Corrosion Mechanism of Zn-4.8wt.%Al Galvanising Metallic Coating; Surface and Cut-edge

Callum Gallagher BEng
Academic Supervisors: Prof. James H. Sullivan, Dr. David Penney
Industrial Supervisors: Dr. Peter Barker, Dr. Patrick Dodds

Introduction

MATERIALS AND MANUFACTURING ACADEMY

- Performing research at Swansea University in partnership with TATA Steel
- Elucidating the corrosion mechanism of Zn-4.8wt.%Al

Zn-4.8wt.%Al

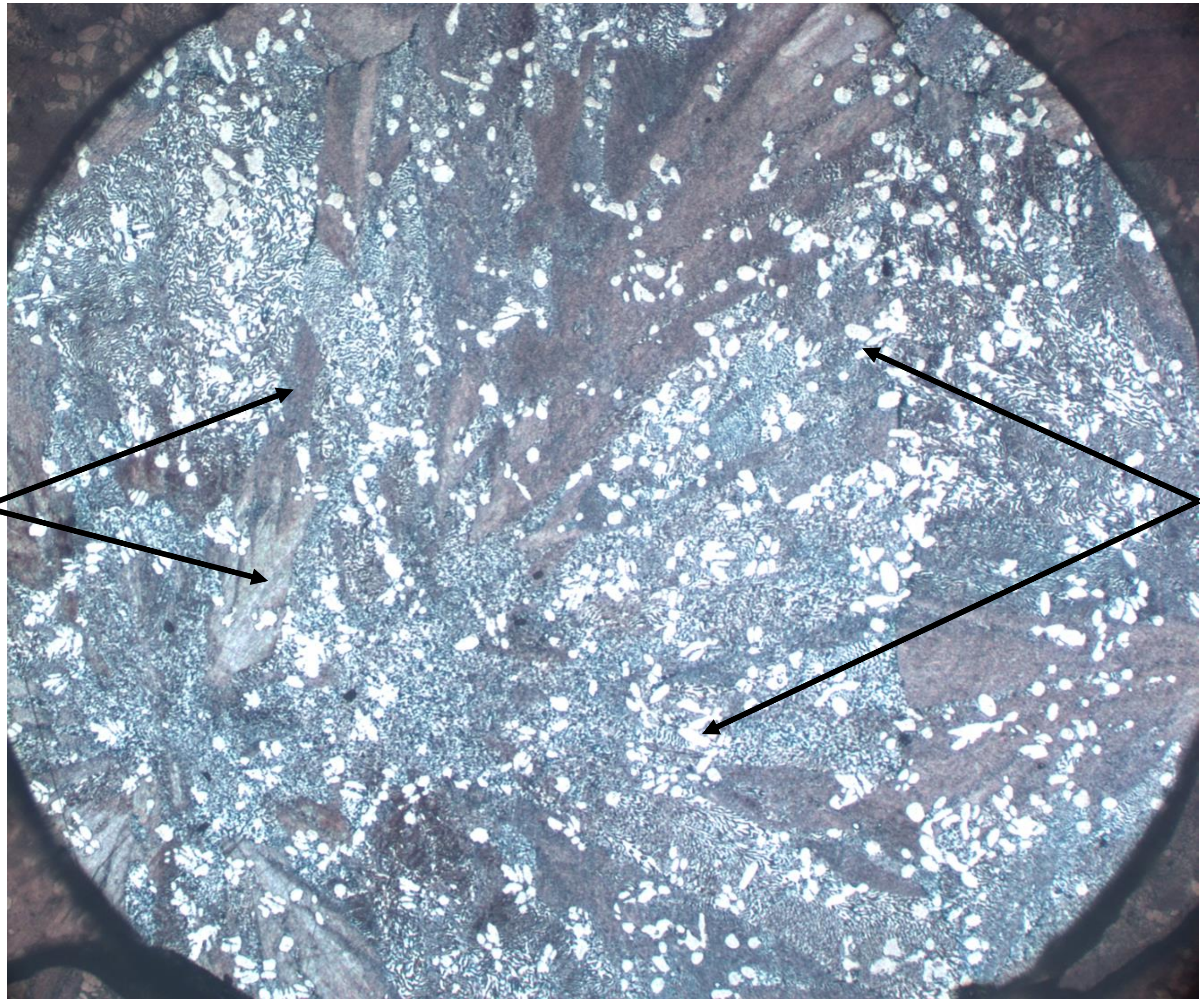
MATERIALS AND MANUFACTURING ACADEMY

- TATA Steel's premium building system product that goes by the name Galvalloy®
- 40 years warranty upheld by TATA due to confidence in the alloy's performance
- Allows a reduced coating weight whilst providing better corrosion performance in comparison to traditional hot dip galvanized steel

Microstructure

M2A
MATERIALS AND MANUFACTURING ACADEMY

Zn-Al
Binary
Lamella
Eutectic



Primary
Zn
Dendrites

Introduction

- Performing research at Swansea University in partnership with TATA Steel

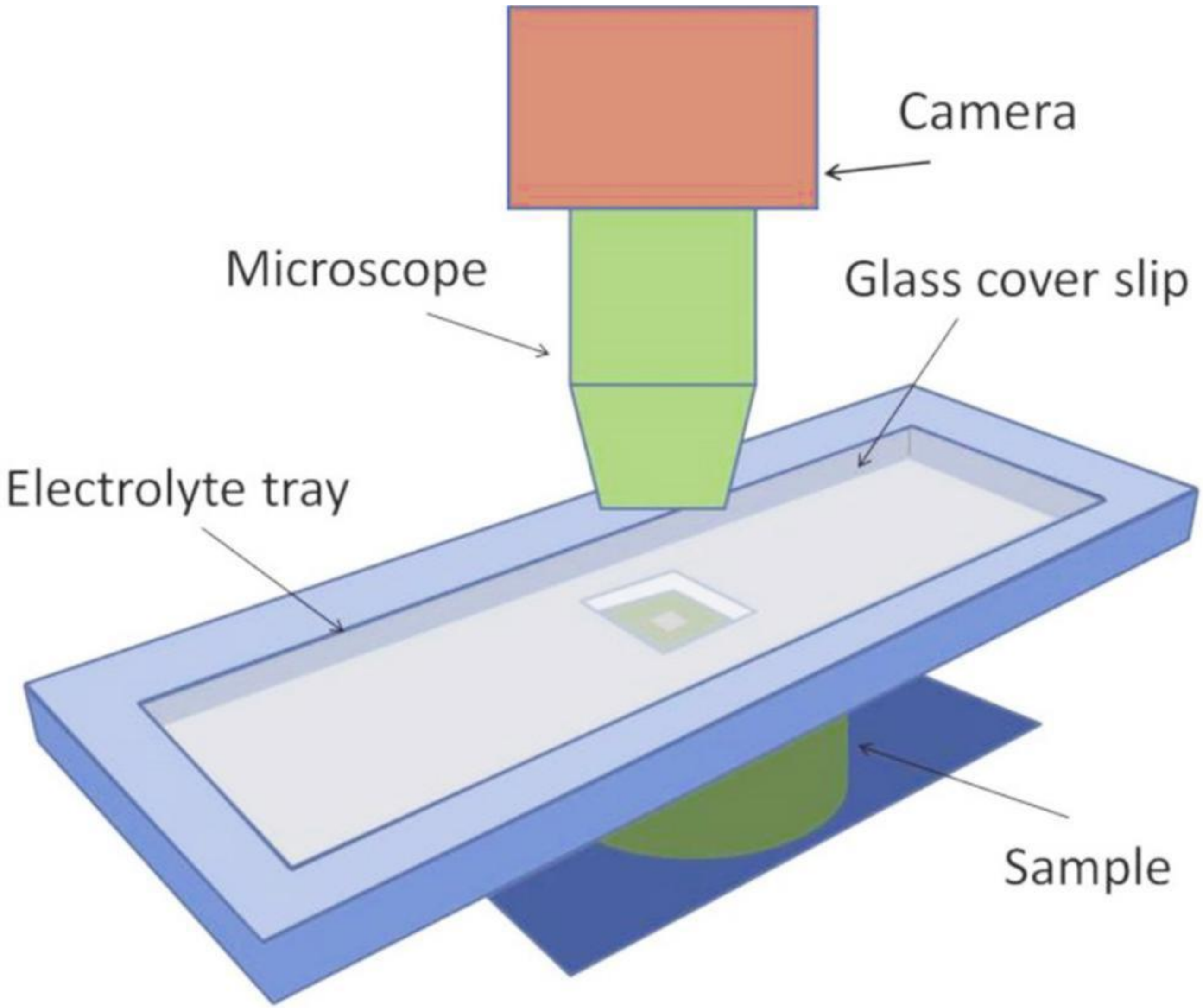
- Elucidating the corrosion mechanism of Zn-4.8wt.%Al

- Using a combination of novel and electrochemical techniques:
    - Time-lapse microscopy
    - OCP (Open Circuit Potential), Potentiodynamic and RDE (Rotating Disc Electrode)

Development of Technique

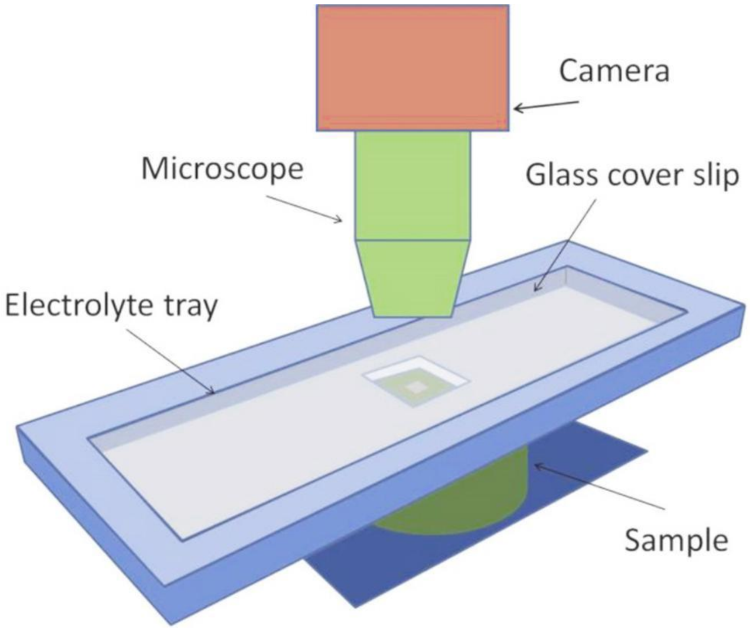
- The initial technique was a trial and basic

