TATA STEEL

M2A
MATERIALS AND MANUFACTURING ACADEMY

Scanning Vibrating Electrode Technique Time-Lapse Imaging (SVET-TLI): Studying Sacrificial Zinc Coatings in Salt Solution

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EPSRC
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EPSRC Centre for Doctoral Training in Industrial Functional Coatings

Llywodraeth Cymru
Welsh Government
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European Social Fund

Overview

- Scanning Vibrating Electrode Technique
- Time Lapse Imaging
- SVET-TLI
- Results
- Conclusions

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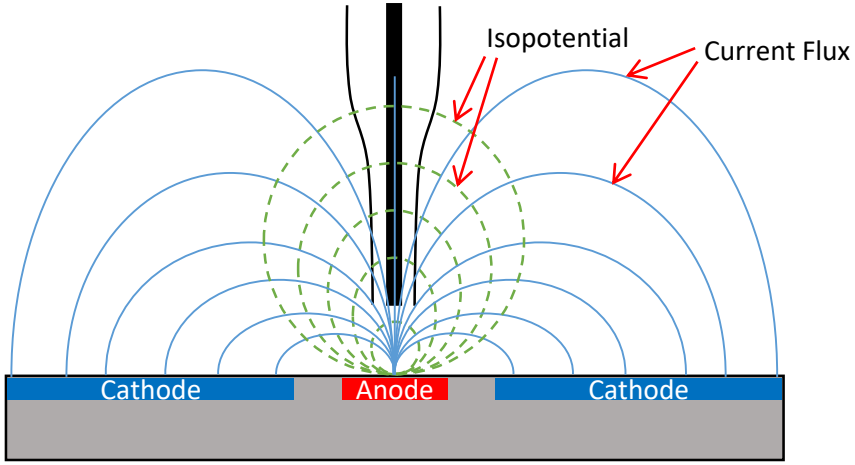
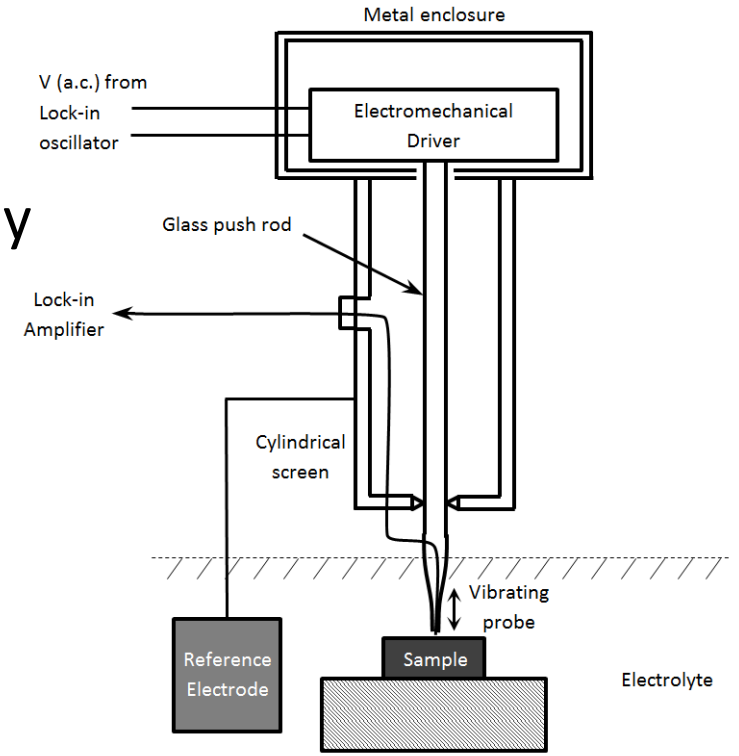
Scanning Vibrating Electrode Technique

- In-situ measurement of localised corrosion activity
- Detects potential gradients produced by local currents generated by actively corroding surfaces



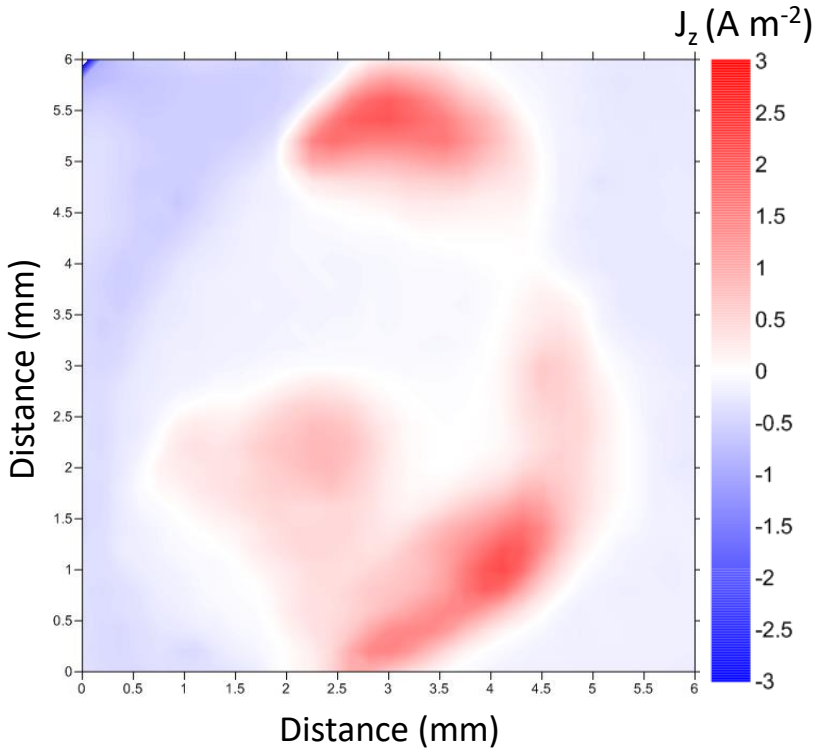


SVET probe assembly, adapted from Williams and McMurray, 2008 [1]

[1] Williams G, McMurray HN. Localized Corrosion of Magnesium in Chloride-Containing Electrolyte Studied by a Scanning Vibrating Electrode Technique. *Electrochem Soc* 2008; 155: C340–C349.

Scanning Vibrating Electrode Technique

- Produces time-based, spatially-resolved current density maps



Red = Anodic = Metal Dissolution

Blue = Cathodic = Oxygen Reduction

Typical SVET map for Magizinc in 5% w/v NaCl after 24 hours

Scanning Vibrating Electrode Technique

Advantages

- Relatively non-perturbing

- Accurate qualitative and quantitative data that is both spatially and temporally resolved

Disadvantages:

- Resolution restricted to probe diameter (100µm)

- No information on visual/physical behaviour

Overview

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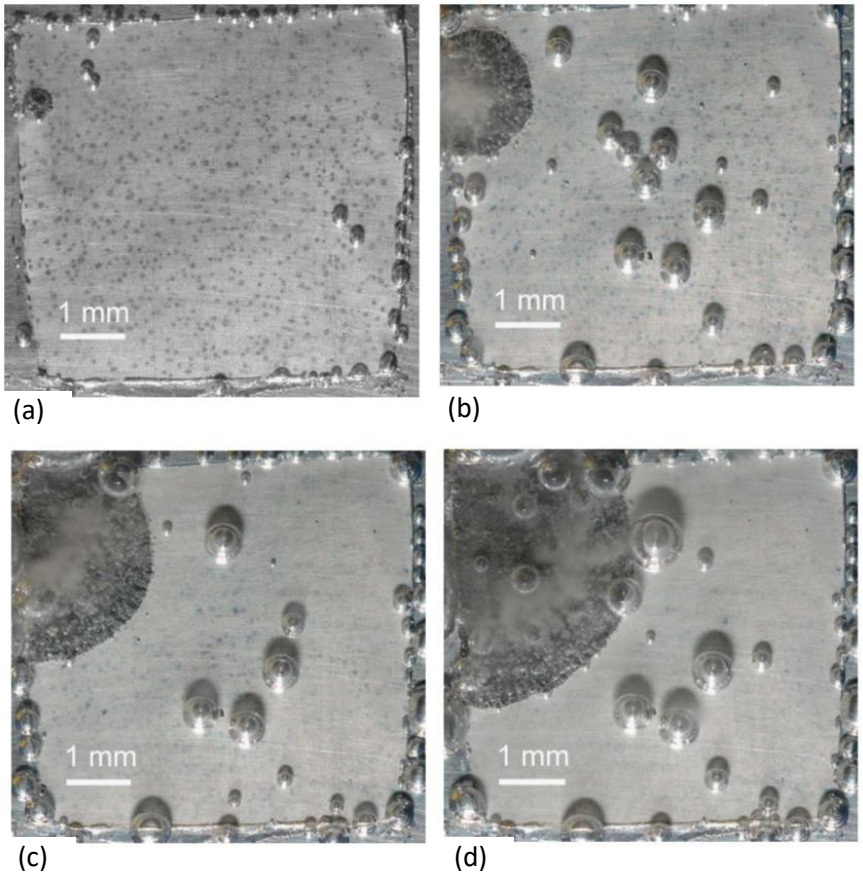
Time Lapse Imaging

- Images captured periodically to monitor activity or behaviour
- Regular intervals
- Automated software allows for long duration studies

Time Lapse Imaging (in situ)



Photographic images of magnesium freely corroding in aerated 5% w/v NaCl (aq) taken at (a) 4, (b) 16, (c) 27, and (d) 38 min following immersion [1]

[1] Williams G, McMurray HN. Localized Corrosion of Magnesium in Chloride-Containing Electrolyte Studied by a Scanning Vibrating Electrode Technique. *Electrochem Soc* 2008; 155: C340–C349.

