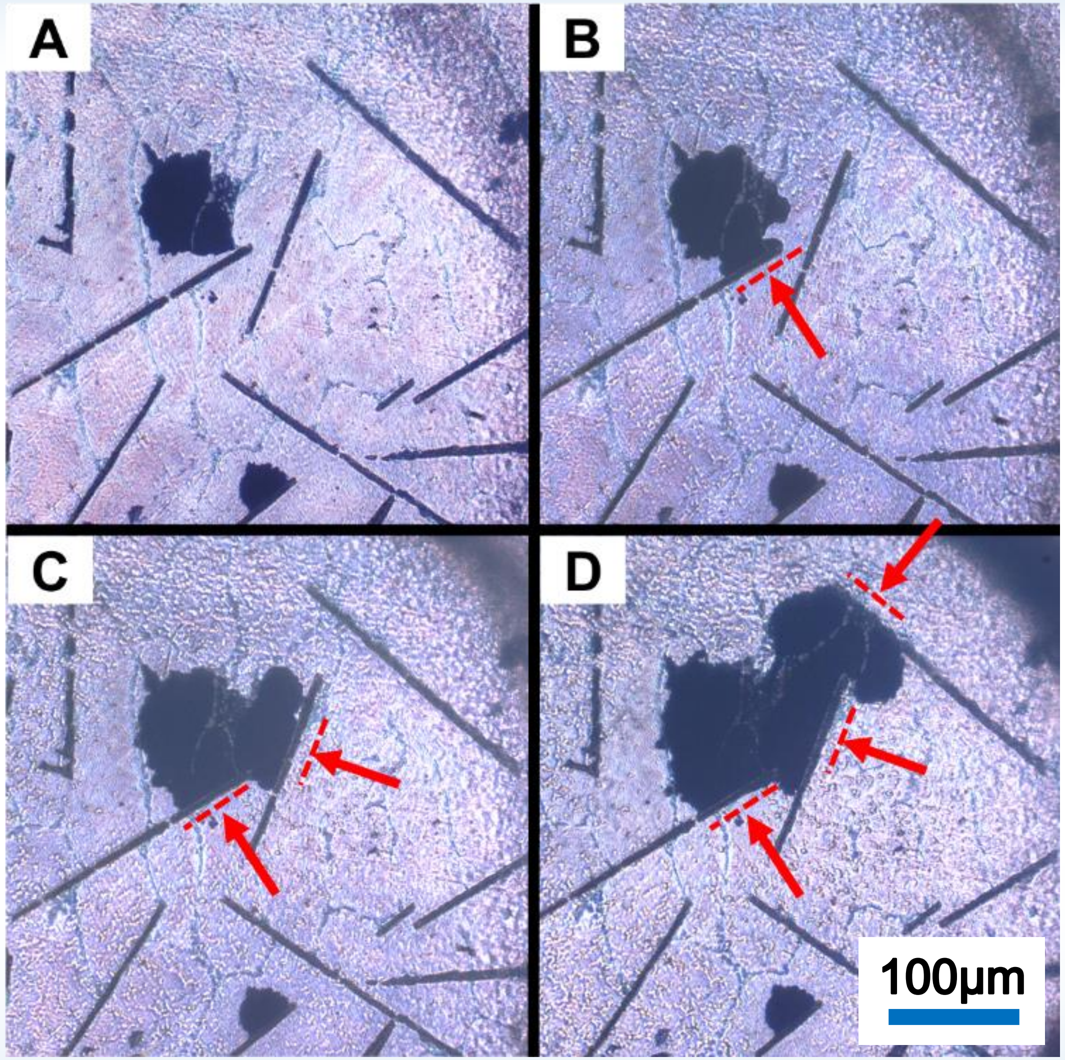


Figure 11 – TLM microscope images at A) 100 minutes, B) 140 minutes, C) 220 minutes, D) 440 minutes

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Mechanical Properties

- Initial hardness testing was completed on each sample using nine indents over a 1mm^2 area
- ZAM-2Sb gave a decrease in mean hardness of approximately 14%