Development of Technique

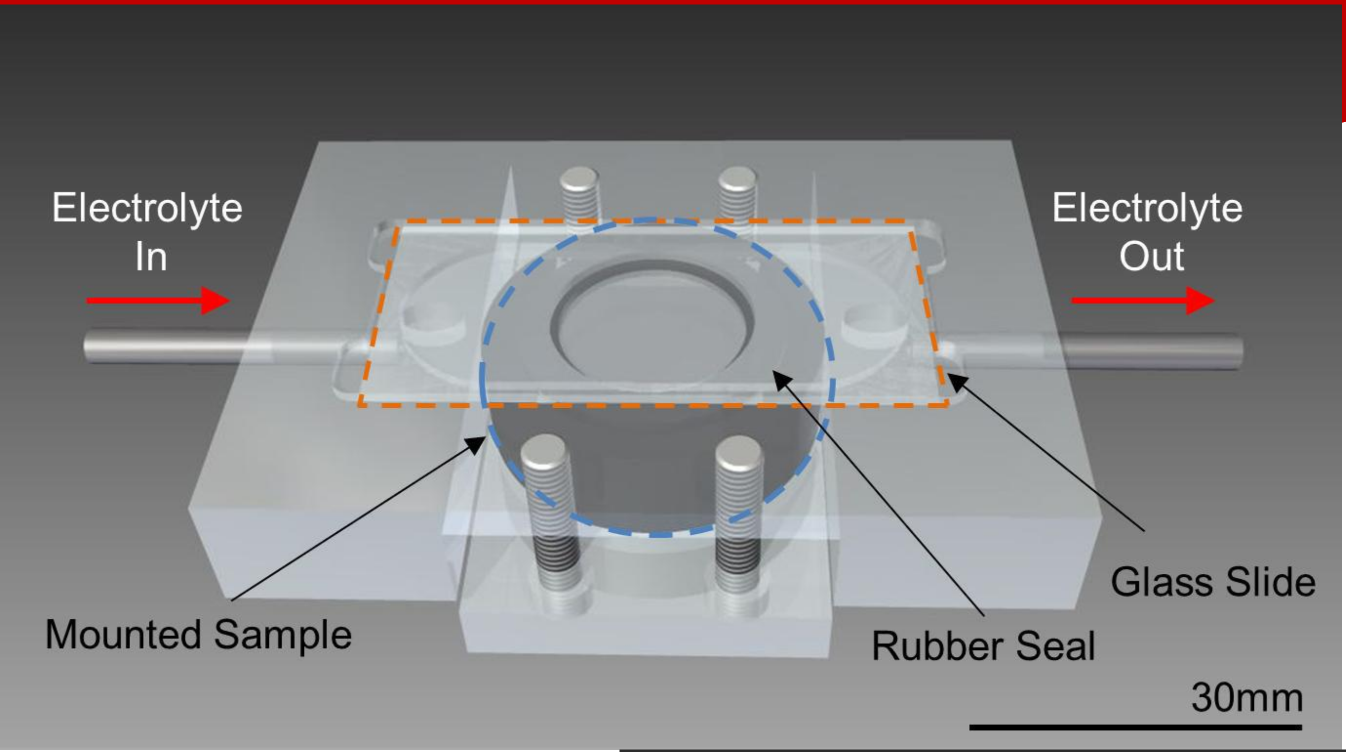


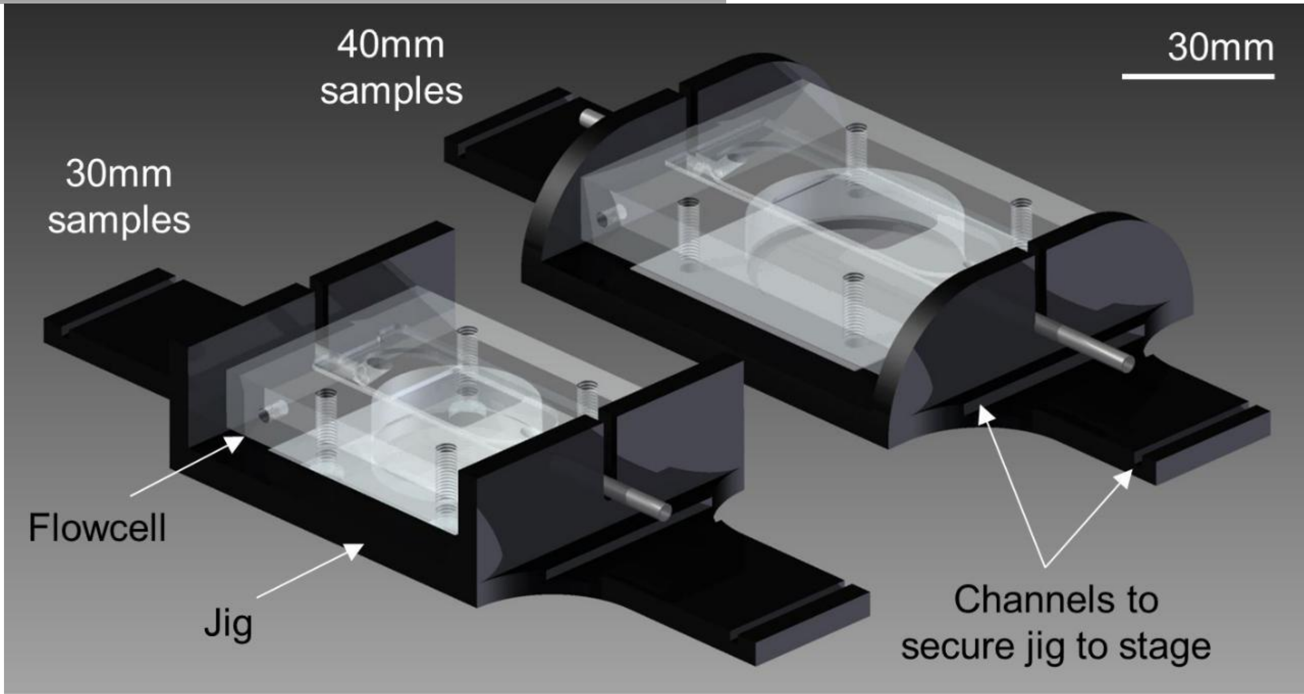
Development of Technique

- The initial technique was a trial and basic
- The second design was more robust



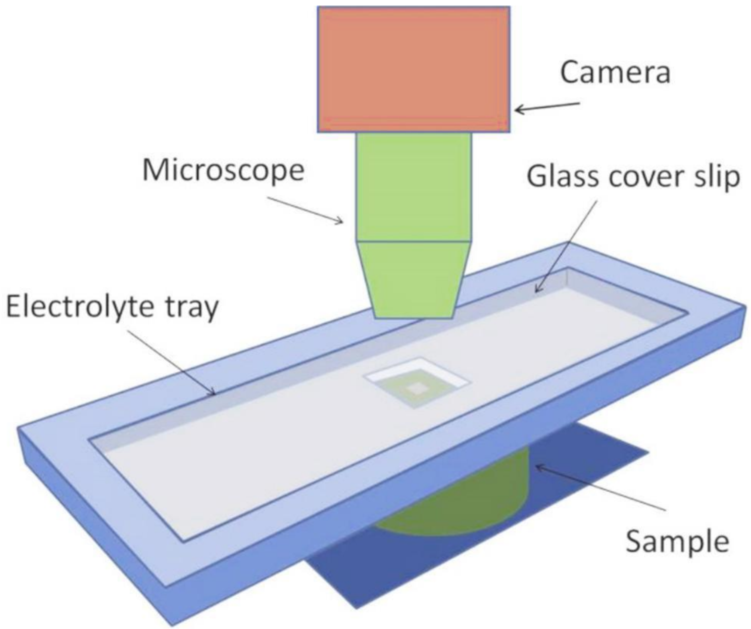
M2A
MATERIALS AND MANUFACTURING ACADEMY

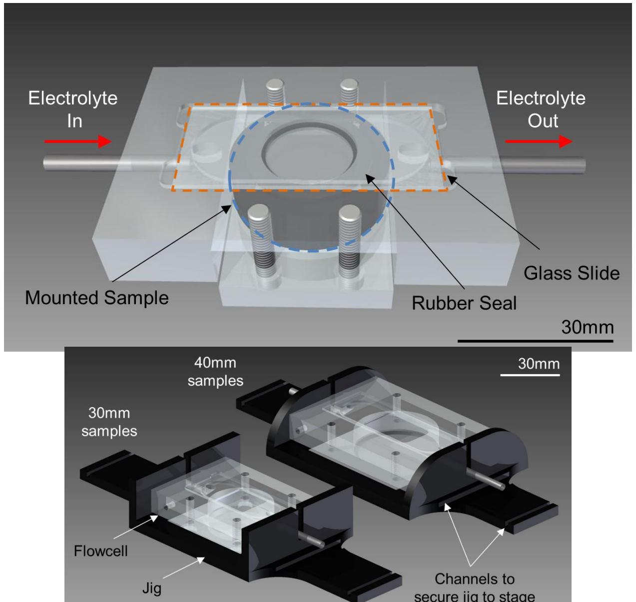




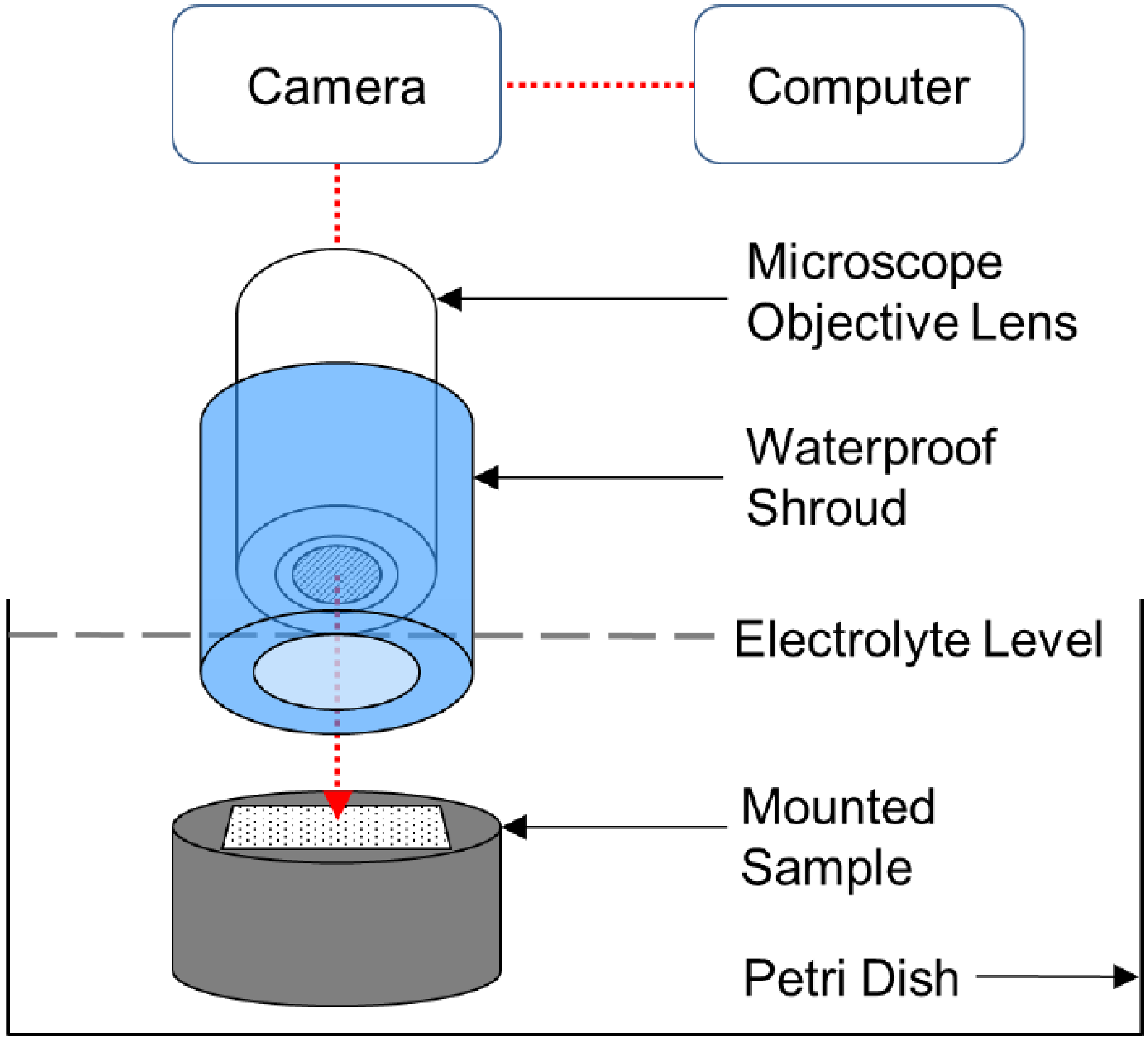
Development of Technique

- The initial technique was a trial and basic
- The second design was more robust
- The third design was simple, required less components, solved some issues, but still has one



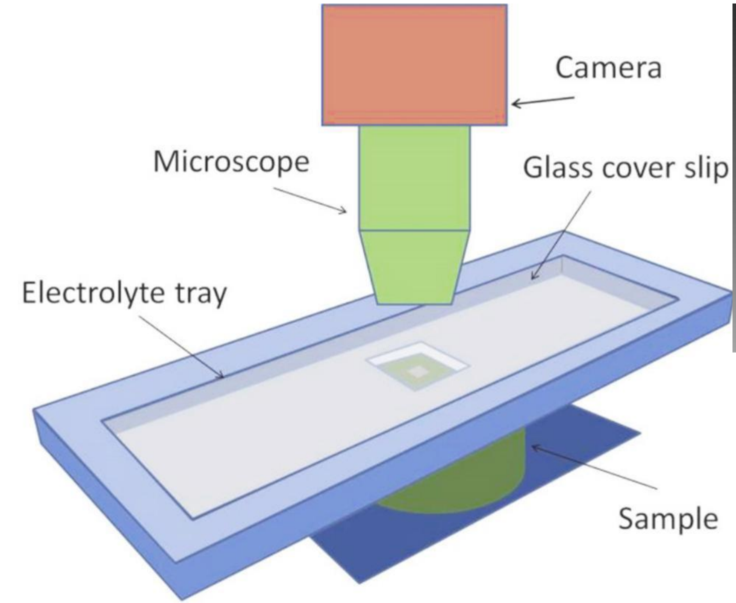


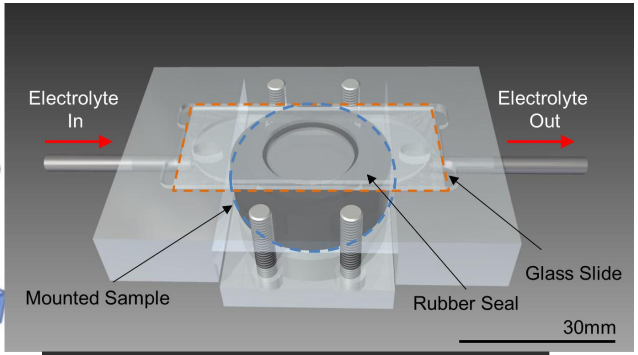
Development of Technique

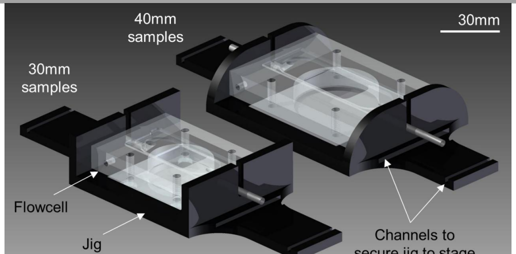


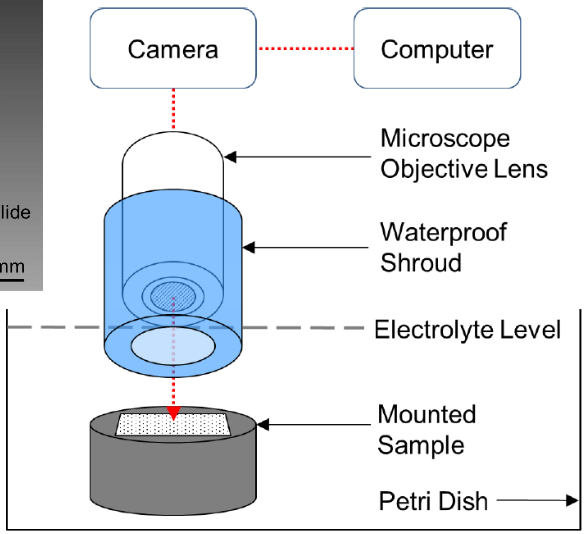
Development of Technique

- The initial technique was a trial and basic
- The second design was more robust
- The third design was simple, required less components, solved some issues, but still has one