Time Lapse Imaging

Advantages:

- Potentially high resolution
- Generates progressive visual data
- Visual progression can also be used for rate data

Disadvantages:

- No information other than visual

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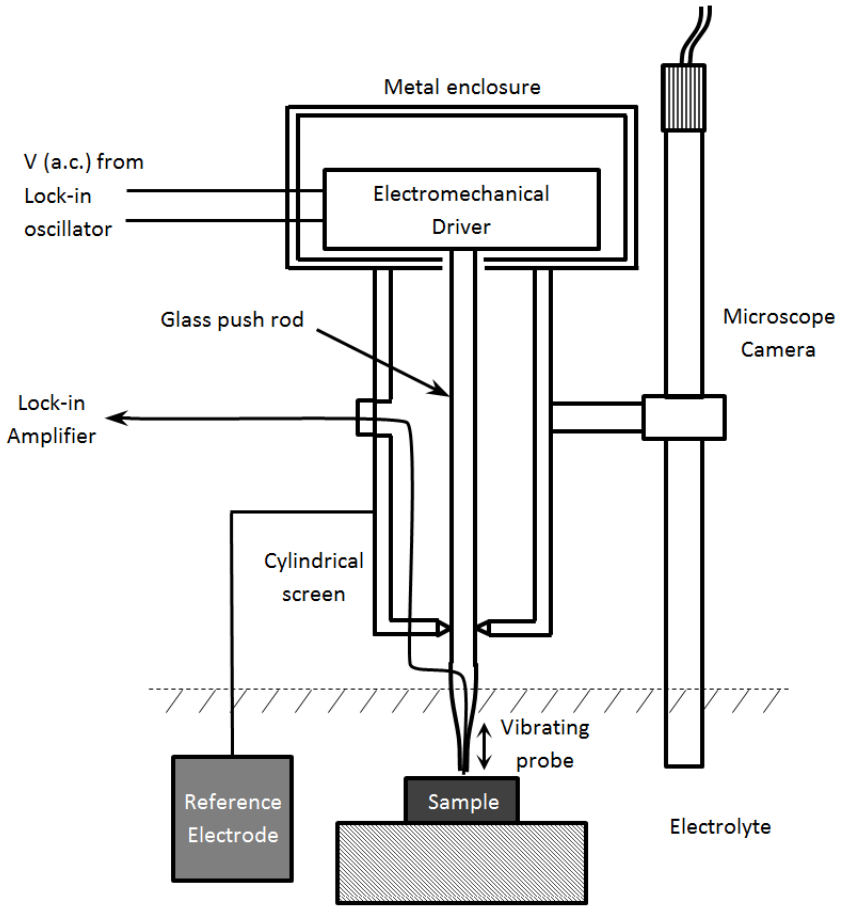
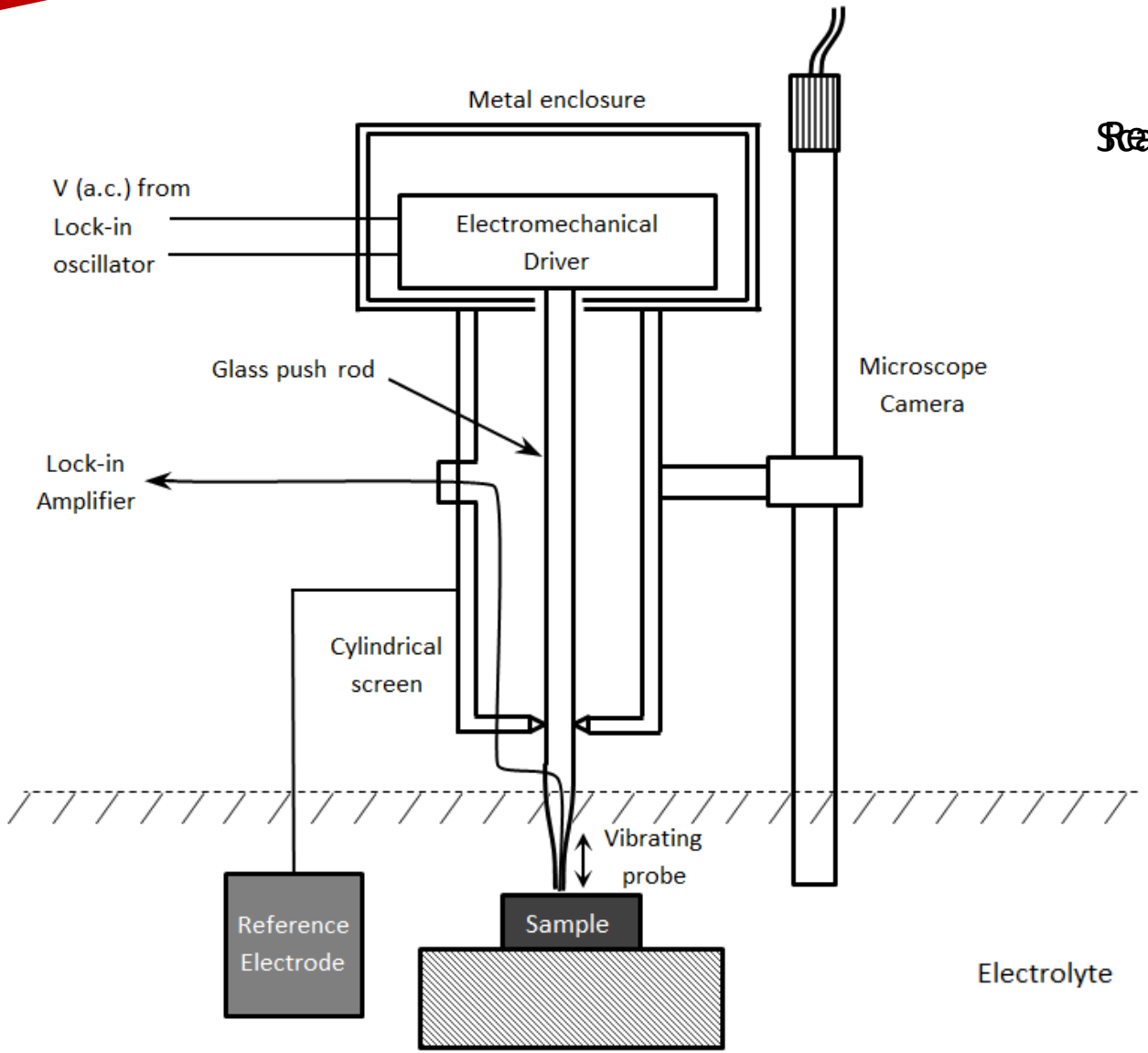
SVET-TLI

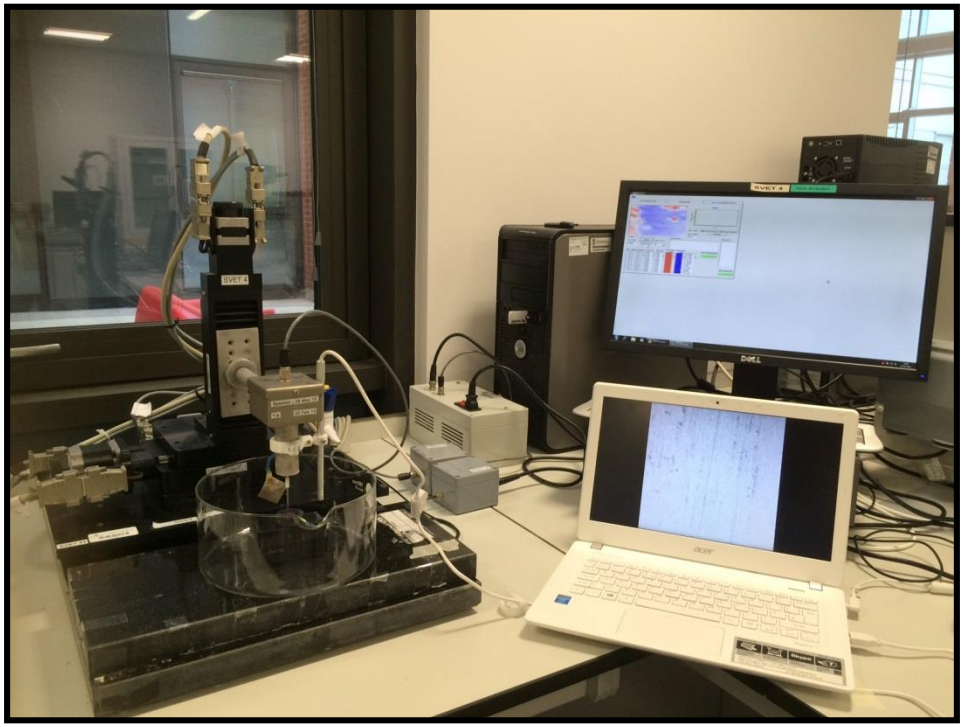
- Combination of both SVET and time lapse photography
- 3D printed friction clamp
- Rest setting: probe assembly moves in the x direction to line up microscope
- Snapshot taken every minute



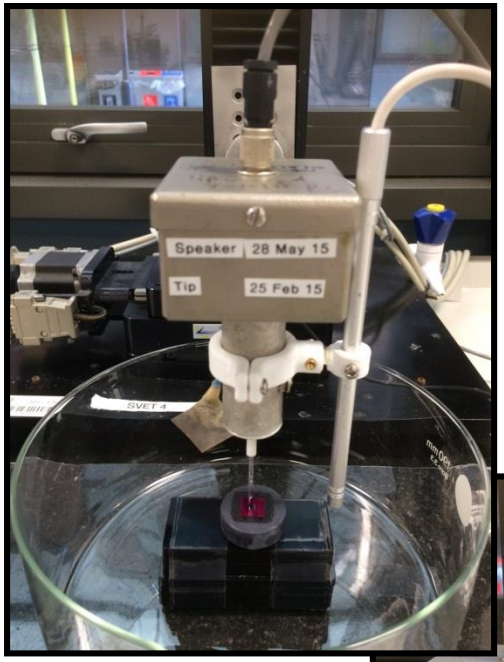
SVET-TLI


Metal enclosure
Scan Mode
V (a.c.) from
Lock-in
oscillator
Electromechanical
Driver
Glass push rod
Microscope
Camera
Lock-in
Amplifier
Cylindrical
screen
Vibrating
probe
Reference
Electrode
Sample
Electrolyte