Equation 1 – Relationship between hardness (H_v) and yield stress (σ_y) [5]

$$H_V = 3 \cdot \sigma_y$$

[5] Zhang et al, Materials Science and Engineering A 529, 2011

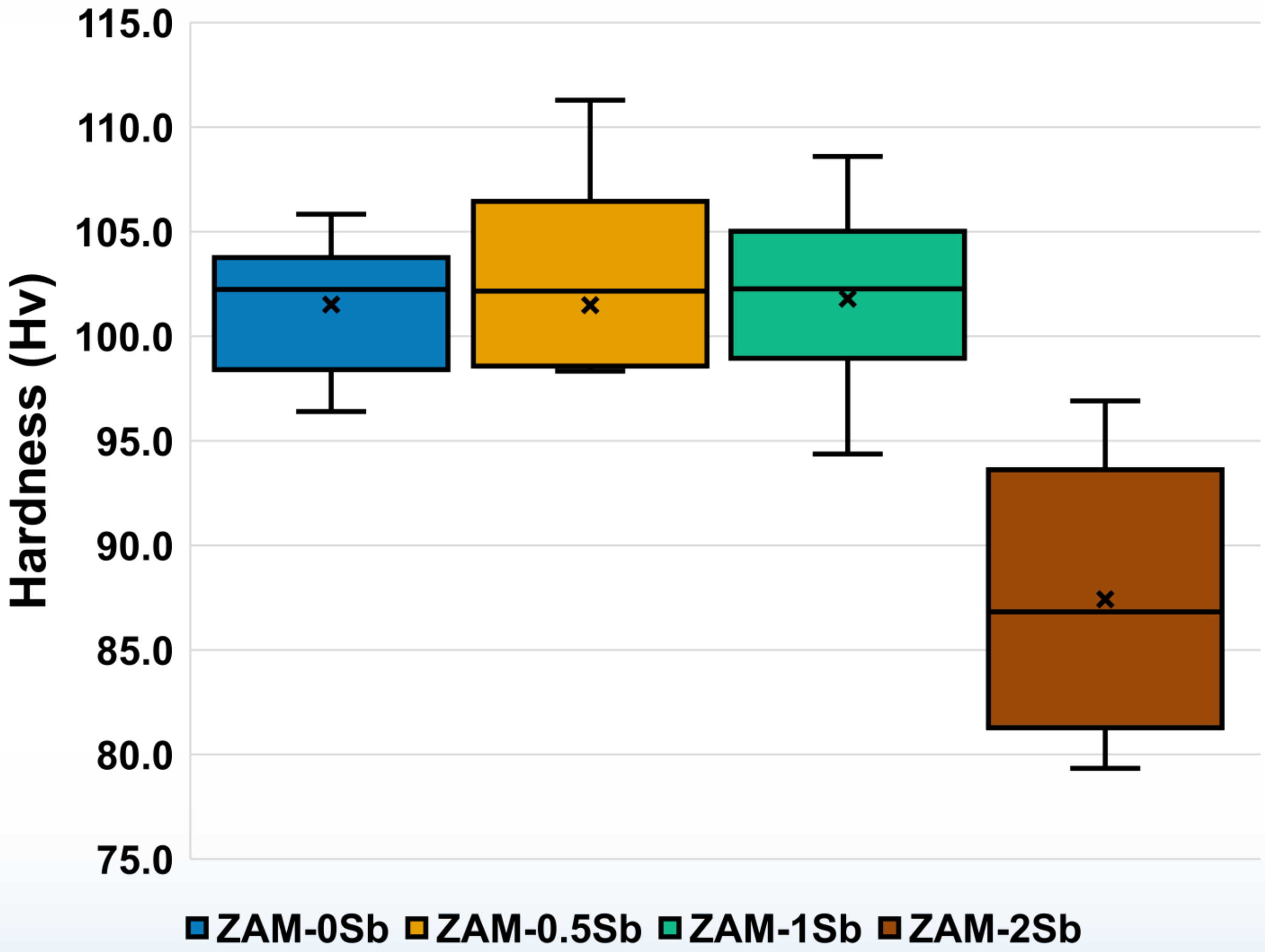

Figure 12 – Hardness Data

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Conclusions

- Antimony was added to ZAM coatings to attempt to improve coating formability whilst maintaining high levels of corrosion protection
- An Mg_3Sb_2 intermetallic was formed, influencing the abundance of the binary eutectic phase
- As antimony additions were increased;
  - ☑Amount of brittle binary eutectic was decreased/removed
  - ☑Hardness reduced
  - ☑Intensity of anodes was decreased
  - ☑Rate of corrosion declined
  - ☒Likelihood of corrosion (thermodynamics) rose

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Thank You for Listening

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