Experimental Procedure

- Zn-4.8wt.%Al samples were metallurgically prepared to a 1 micron finish and etched using 3% Nital

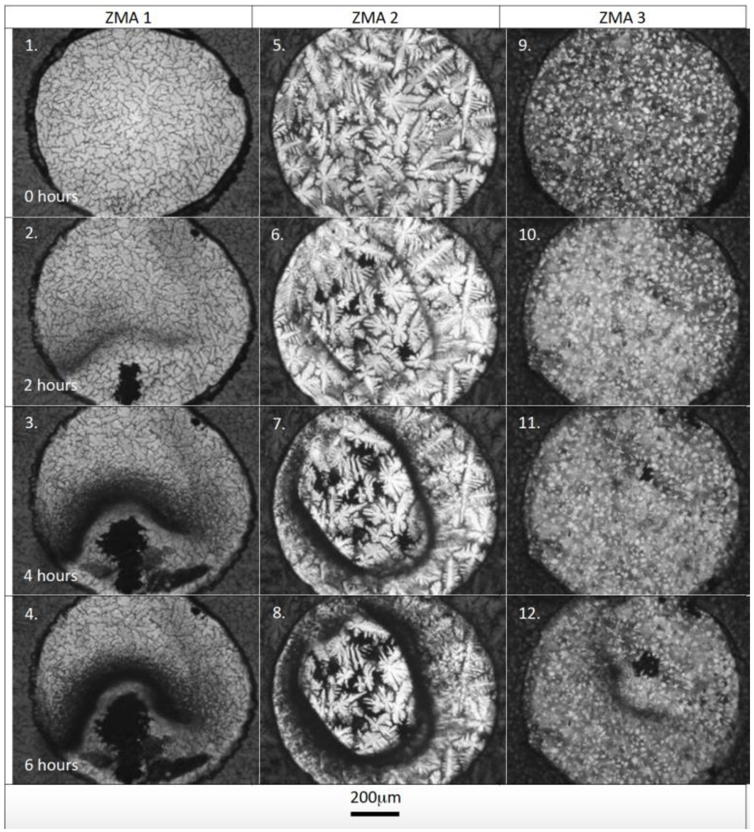
- Cut-edge samples were submerged in HCl to strip the metallic coating to reveal the substrate

- The samples were immersed in 1wt.% NaCl pH 7

- Computer software captured images every 2 minutes

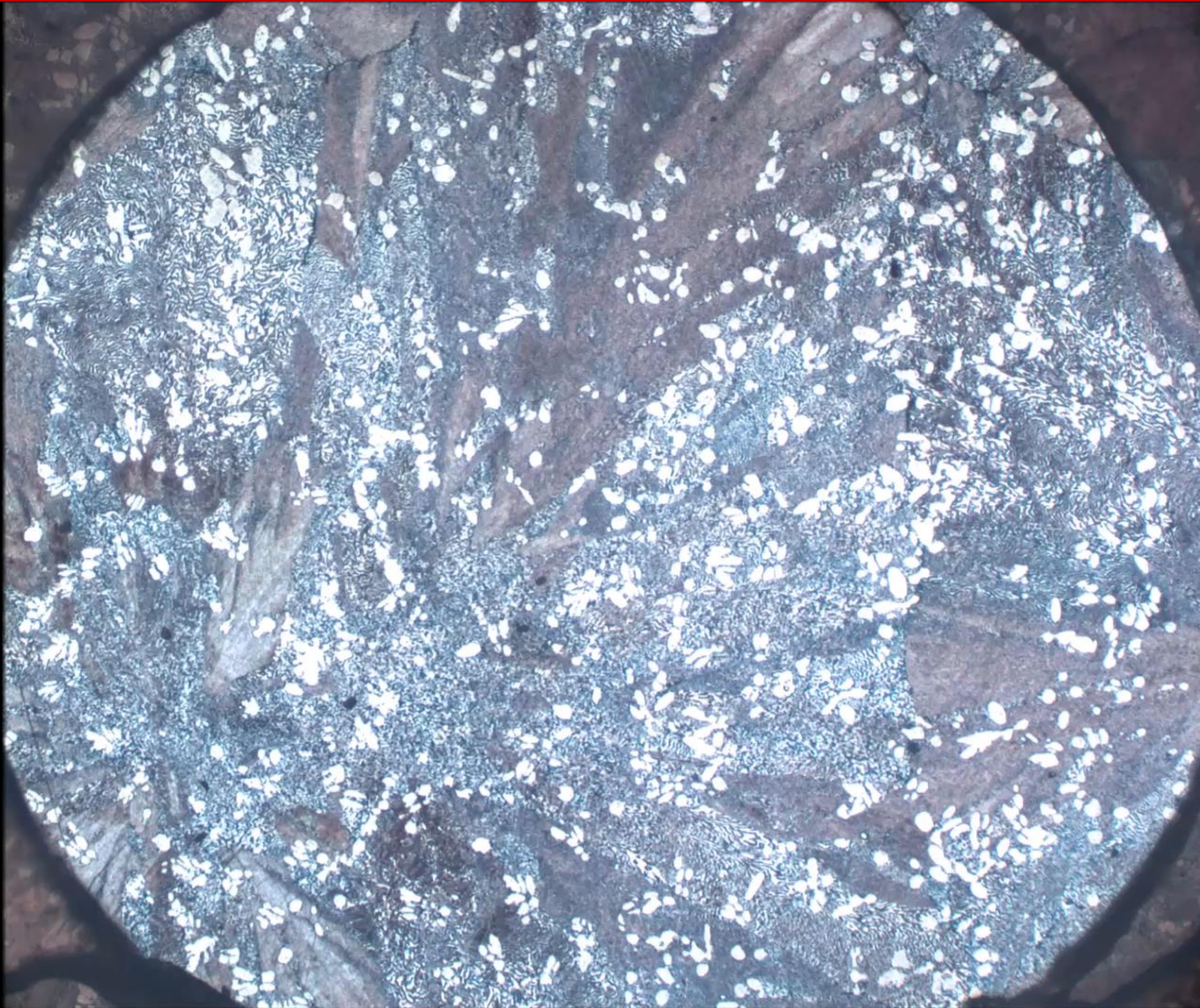
Previous Time-Lapse Work MagiZinc

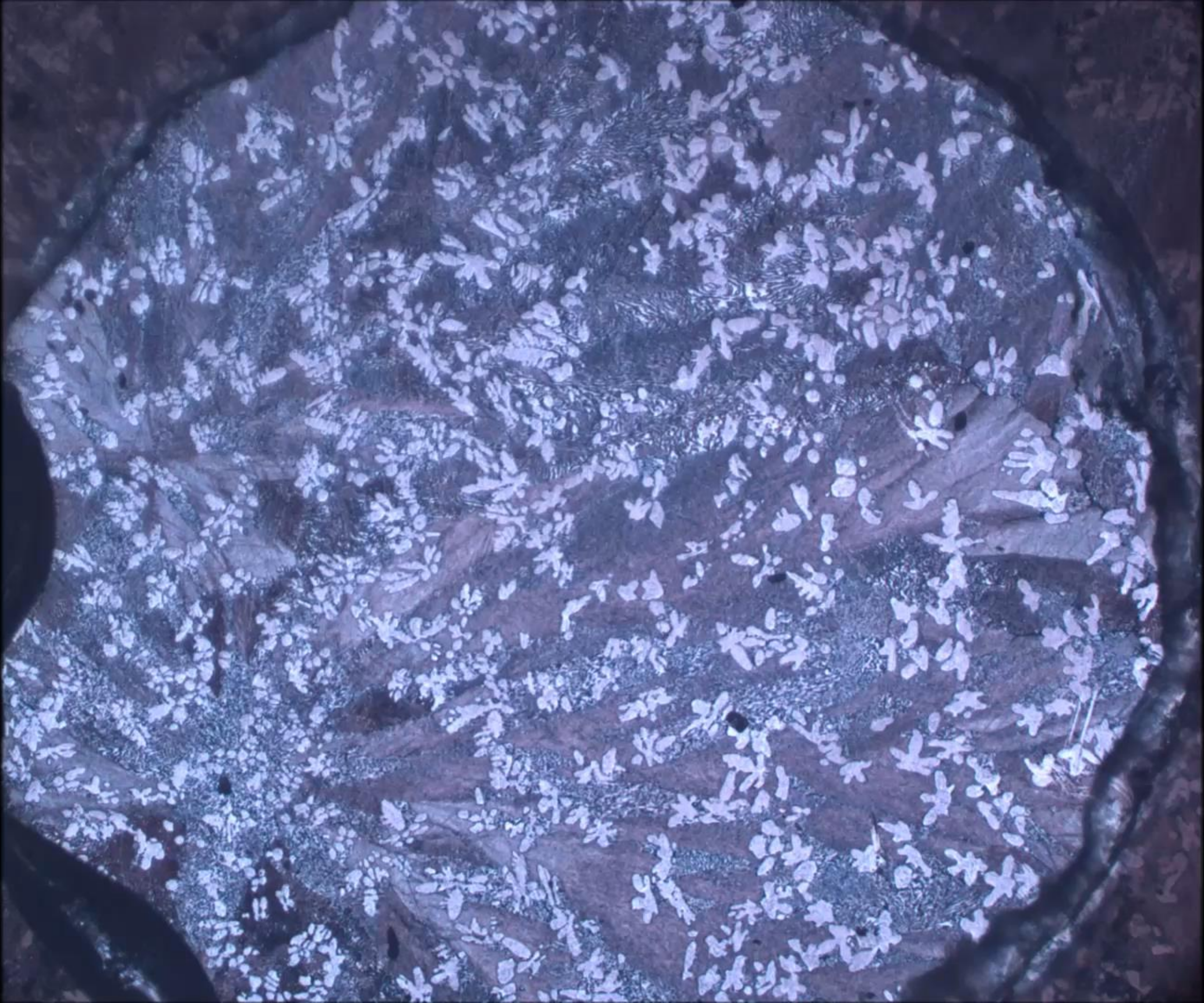
MATERIALS AND MANUFACTURING ACADEMY

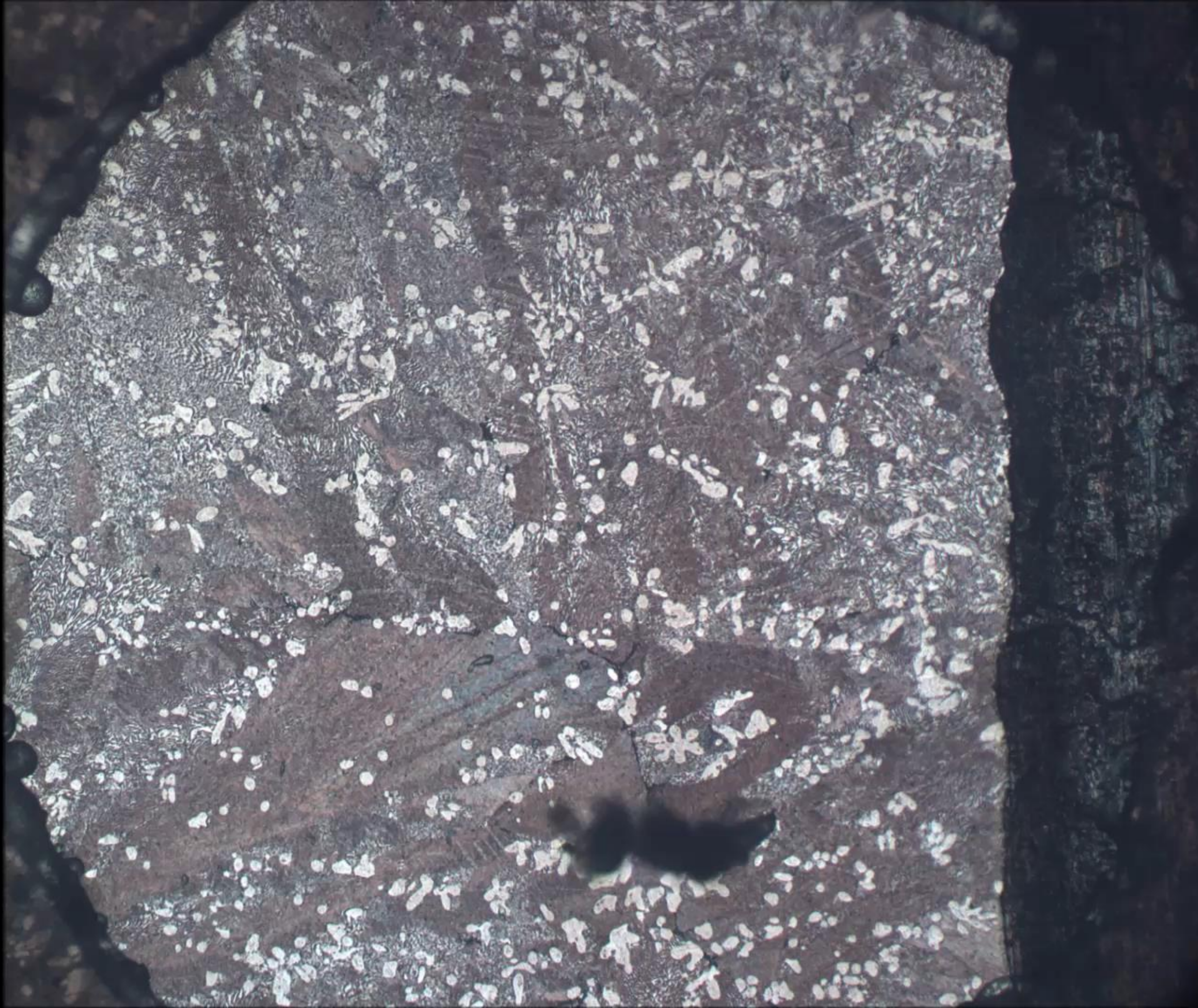


In-situ monitoring of corrosion mechanisms and phosphate inhibitor surface deposition during corrosion of Zinc Magnesium Aluminium (ZMA) alloys using novel time-lapse microscopy.