SVET-TLI



(a)



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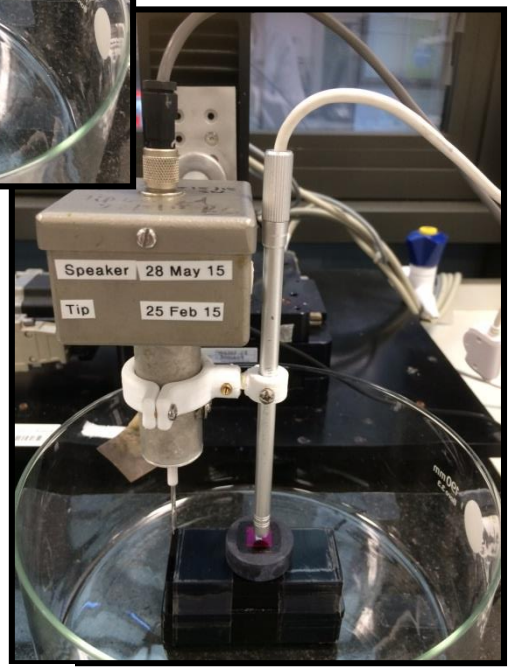

(c)

Overview

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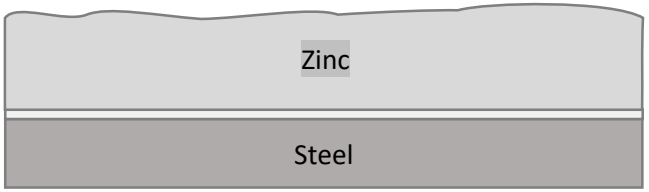
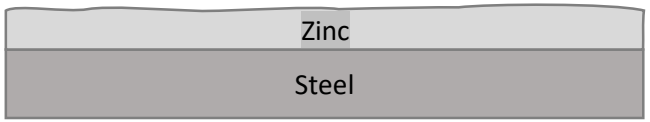
SVET-TLI

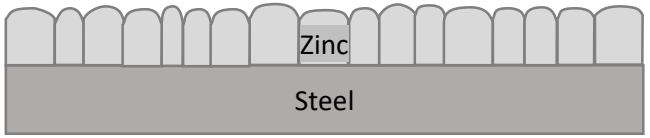
- Zn coatings:
  - Hot Dip Galvanised (HDG)
  - Electrogalvanised (EG)
  - Physical Vapour Deposited (PVD0)
- Electrolytes:
  - 1% w/v NaCl
  - 5% w/v NaCl
- 6mm x 6mm surface scan area



HDG

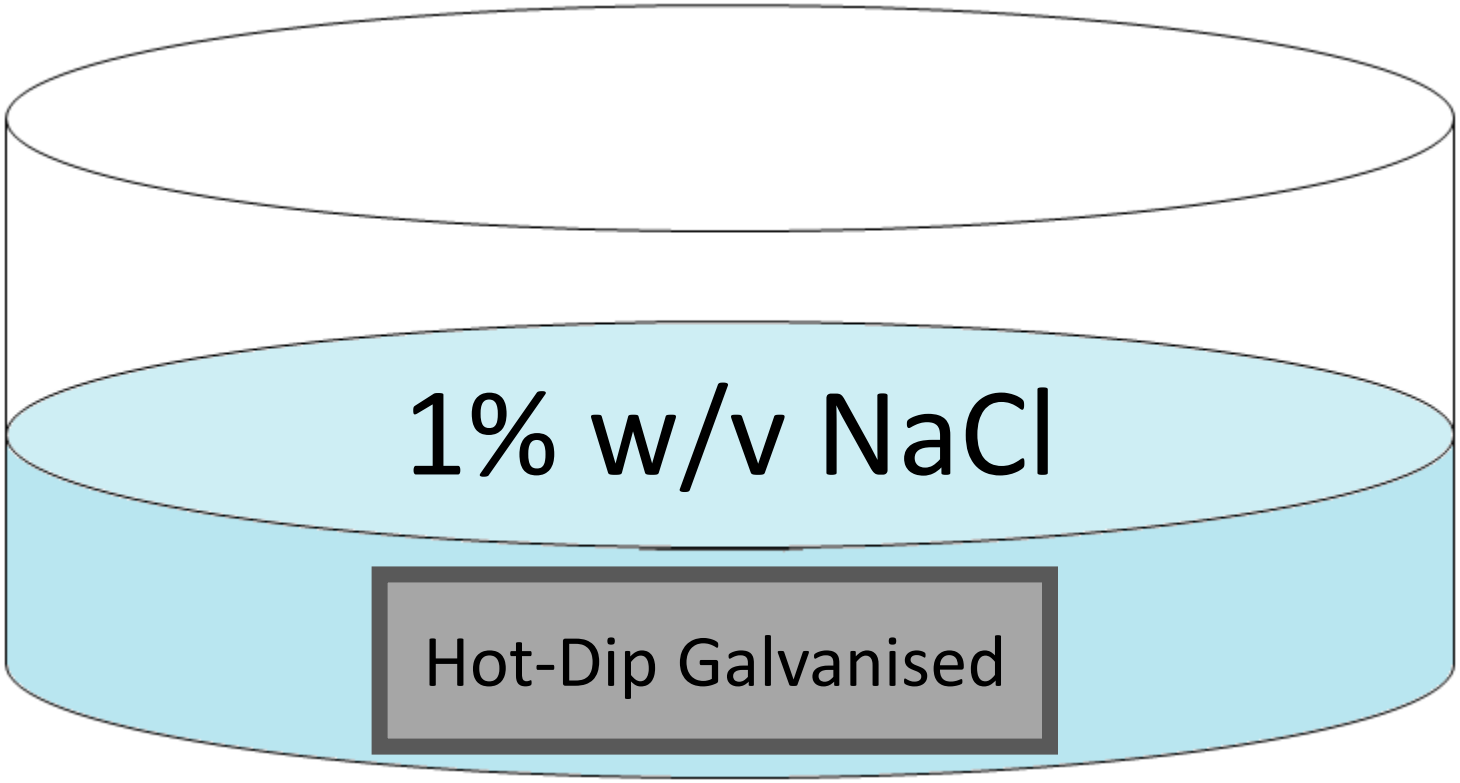


EG



PVD0

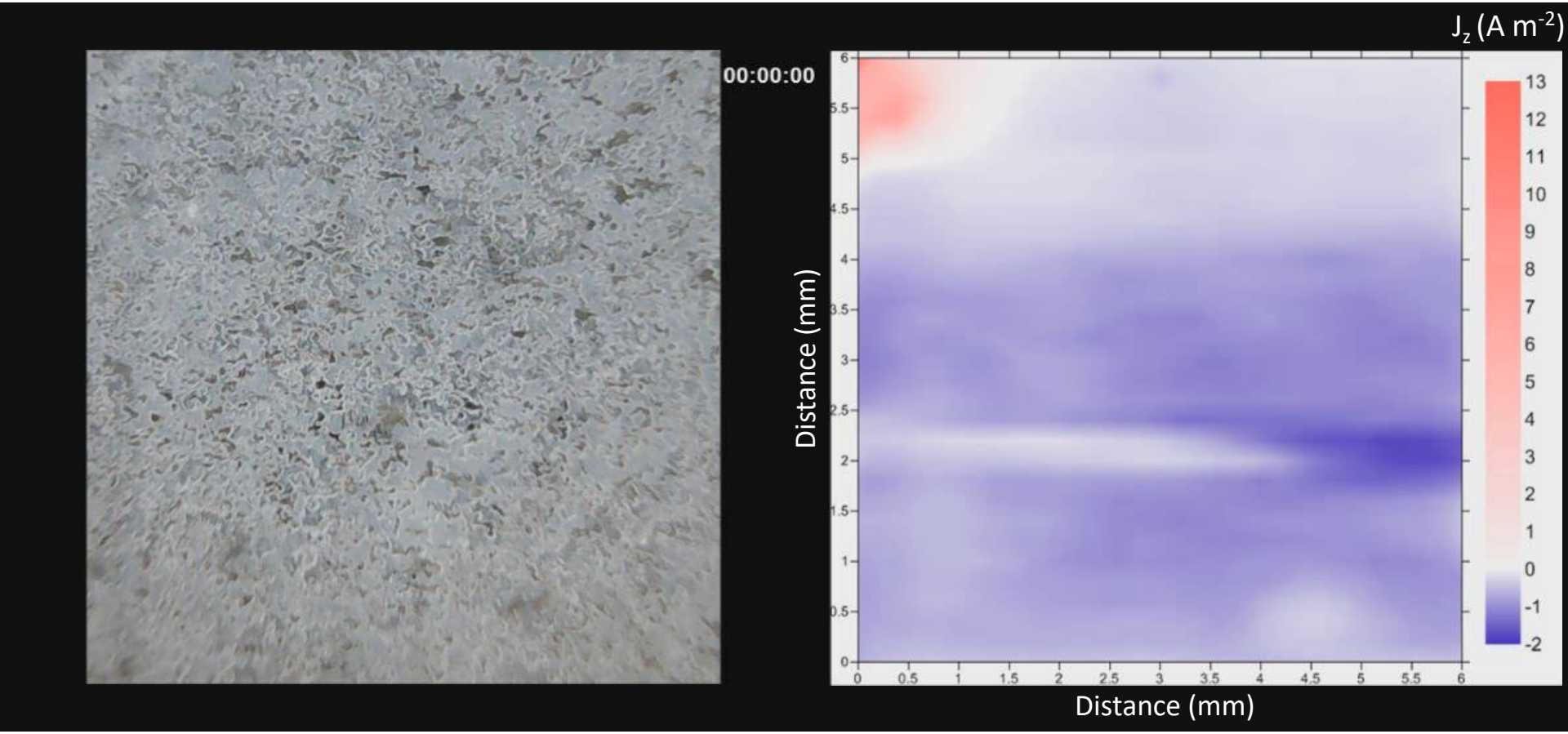
Results



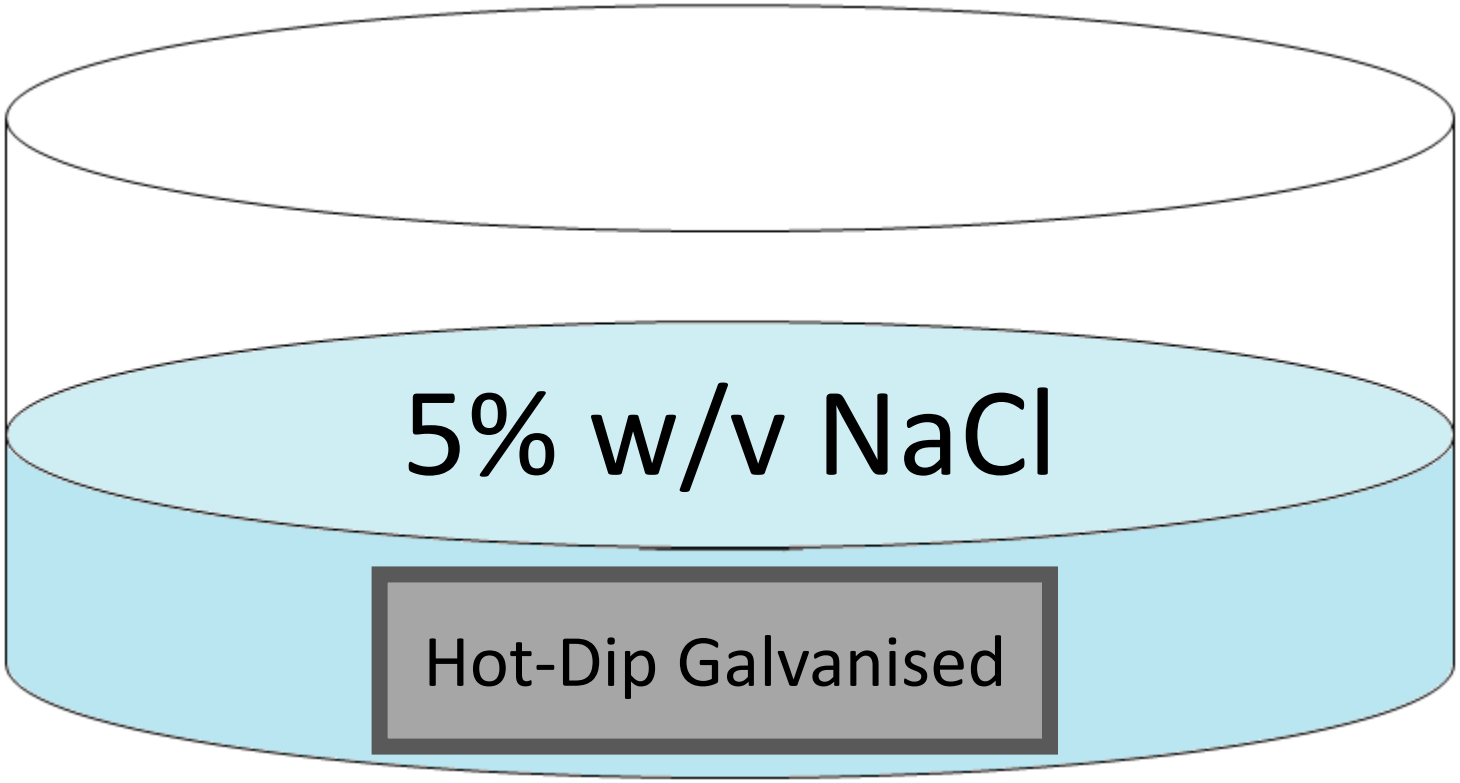
Results
1% NaCl

MATERIALS AND MANUFACTURING ACADEMY

- Hot-Dip Galvanised Zinc



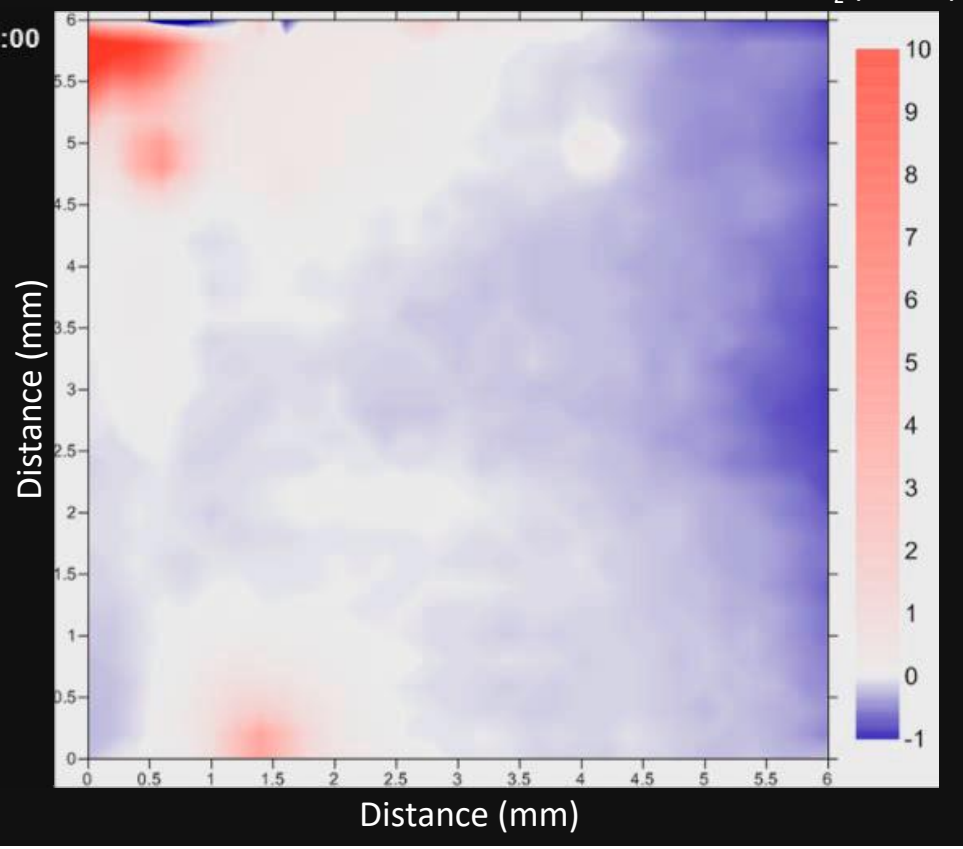
Results