James Sullivana, Nathan Coozea, Callum Gallaghera, Tom Lewisa, Tomas Prosekb, Dominique Thierryb a College of Engineering, Swansea University, Singleton Park, Swansea SA2 8PP
b Instituit de la corrosion, 220 Rue Pierre Rivoalon, 29200 Brest, France







Summary of Videos

- Videos of the time-lapse, showing the corrosion of Galvalloy surface samples initiating corrosion in the binary eutectic lamellar phase (Zn-Al)

- Videos of the time-lapse with a ‘cut-edge’ effect showing corrosion initiating in the primary Zinc dendritic phase and within the nodule boundary

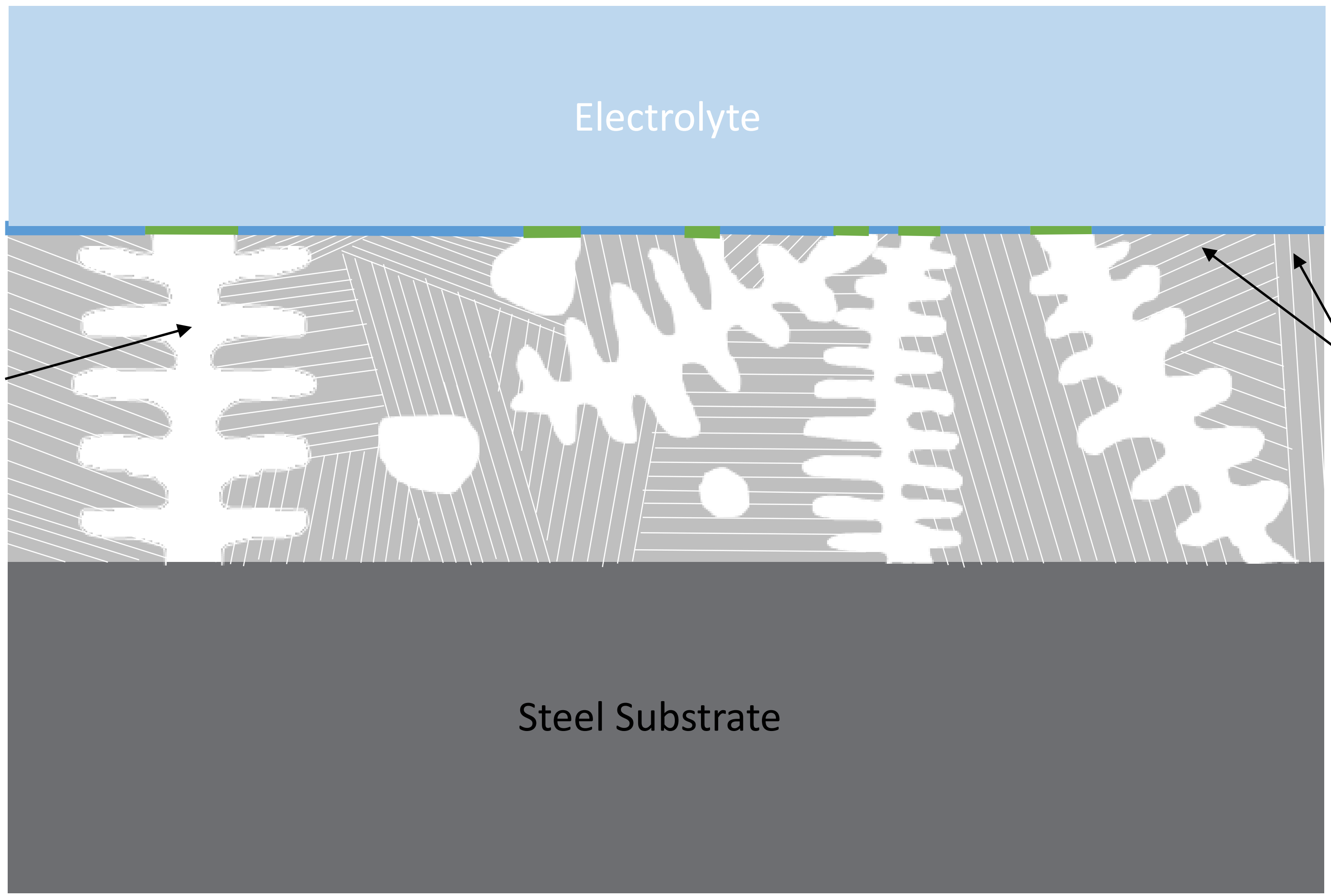
Mechanism

- During surface corrosion, the corrosion initiates in the binary eutectic:
  - Alumina patina (insulator) → Binary eutectic
  - Zinc oxide (semi conductor) → Primary Zinc dendrites
  - The primary zinc dendrites will act as a site of cathodic activity driving the anodic dissolution of the binary eutectic

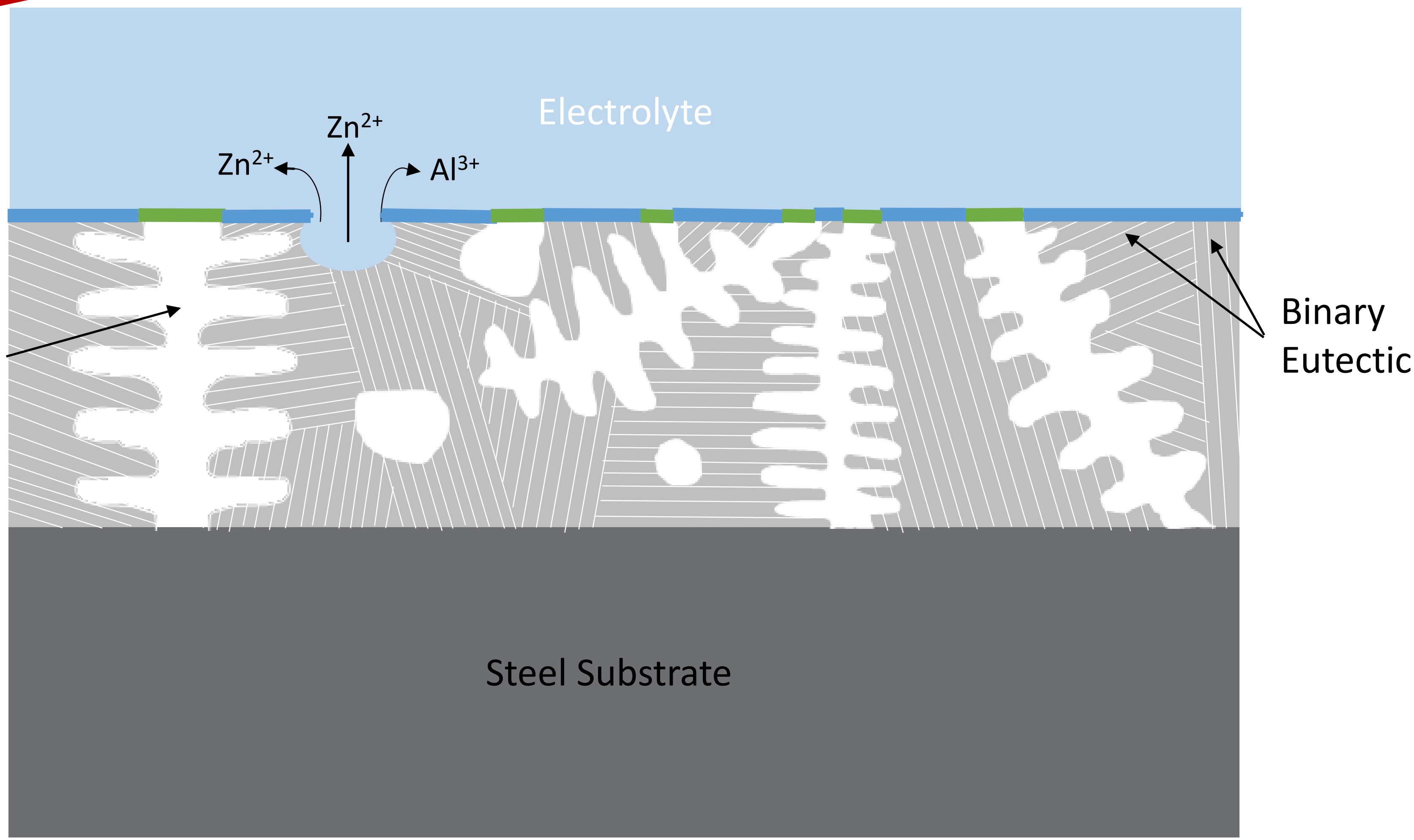
- During cut edge corrosion, the steel, a strong cathode, replaces the dendrites as the cathodic site and drives the corrosion throughout the alloy.
  - The dendrites appear to be preferentially attacked