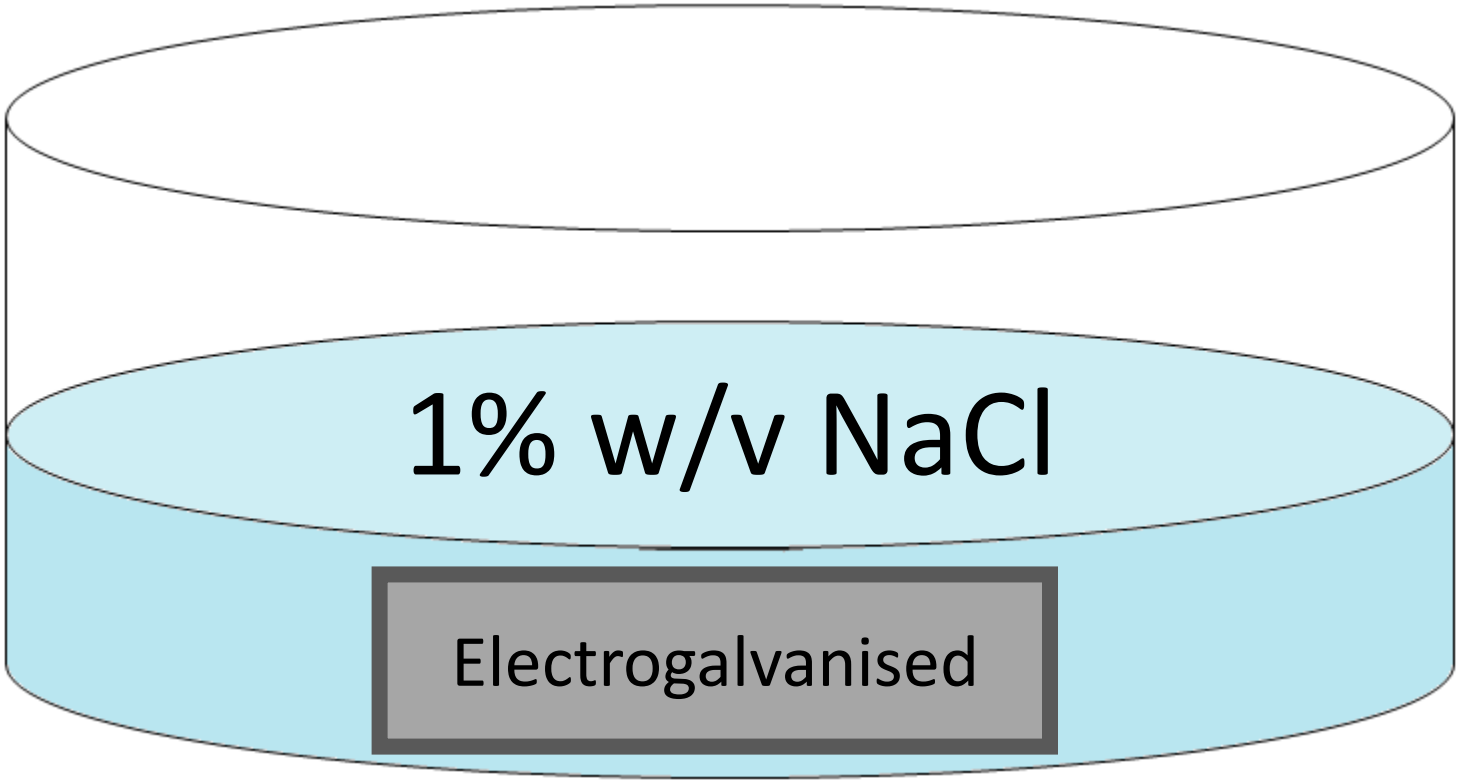
Results
5% NaCl

MATERIALS AND MANUFACTURING ACADEMY

- Hot-Dip Galvanised Zinc



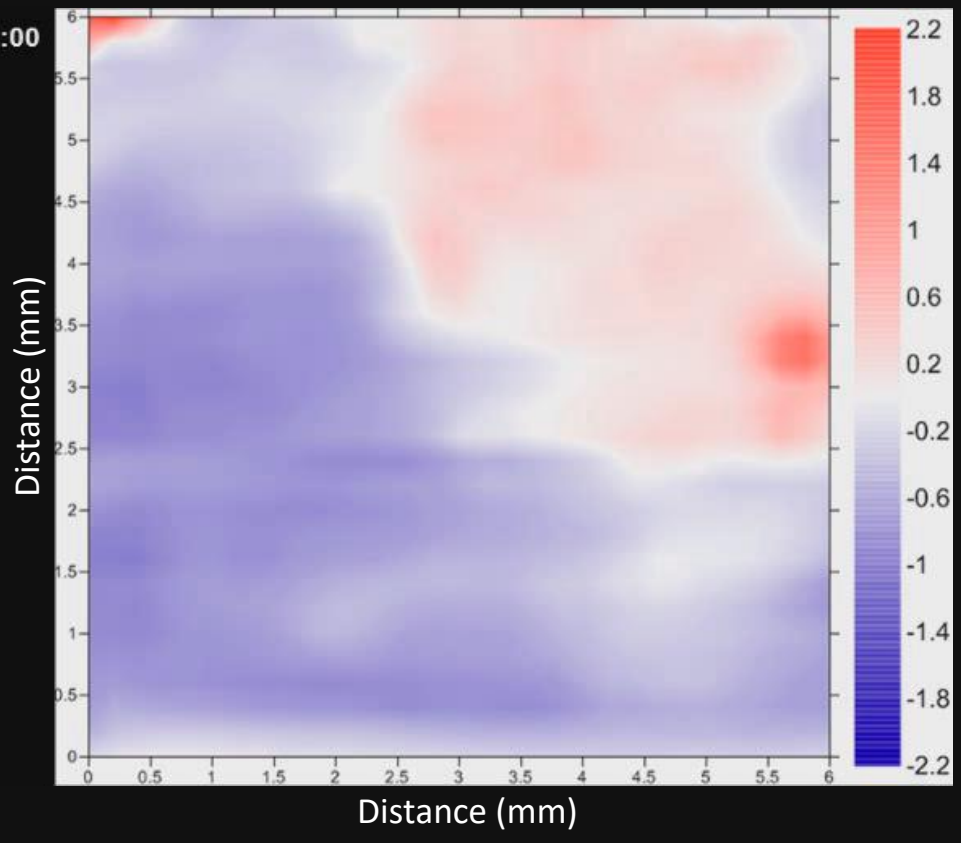
Results



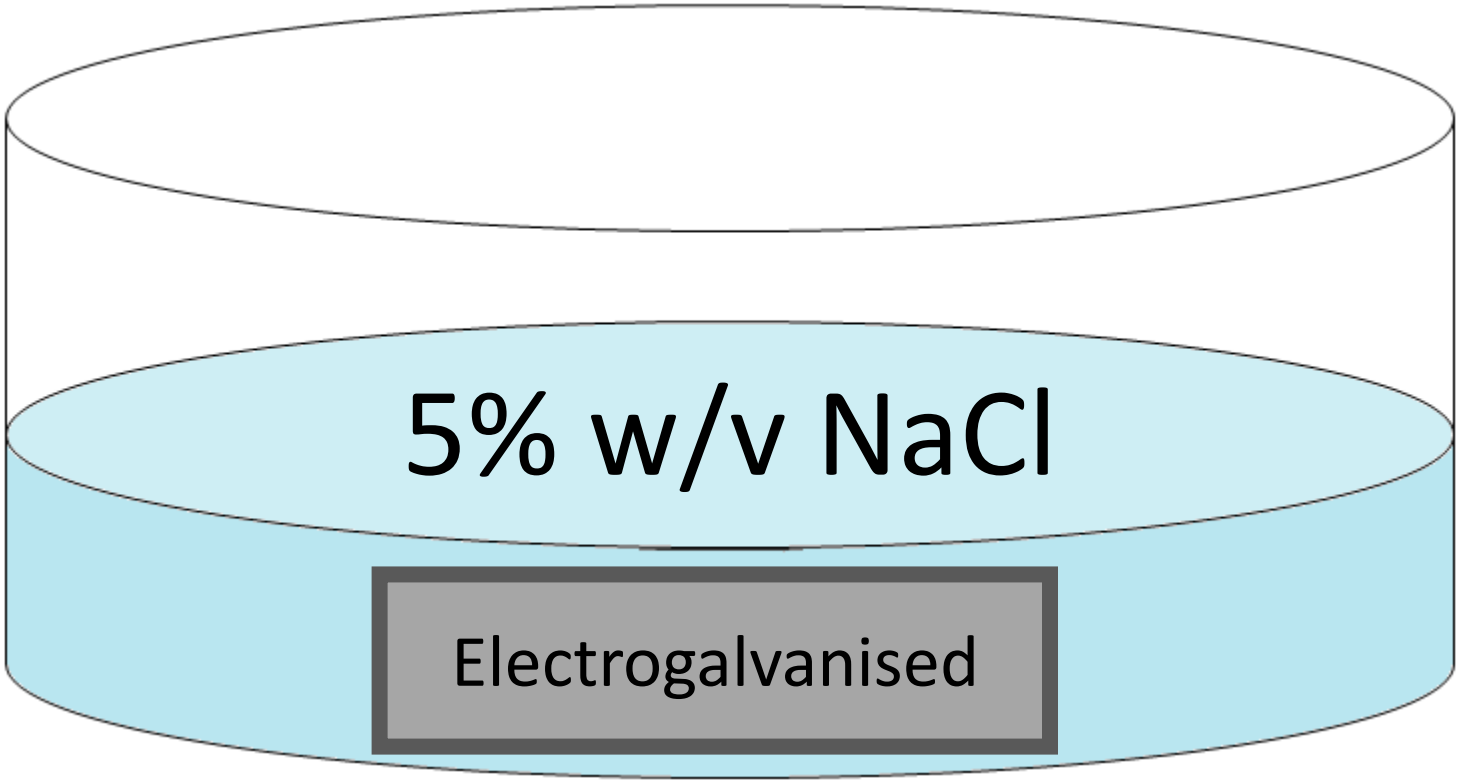
Results
1% NaCl

MATERIALS AND MANUFACTURING ACADEMY

- Electrogalvanised Zinc

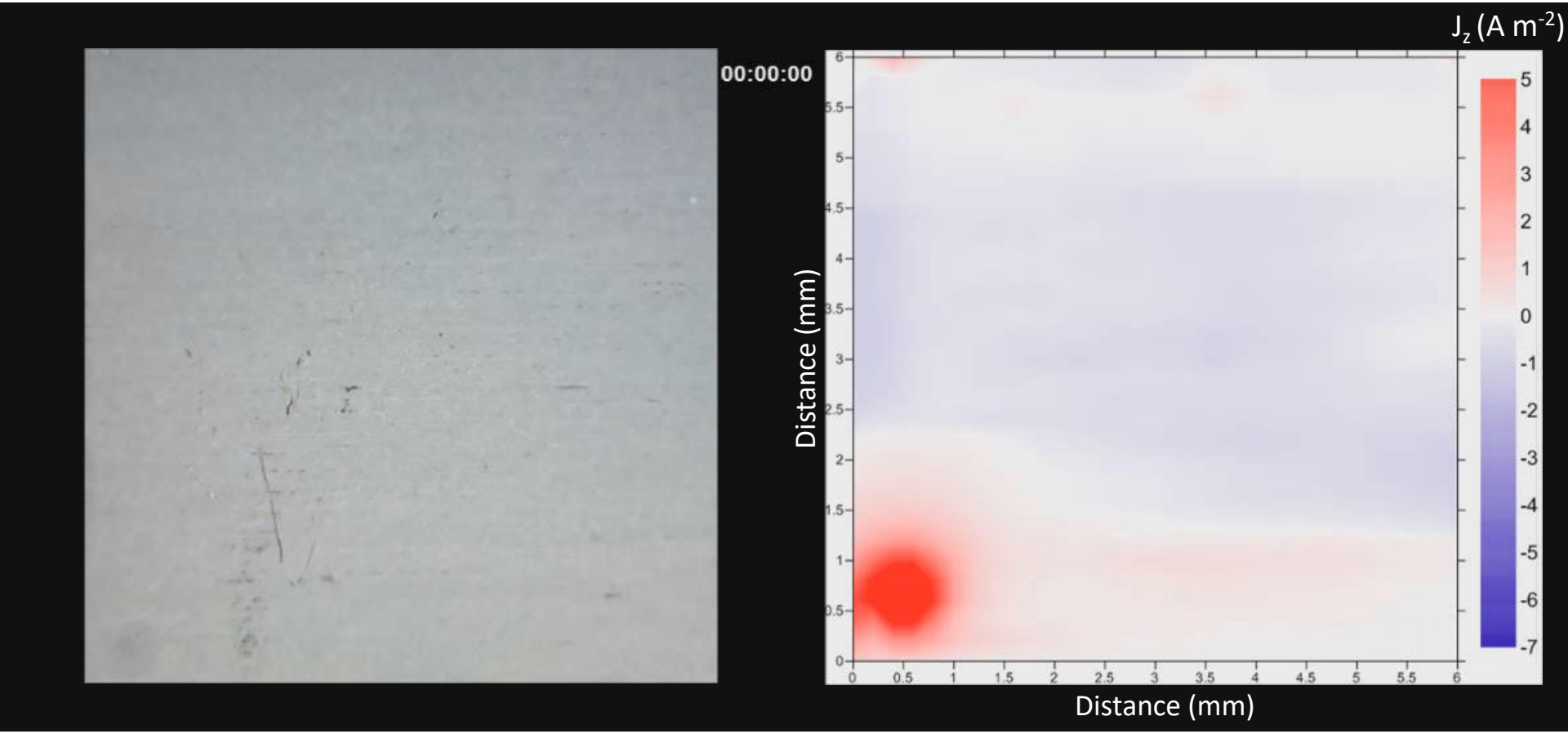


Results

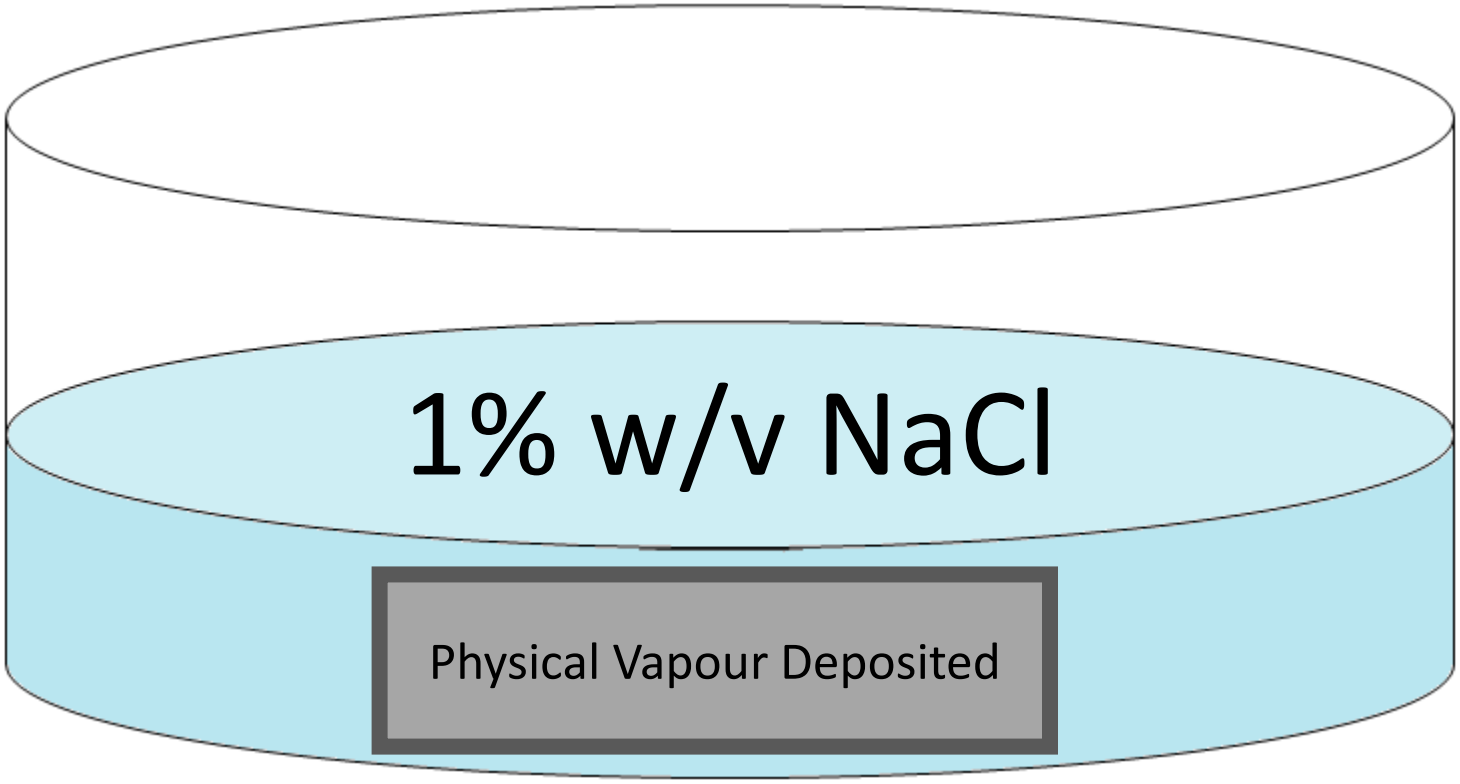


Results
5% NaCl

- Electrogalvanised Zinc



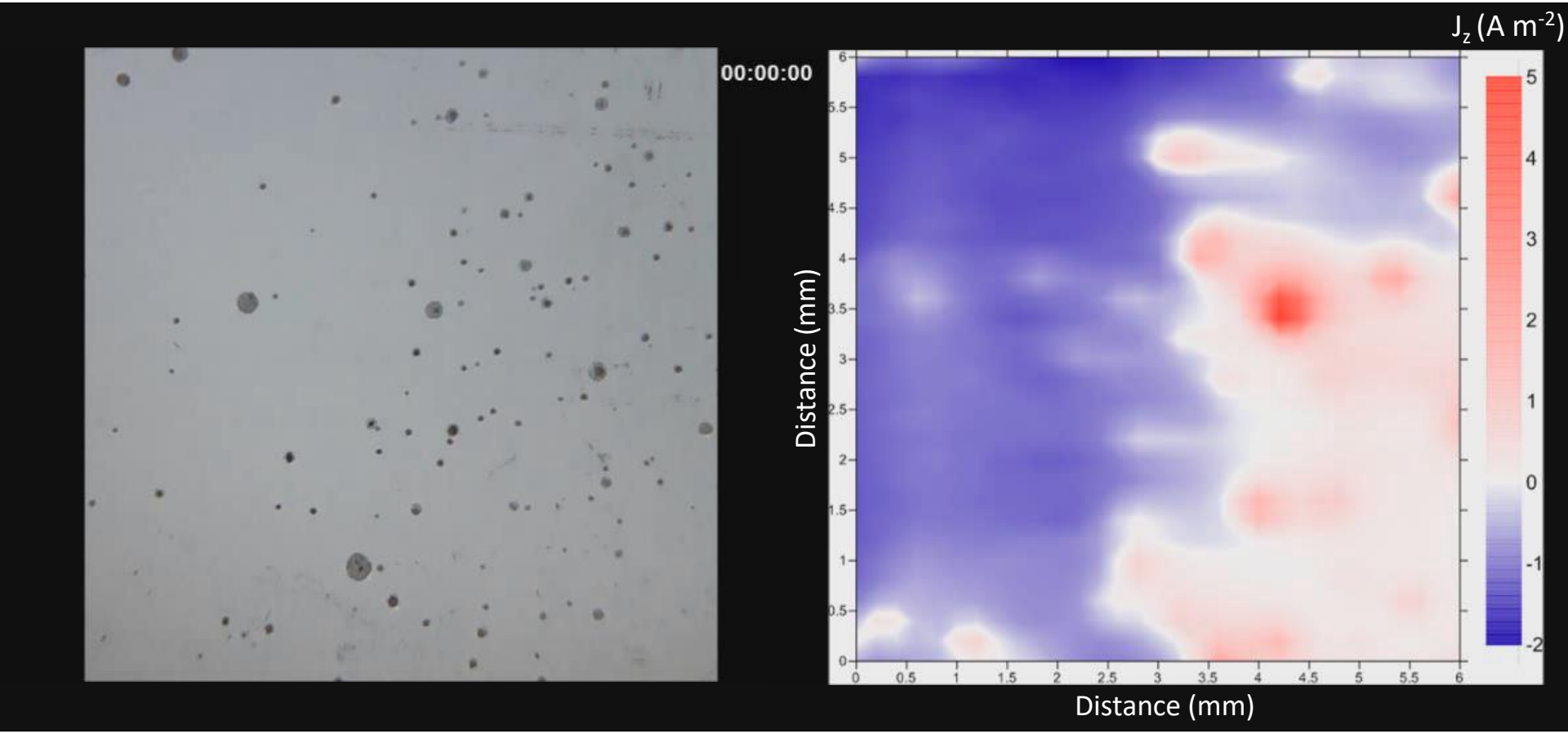
Results



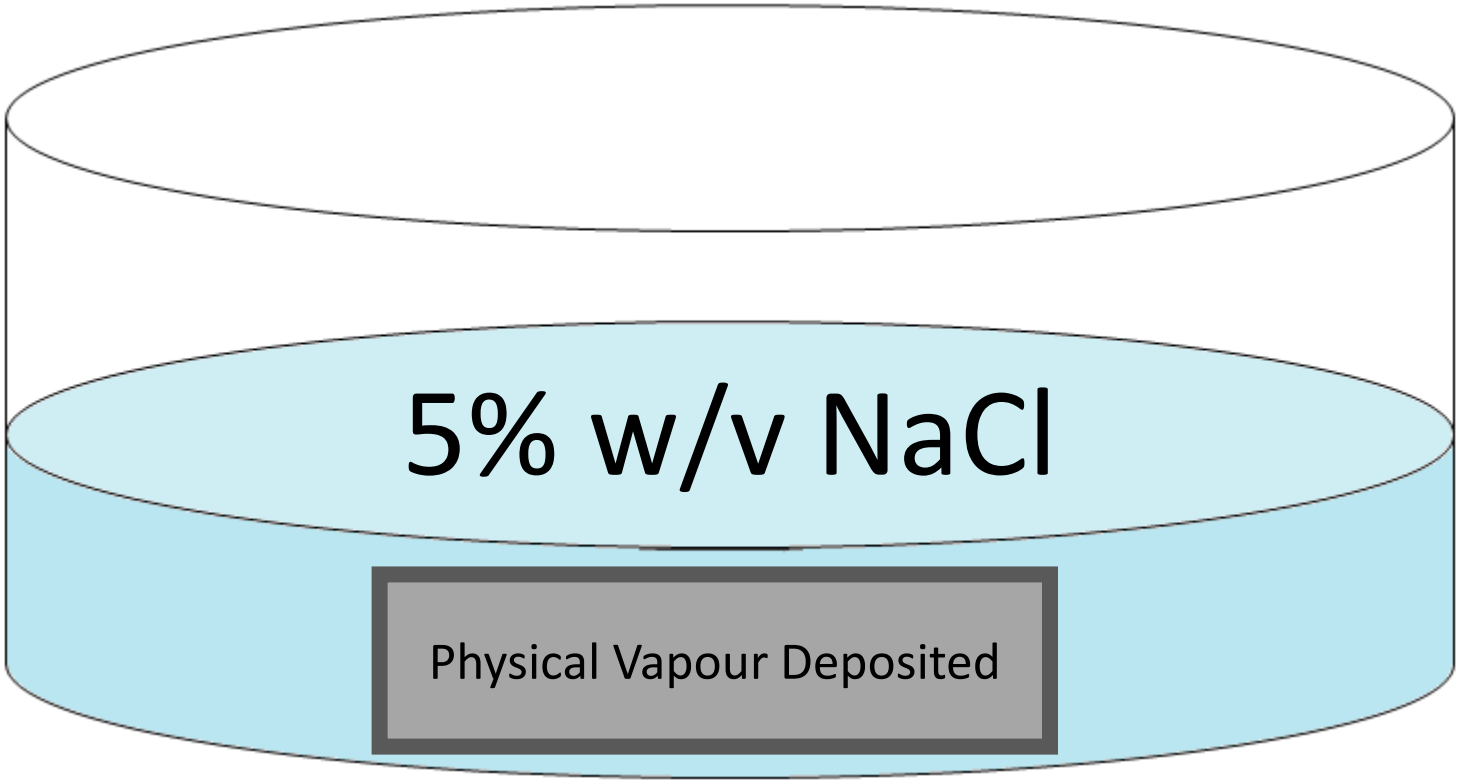
Results
1% NaCl

MATERIALS AND MANUFACTURING ACADEMY