Galvalloy Surface

M2A
MATERIALS AND MANUFACTURING ACADEMY



Galvalloy Surface

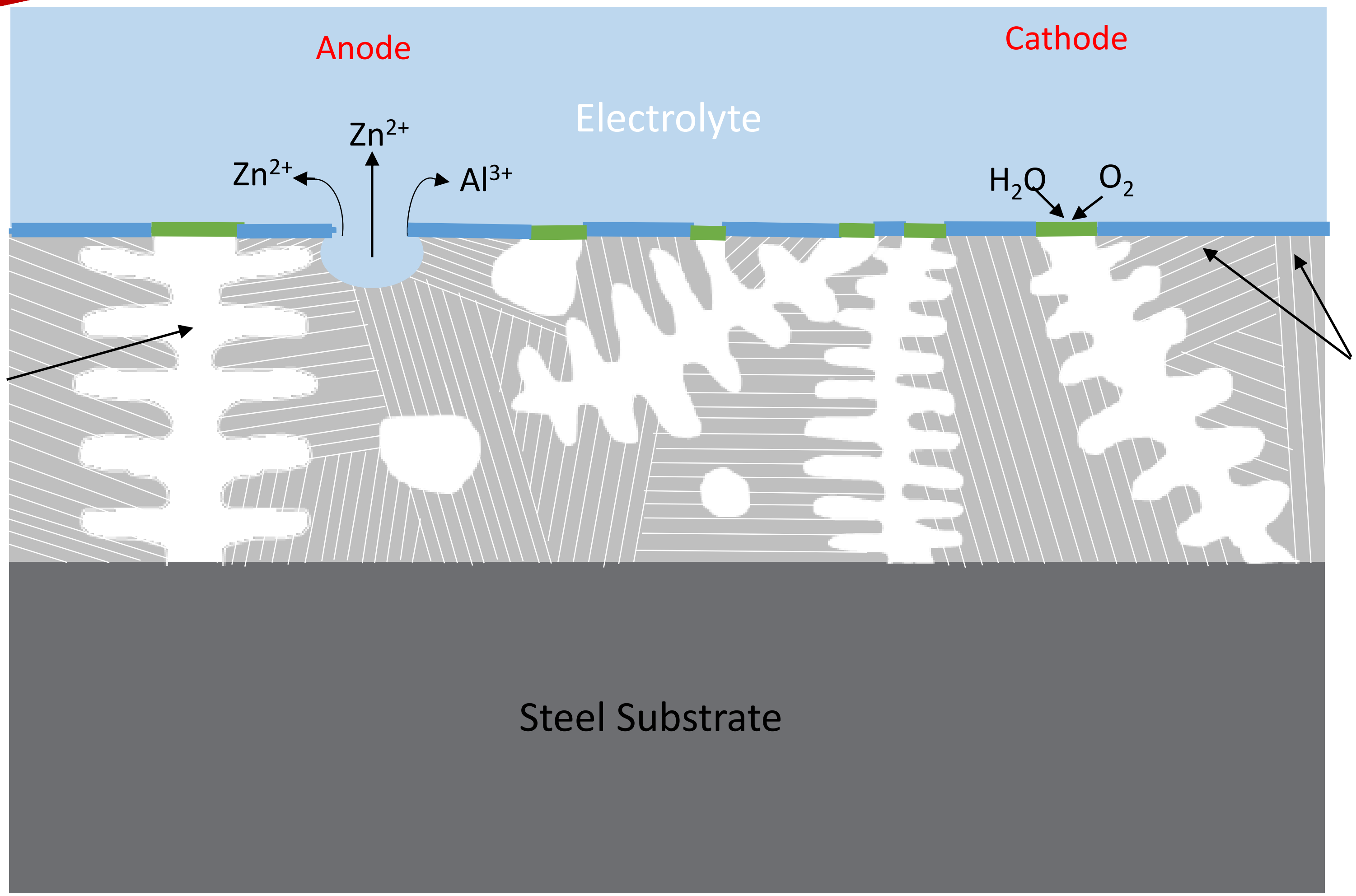


Zinc Oxide

Aluminium Oxide

Galvalloy Surface

MATERIALS AND MANUFACTURING ACADEMY



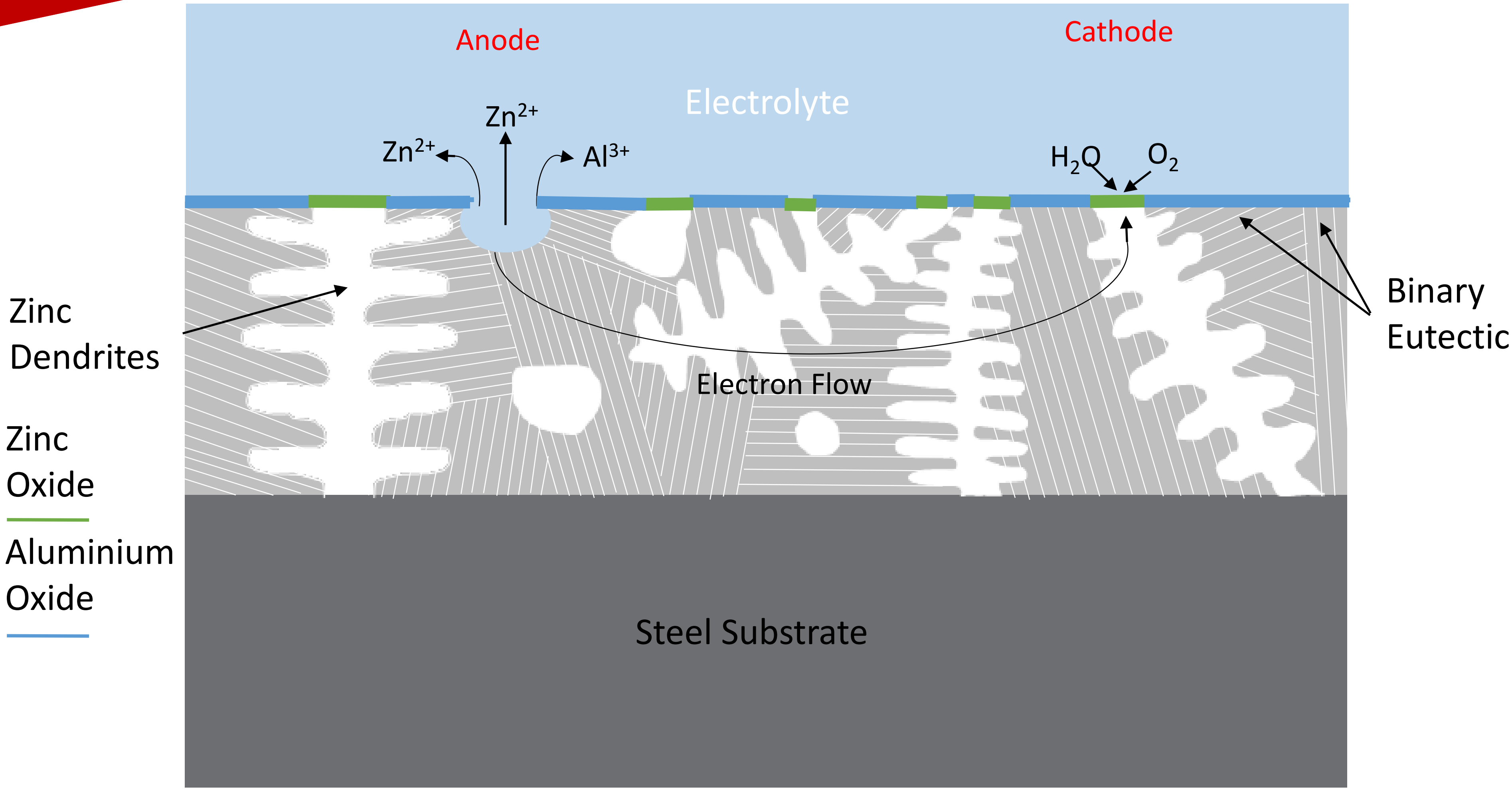
Zinc Dendrites

Zinc Oxide

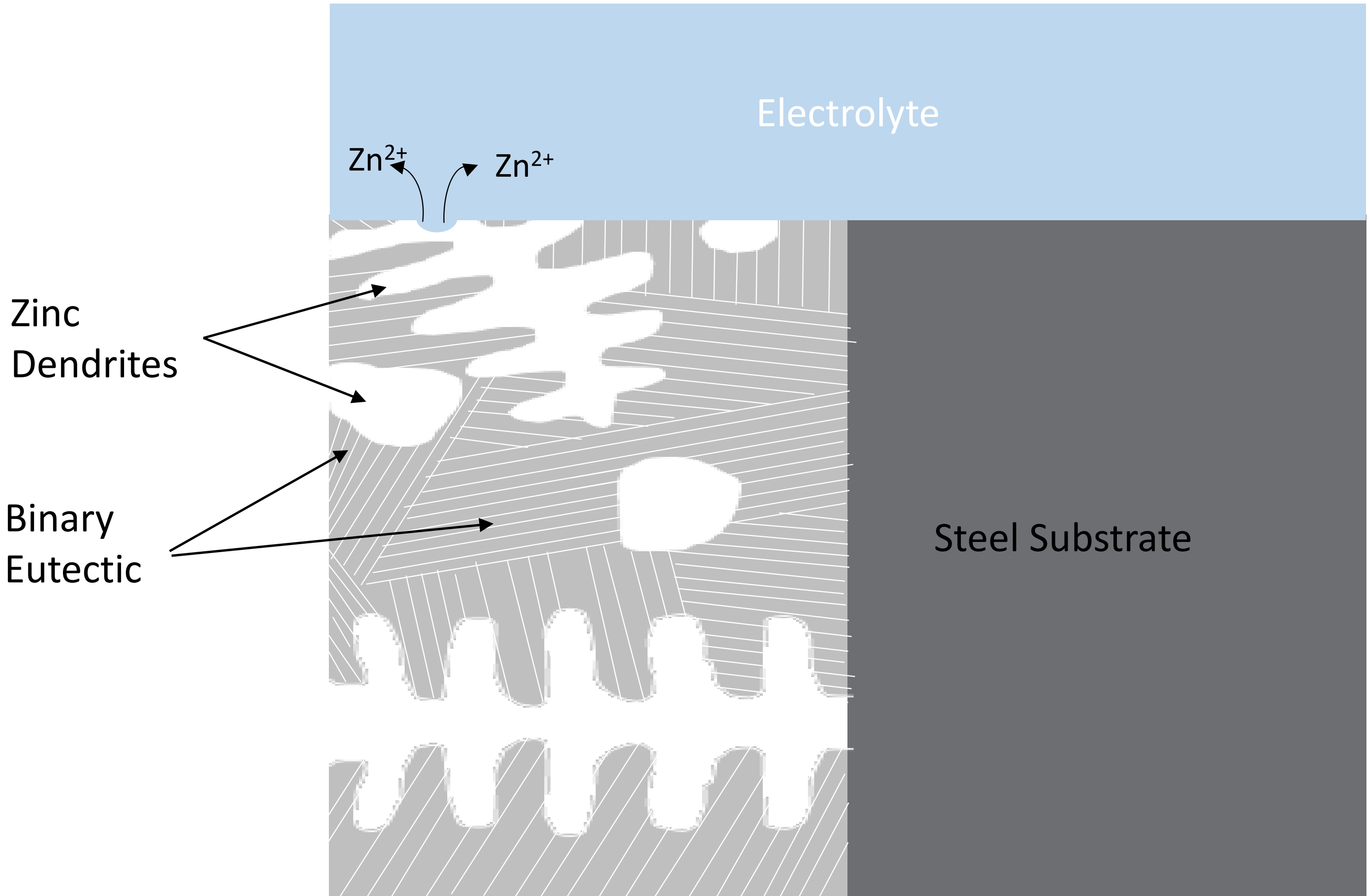
Aluminium Oxide

Binary Eutectic

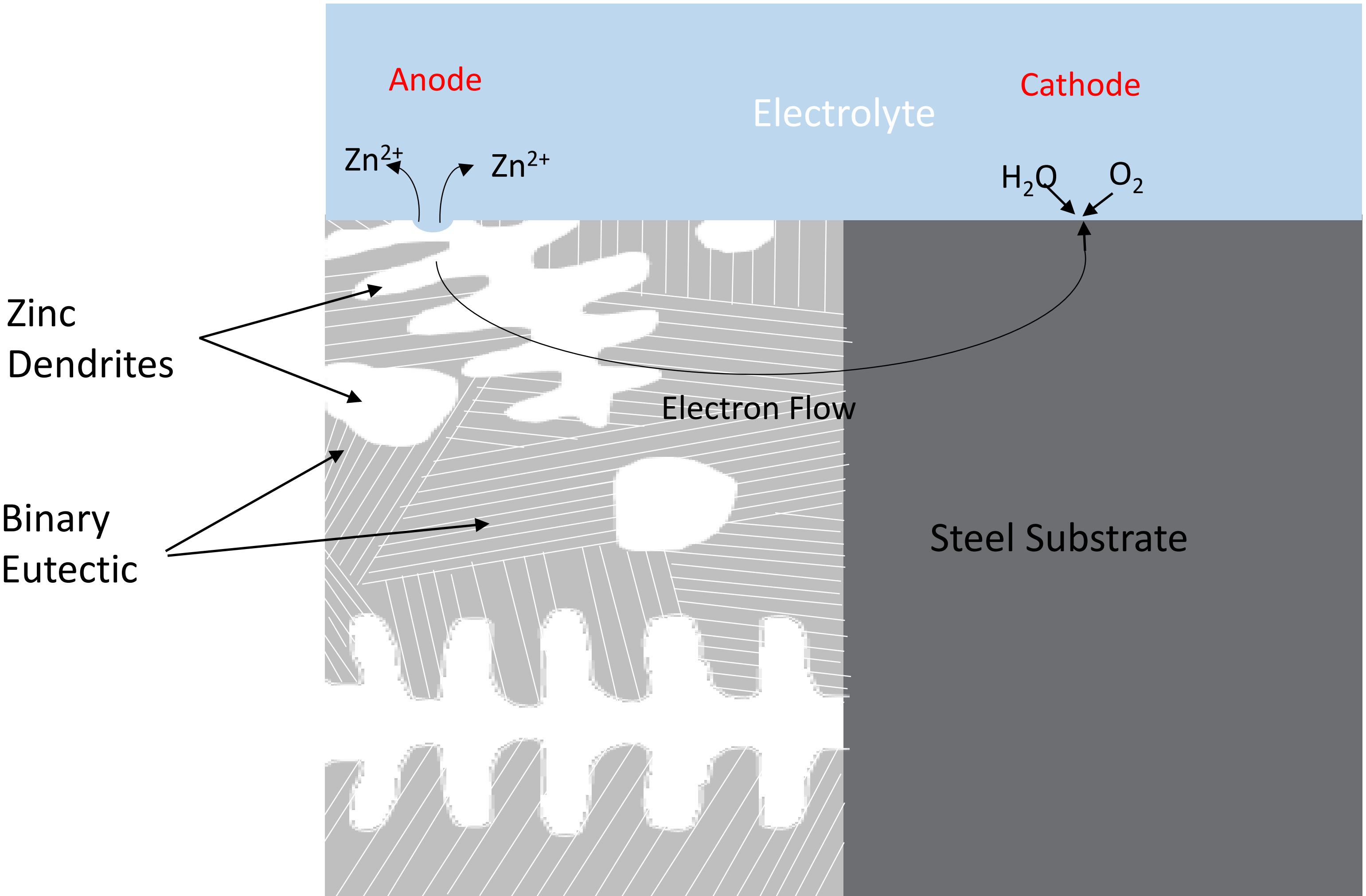
Galvalloy Surface

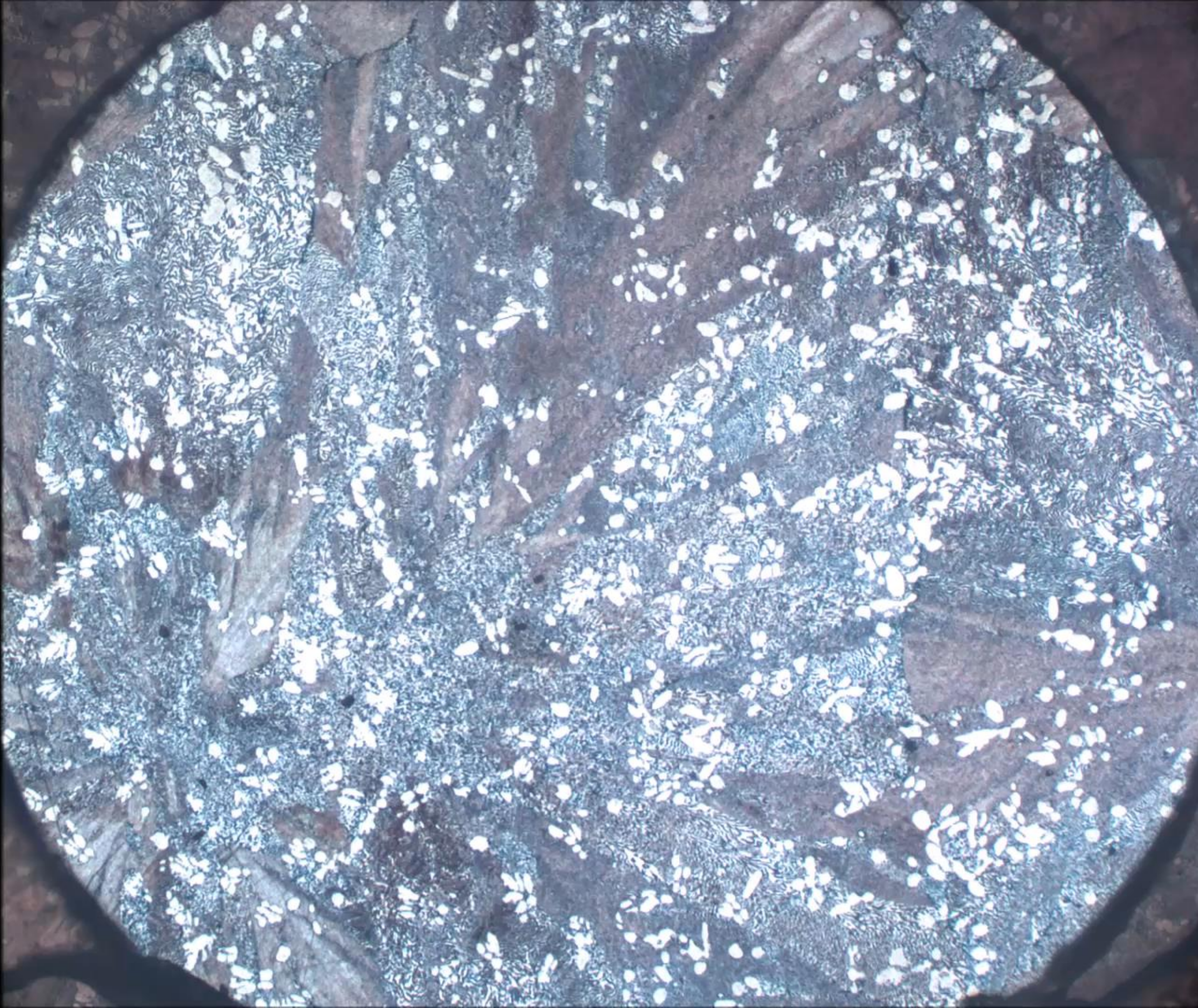