- Physical Vapour Deposited Zinc



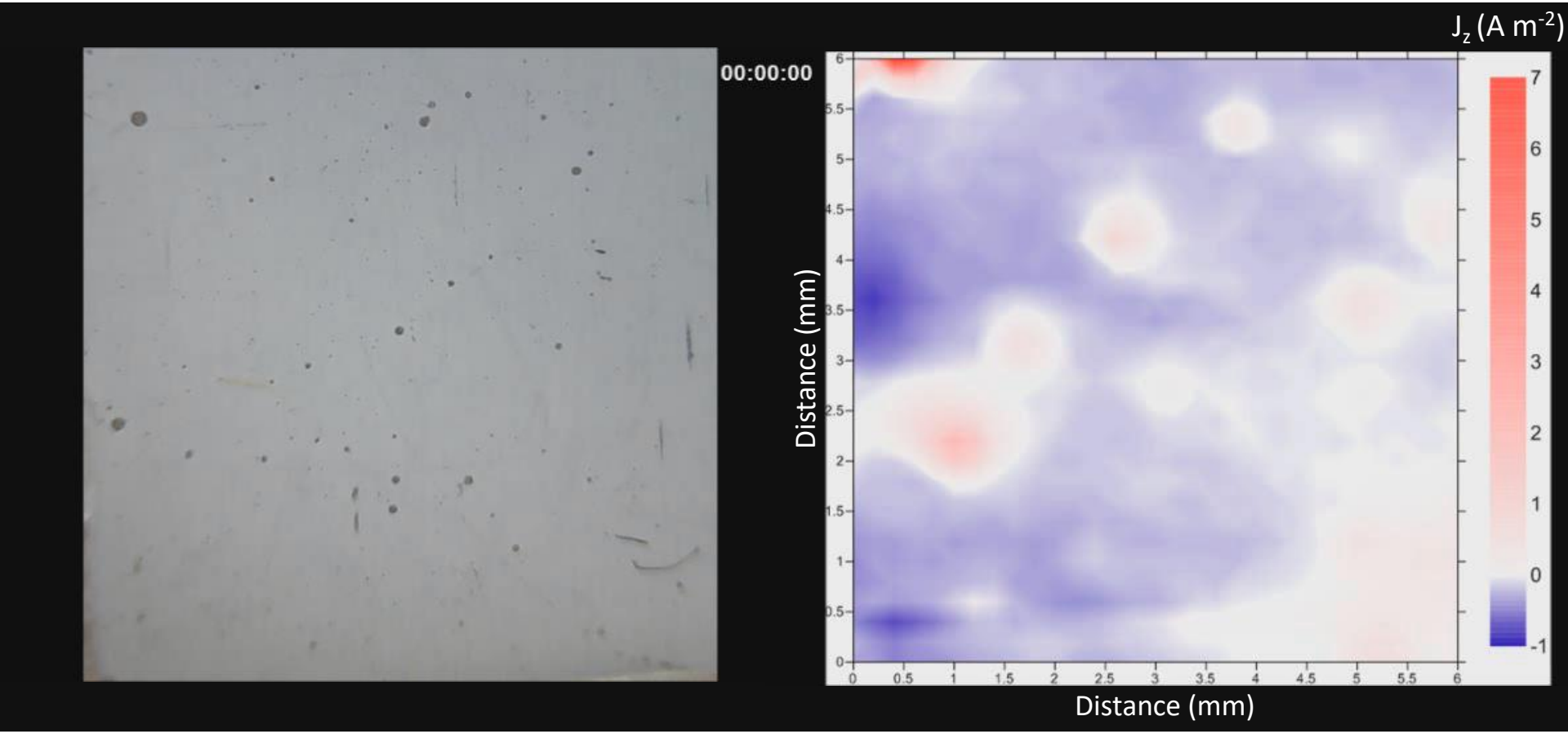
Results



Results
5% NaCl

MATERIALS AND MANUFACTURING ACADEMY

- Physical Vapour Deposited Zinc



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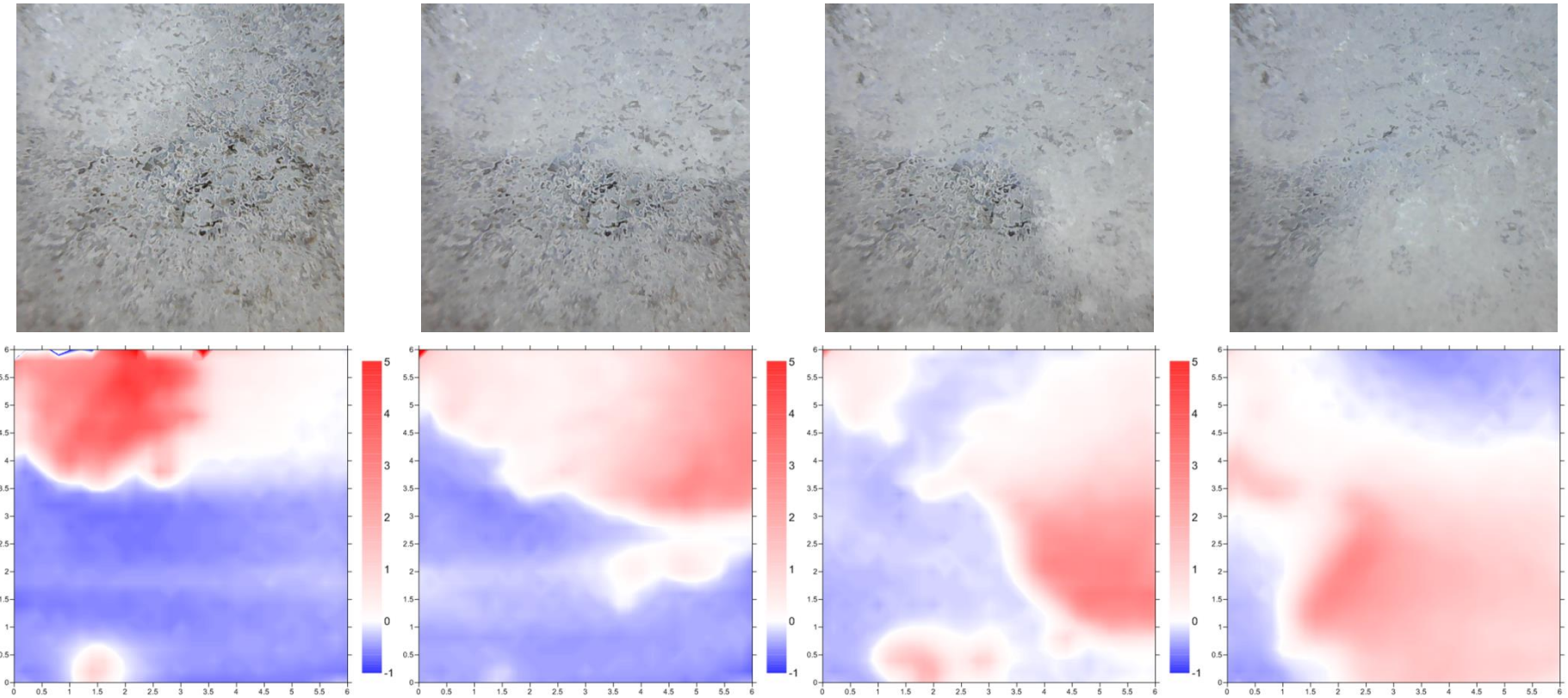
Conclusions