Galvalloy Cut-Edge

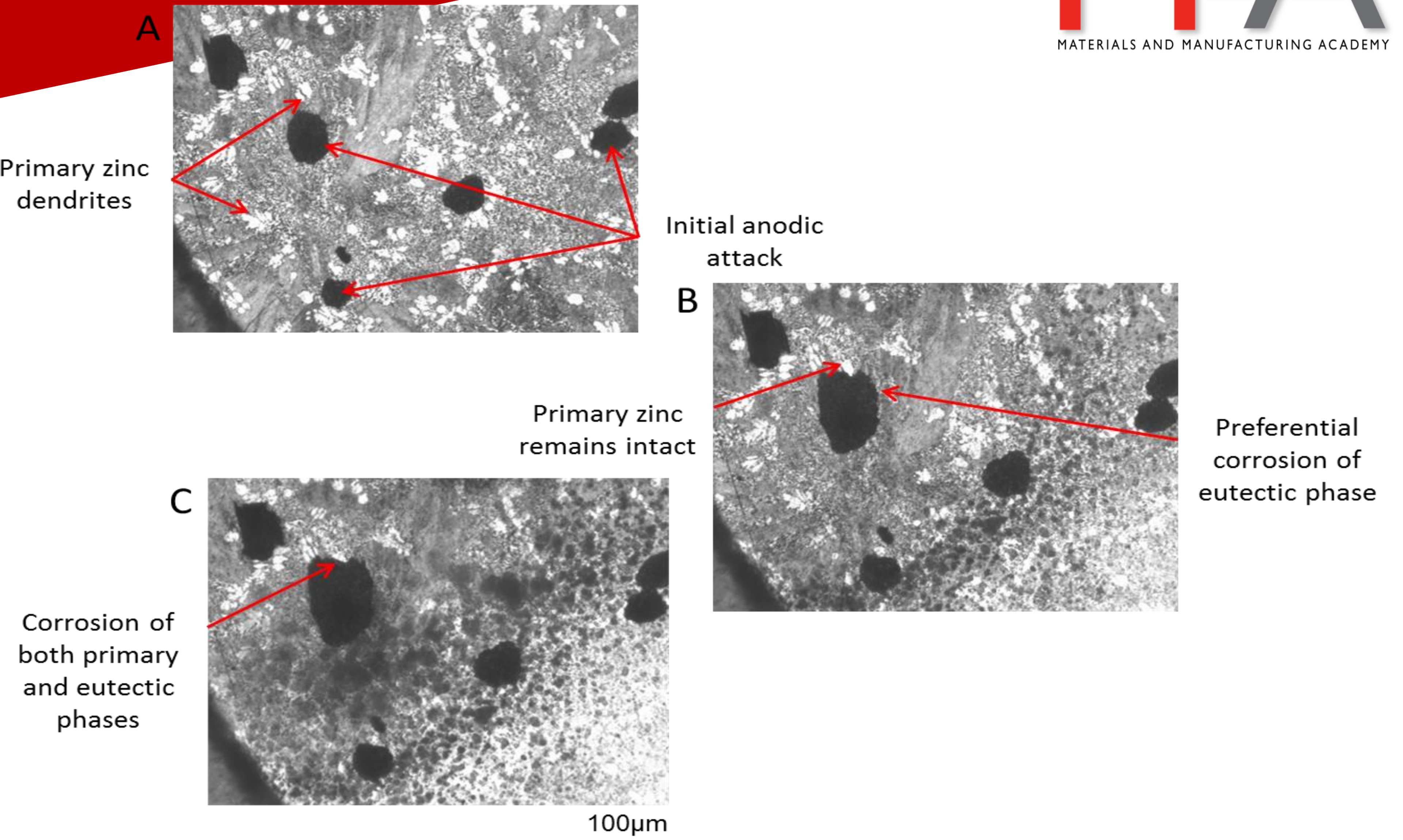


Galvalloy Cut-Edge





Summary of Video



SEM Imaging

MATERIALS AND MANUFACTURING ACADEMY

Aims

To find out:

- If etching has an effect on the mechanism
- Which regions are the initiation site for corrosion

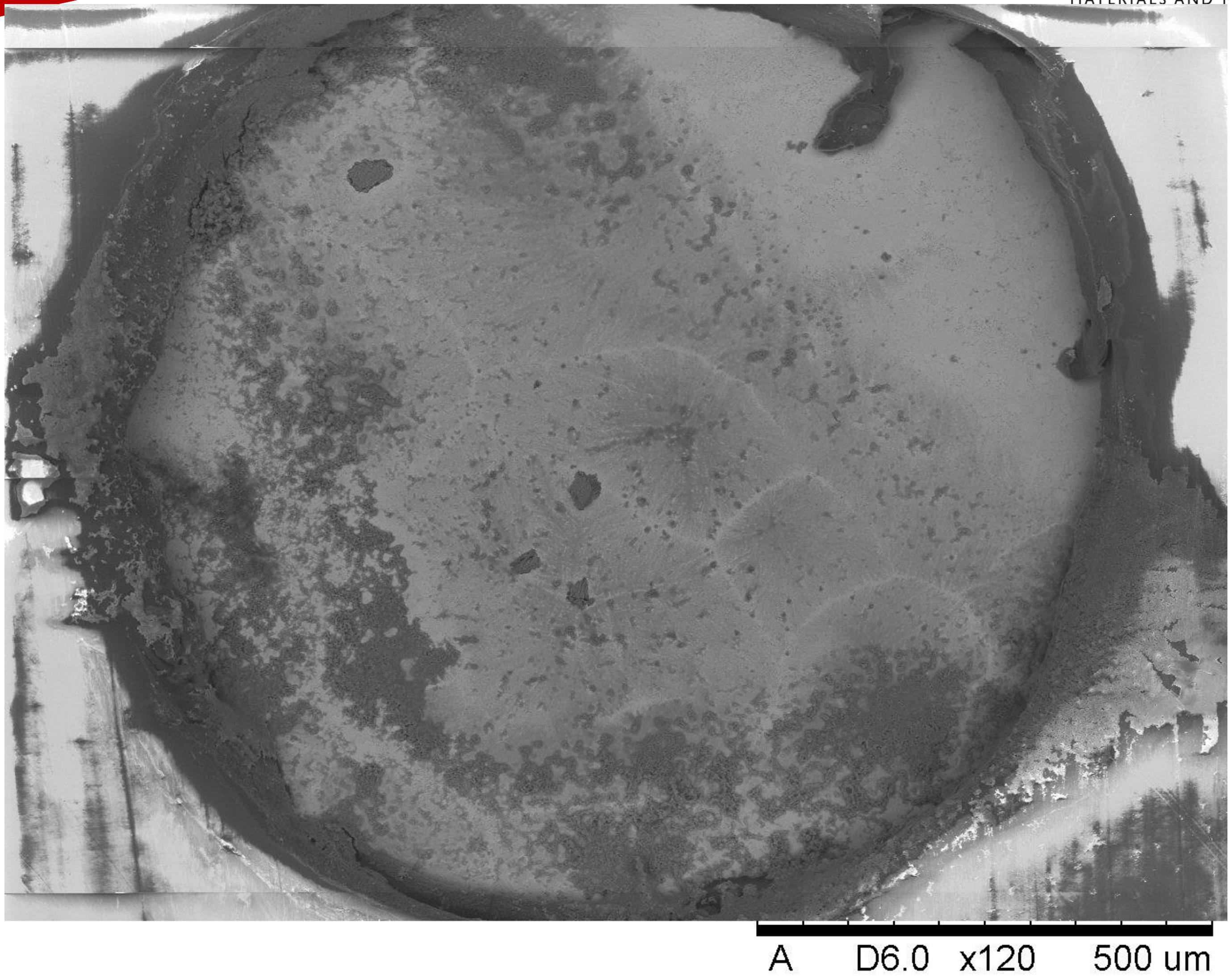
Requirements

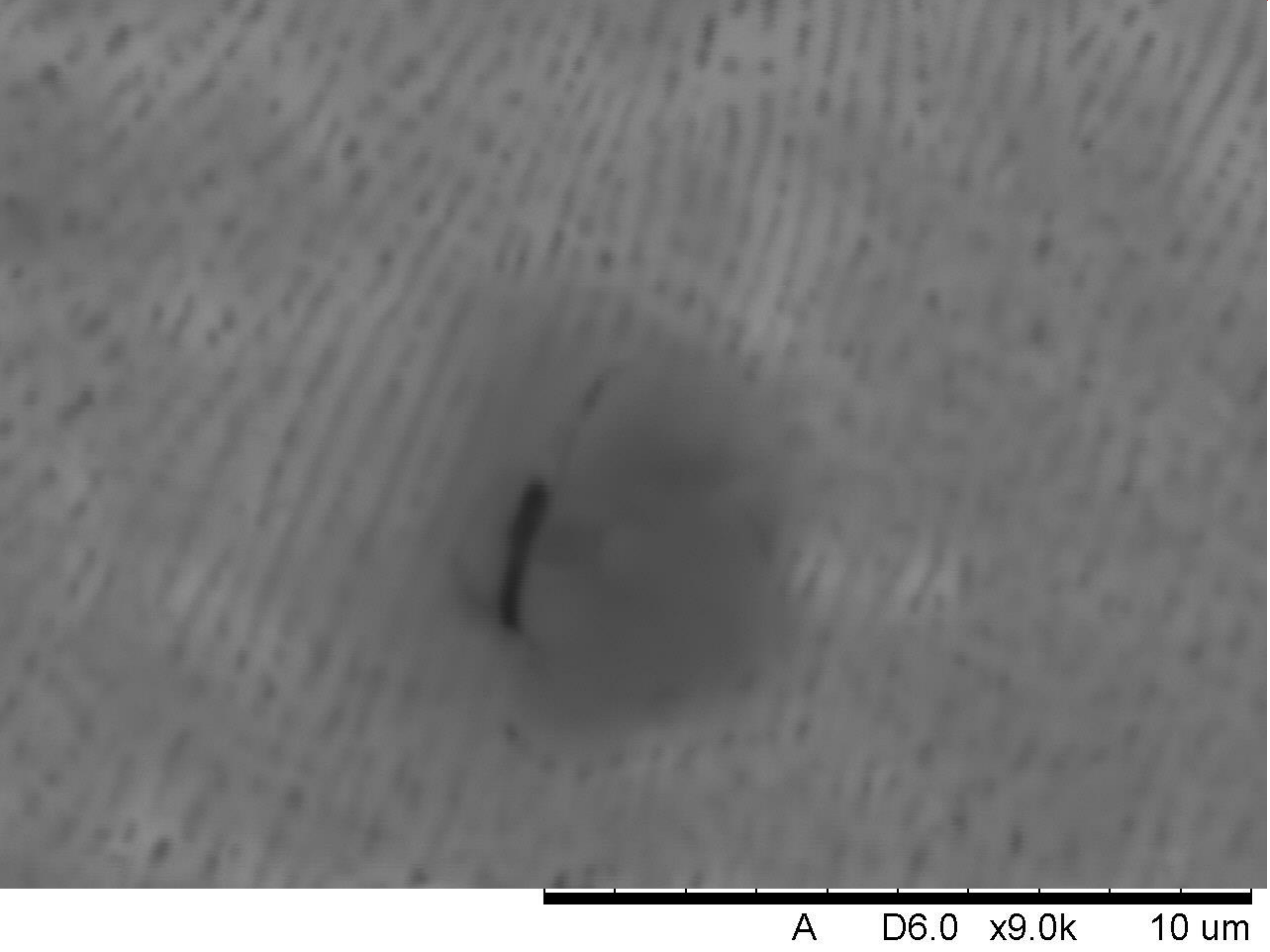
Take images before and after of a region exposed to electrolyte with etched and unetched samples