	Hot Dip Galvanised	Electrogalvanised	Physical Vapour Deposited
1% NaCl	• Approx. 30 total anodes • Rapid growth to a max size (600µm) • Growth restricted by corrosion product	• 150+ anodes • Rapid nucleation (200µm) and passivation followed by reactivation (600µm+) • Entire surface corroded	• Approx. 100 anodes • Rapid nucleation (400µm) followed by agglomeration • Entire surface corroded
5% NaCl	• One large anodic front • Corrosion product deposited in wake of the front • Anodic activity restricted by corrosion product	• One large anodic front • Corrosion product deposited either side and in wake of the front • Anodic activity restricted by corrosion product	• Three large, expanding anodes • Corrosion product deposited in wake of expansion • Fronts meet and cease anodic activity

Conclusions

- Photographic images display the visual effects of corrosion activity:

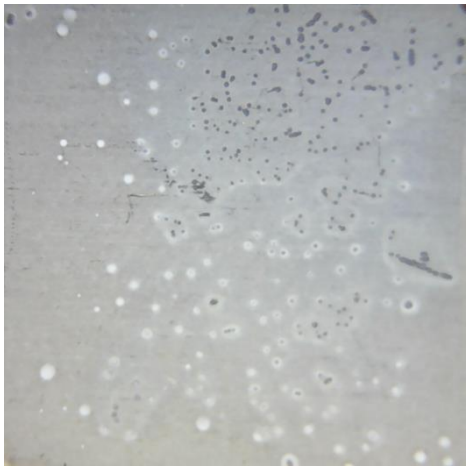


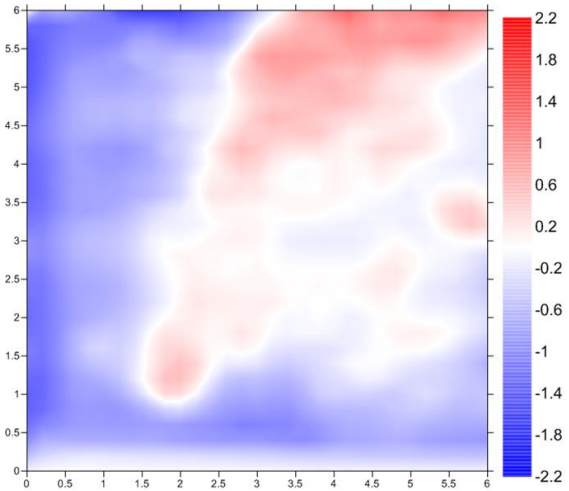
1 Hour | 2 Hours | 3 Hours | 4 Hours

HDG Zinc in 5% NaCl

Conclusions

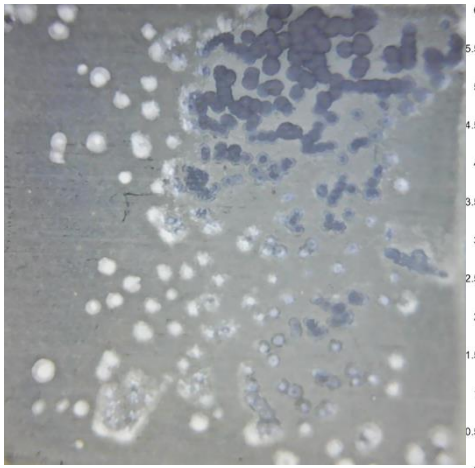
- Photographic images resolve areas of net activity in SVET maps

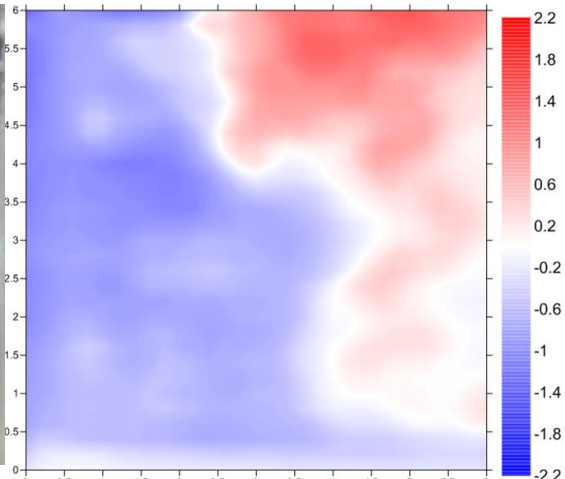




Electrogalvanised Zinc
1% w/v NaCl
At 1 hour

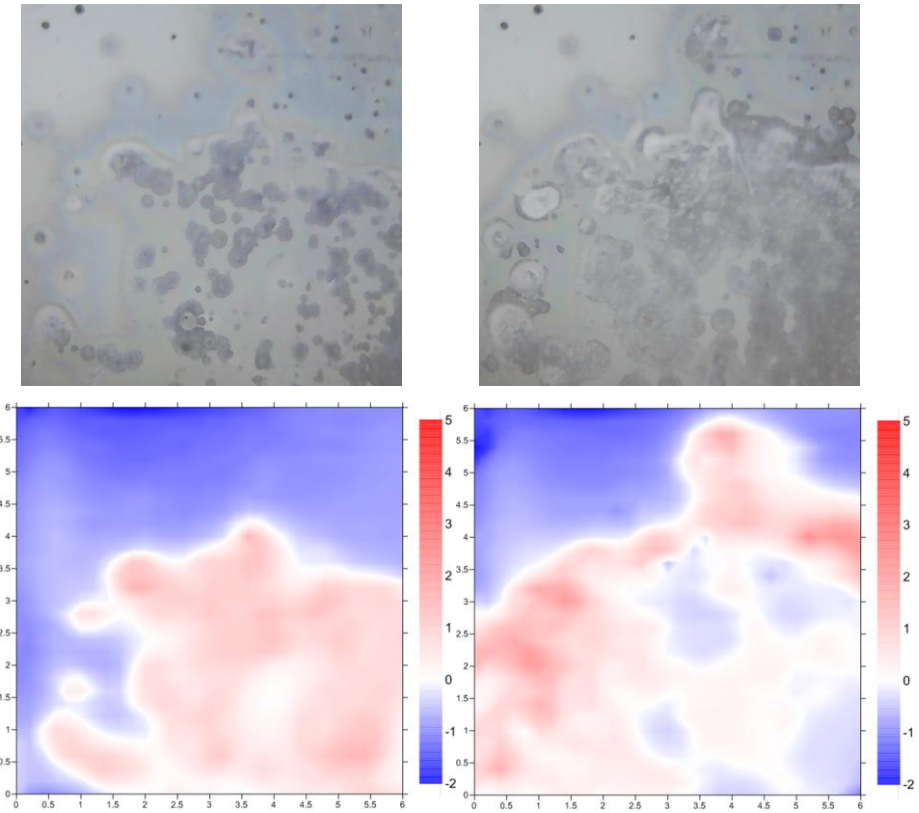
Electrogalvanised Zinc
1% w/v NaCl
At 8 hours



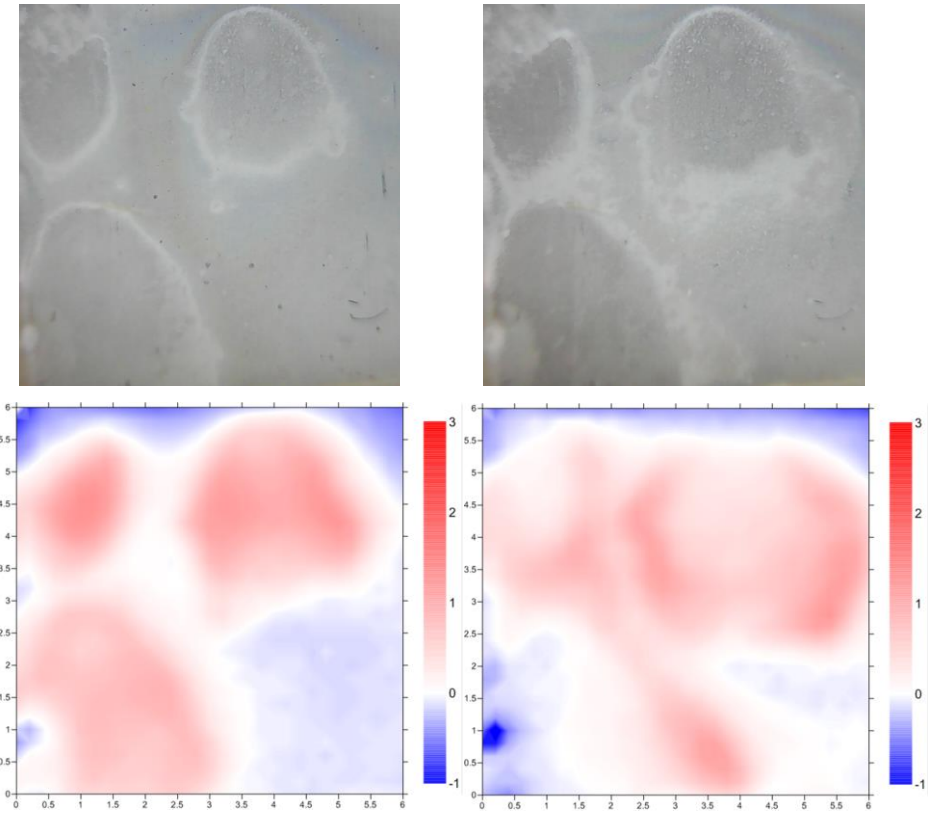


Conclusions

- Photographic images complement SVET data for comparative studies



PVD Zinc in 1% NaCl at 6hrs and 12hrs



PVD Zinc in 5% NaCl at 6hrs and 12hrs

Conclusions

- SVET map anodic and cathodic regions correlate with visual corrosion behaviour in photographs
- SVET-TLI is a useful technique to monitor both electrochemical and visual behaviour simultaneously and automatically
- Results show variation in corrosion mechanisms due to both the difference in coating production and electrolyte concentration

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Thank you for your attention

Any Questions?

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