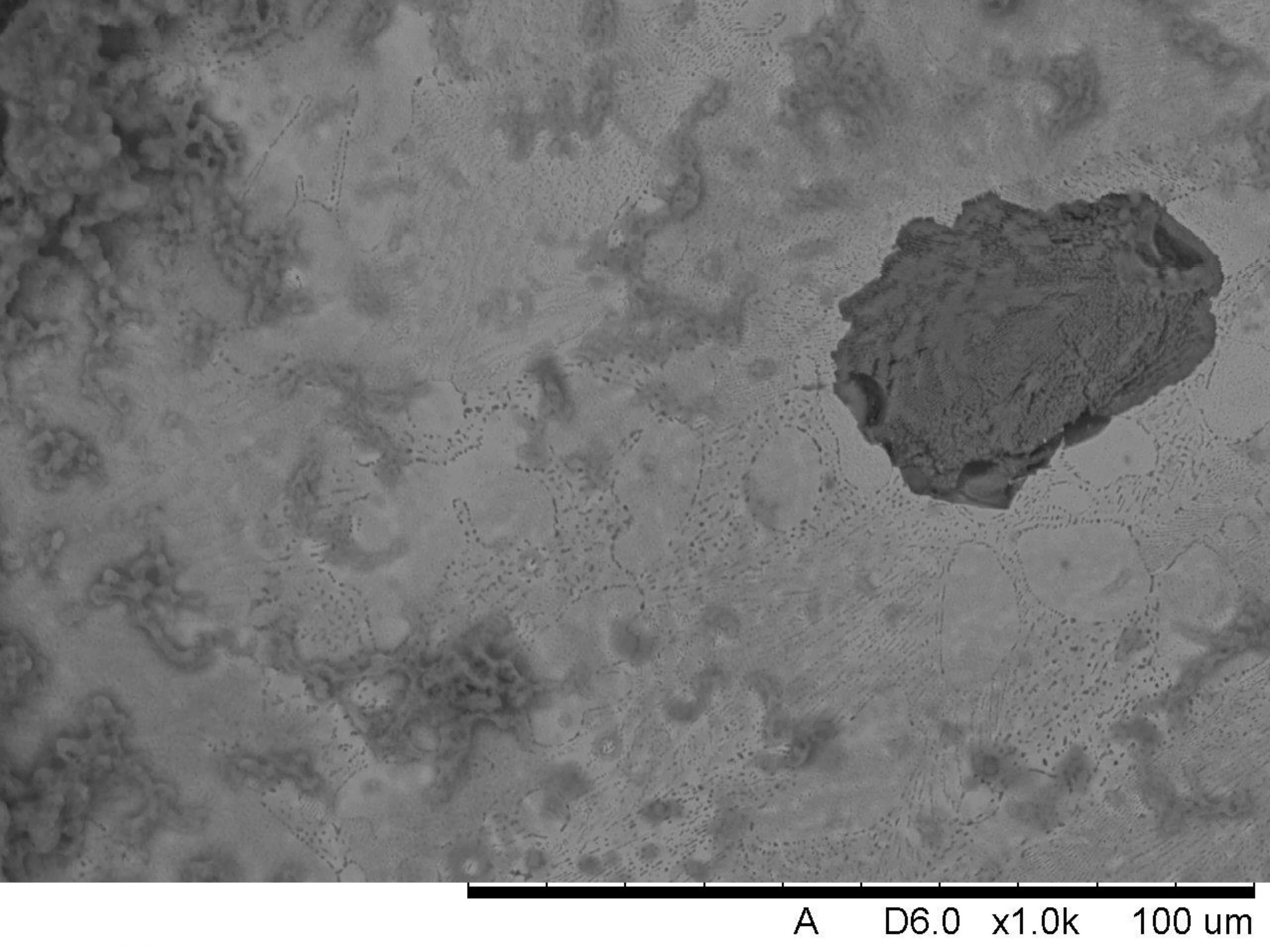
Method

- Metallurgically prepared two samples, etching only one
- Immersed the samples in electrolye for 30 mins to initiate corrosion
- Examined in desktop SEM

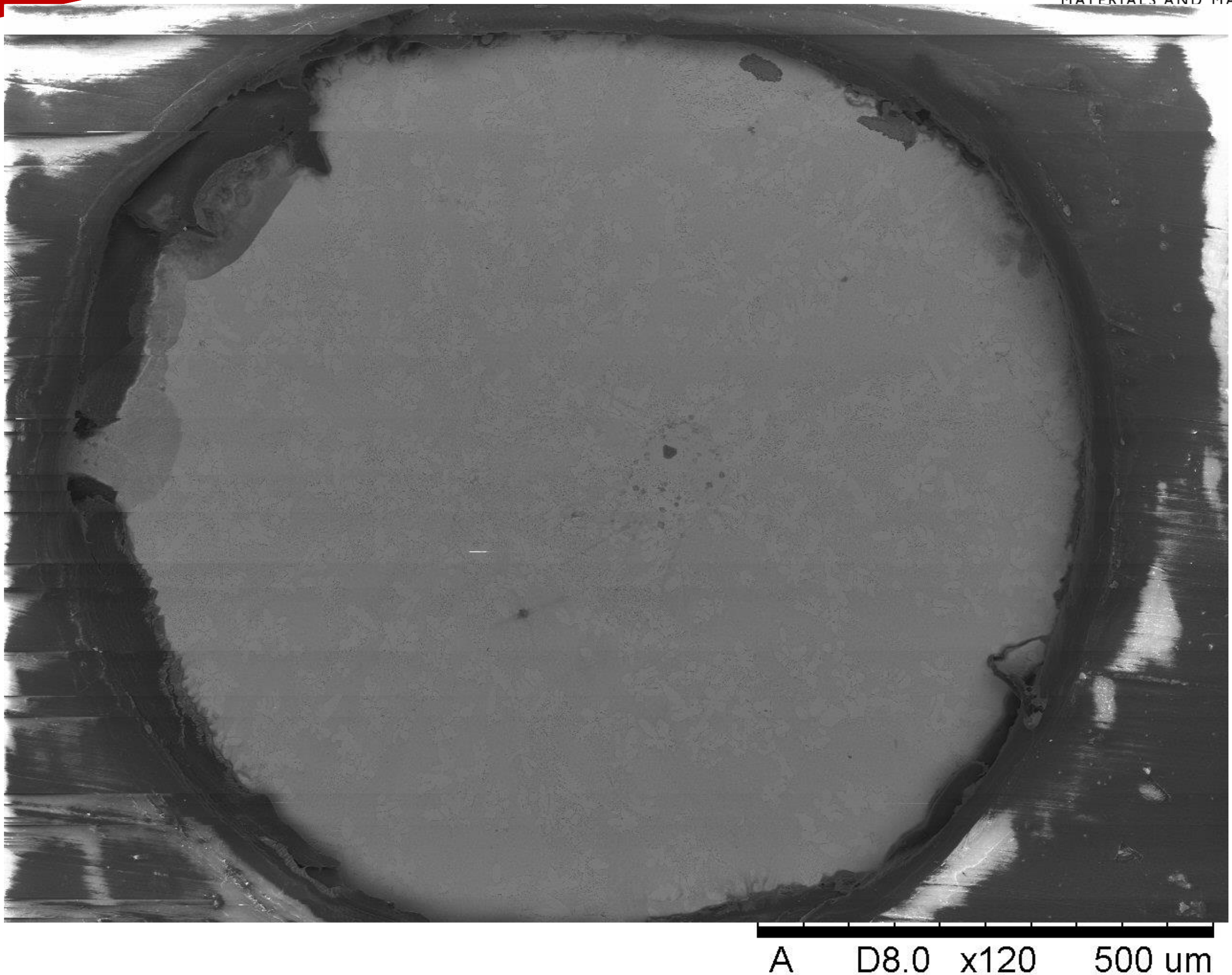
Unetched

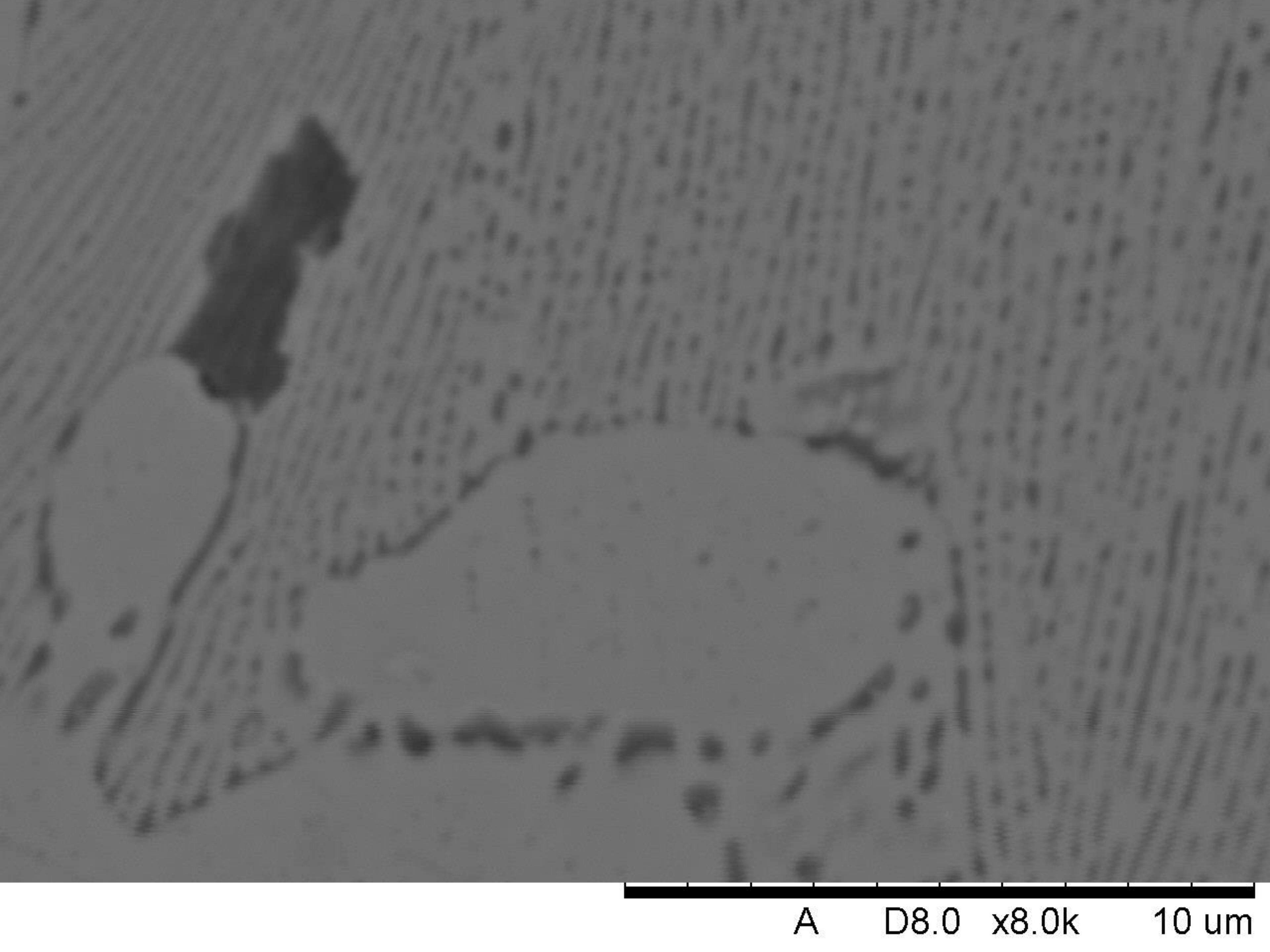


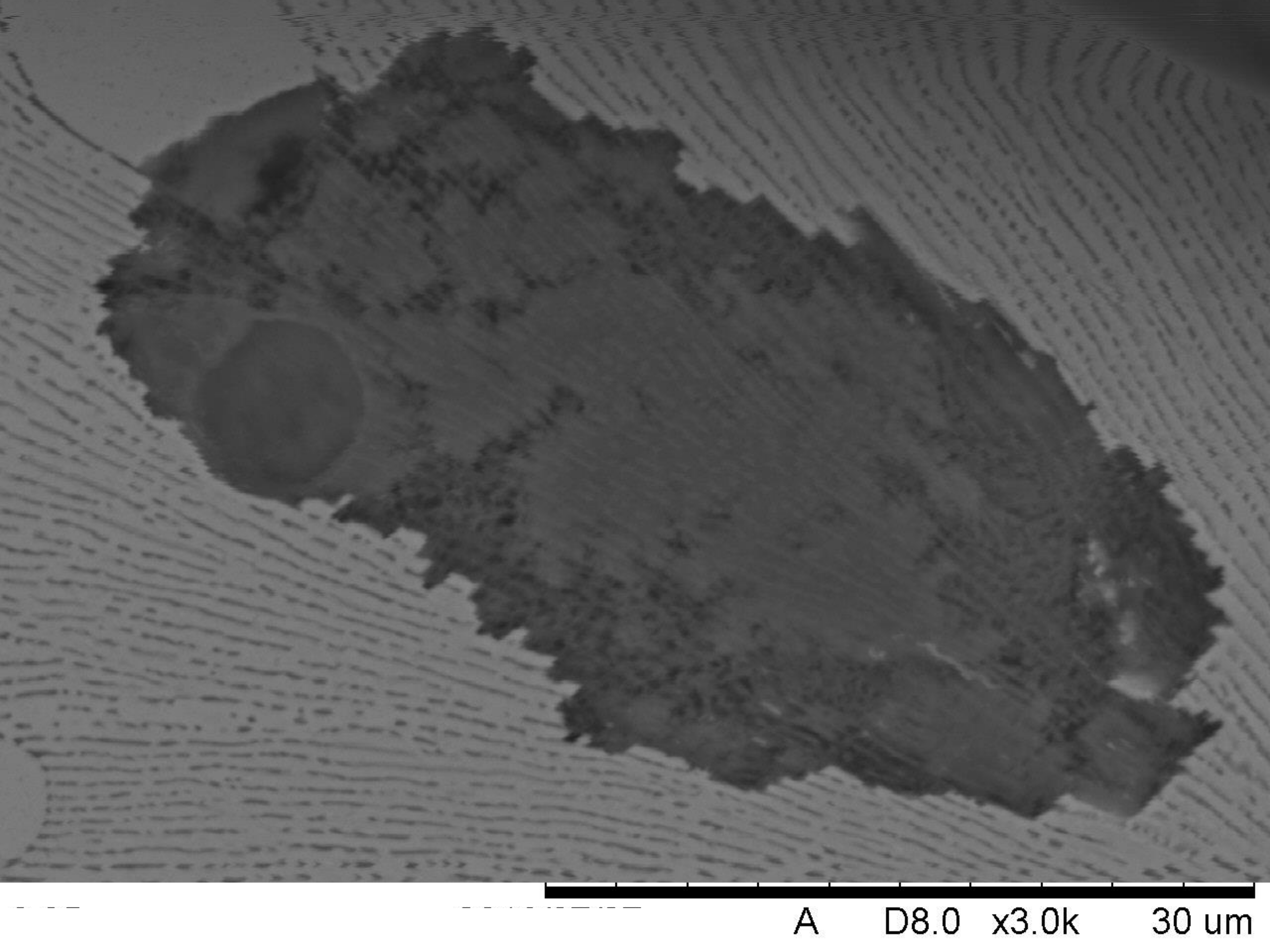

A D6.0 x9.0k 10 um

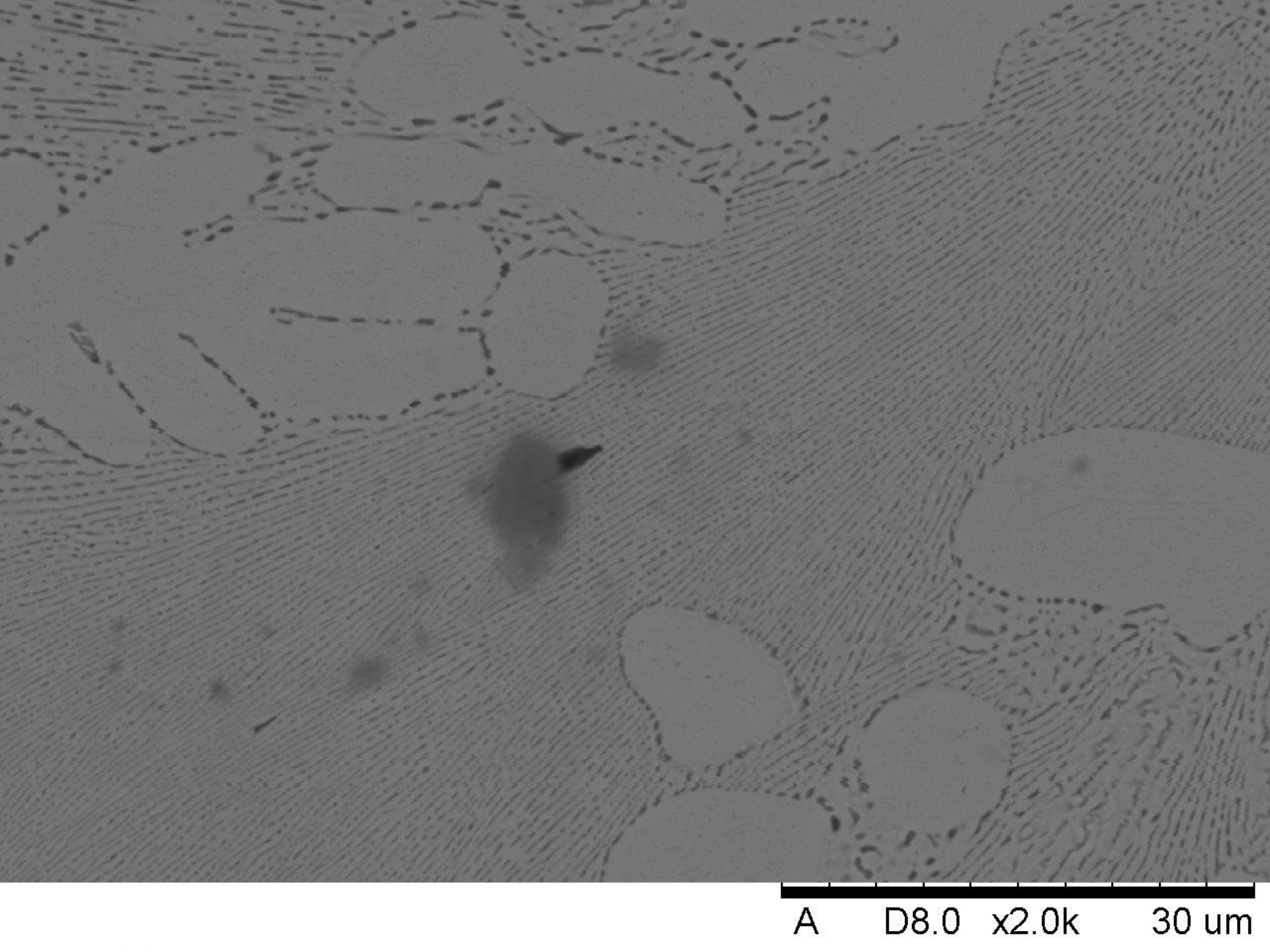

A
D6.0
x1.0k
100 um

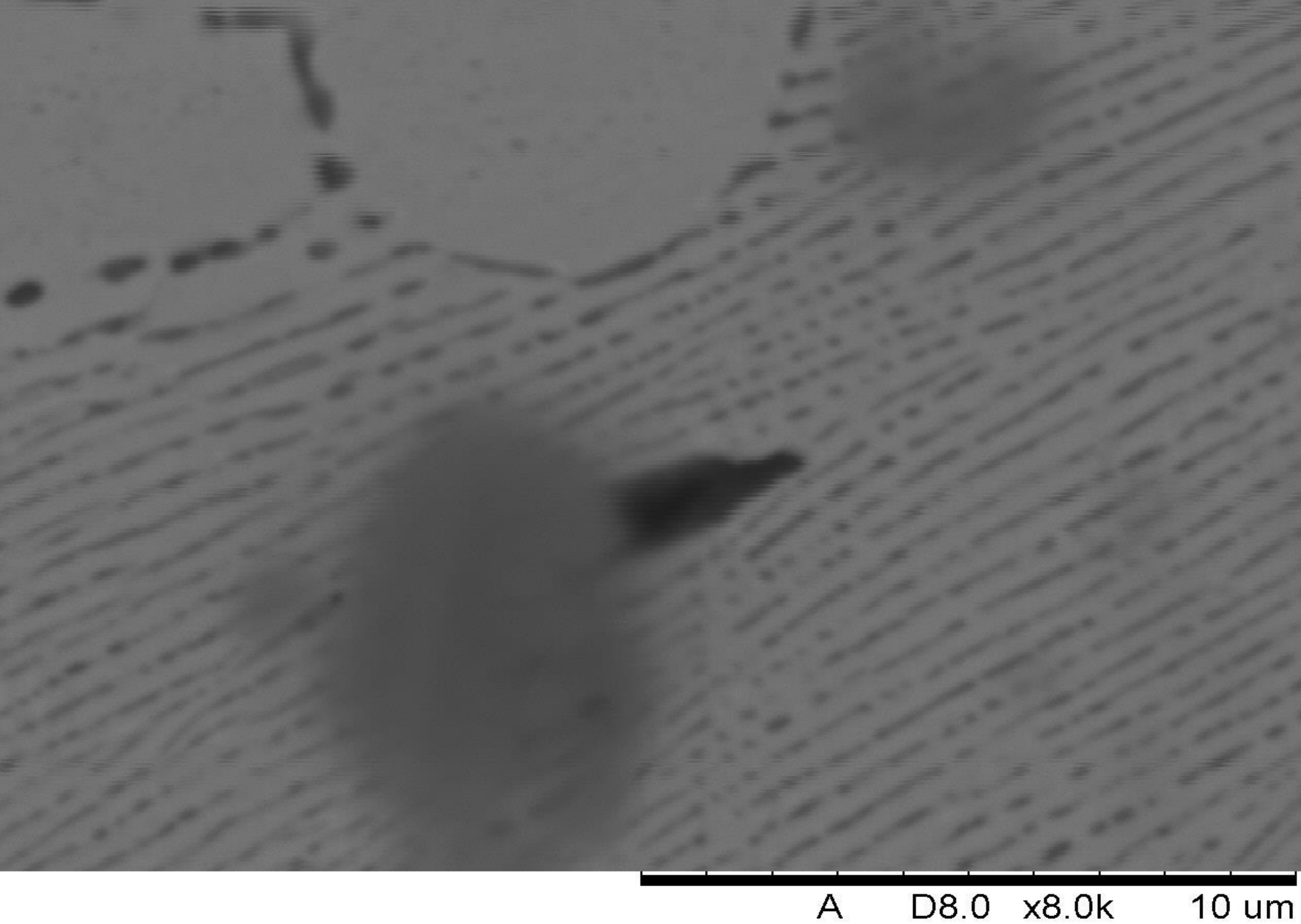
Etched

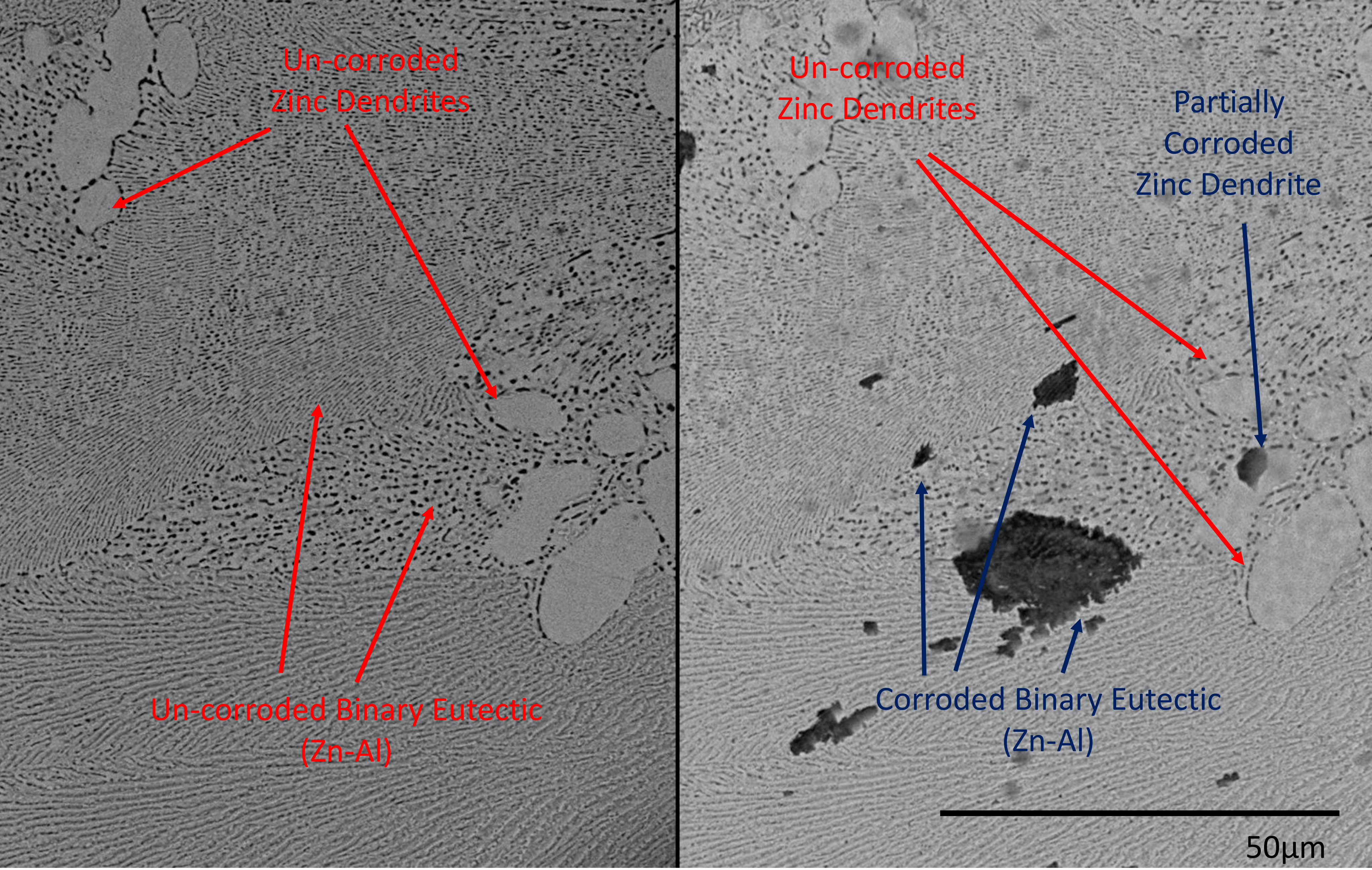



A
D8.0
x8.0k
10 um


A
D8.0
x3.0k
30 um


A D8.0 x2.0k 30 um


A
D8.0
x8.0k
10 um


Un-corroded
Zinc Dendrites
Un-corroded Binary Eutectic
(Zn-Al)
Un-corroded
Zinc Dendrites
Partially
Corroded
Zinc Dendrite
Corroded Binary Eutectic
(Zn-Al)
50μm

Conclusion

Change of mechanism

- Corrosion on the surface initiates in the binary eutectic
- In cut-edge the corrosion initiates in the zinc dendrites
- Suspected that the oxide layers are the cause
- Steel then polarises the surface and acts as cathode

No etching effect

Current work

- Conducting RDE on pure phases to deduce cathodic activity

Thanks for Listening

Thank you to The Materials Processing Institute and Worshipful Company of Armourers and Brasiers

Swansea University
Prifysgol Abertawe

TATA
TATA STEEL

EPSRC
Engineering and Physical Sciences Research Council

UNDEB EWROPEAIDD
EUROPEAN UNION
Llywodraeth Cymru
Welsh Government
Cronfa Gymdeithasol Ewrop
European Social Fund