CORSYM2017
International Corrosion Prevention Symposium for Research Scholars 2017

Universiti Malaysia PAHANG
Engineering • Technology • Creativity

The Influence of Hot Forming Process on the Microstructure and Corrosion Performance of Recycled Magnesium Alloys

CORSYM 2017 Presentation

Presenter : Juliawati Binti Alias

University : Universiti Malaysia Pahang

Date: 3rd May 2017

NACE INTERNATIONAL FOUNDING MALAYSIA SECTION

NACE INTERNATIONAL EAST ASIA & PACIFIC AREA

OUTLINE

1. Introduction
2. Experimental
3. Results
   - Microstructure evolution
   - Corrosion behaviour
4. Conclusions

PRESENTATION BACKGROUND

Introduction

- Usage & Recyclability for Magnesium Alloy – Challenges
- Deformation mechanism of magnesium and its alloys
- Casting and Hot Forming-Quenching (HFQ) process
- Corrosion of magnesium alloy

Experimental

- Specimen preparation
- Microstructure characterization
- Corrosion morphology observation and measurement

Result

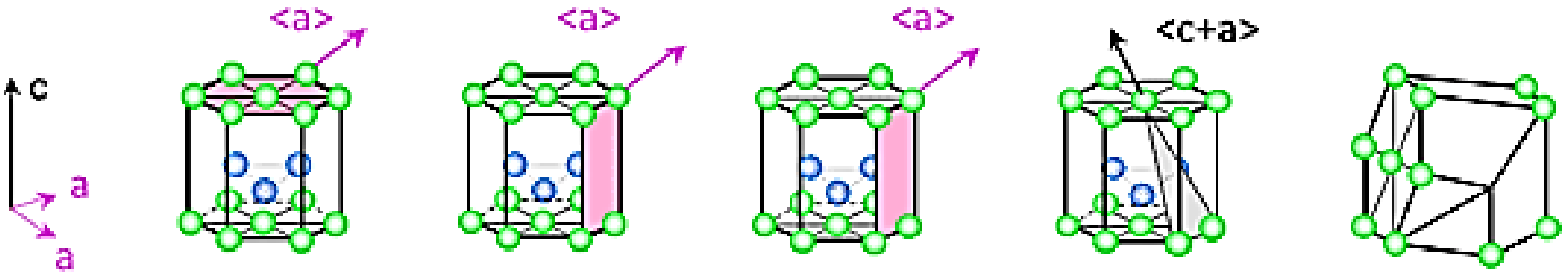
- Microstructure evolution
- Corrosion behaviour

Usage & Recyclability for Magnesium Alloys

- Energy saving and cost effective magnesium sheet – vehicle lightweighting
- Limitation in deformation due to very few slip system.
- Anisotropy properties (crystallography orientation)
- Unsatisfactory corrosion performance in most environment.

DEFORMATION MECHANISM OF MAGNESIUM

SLIP TWINNING



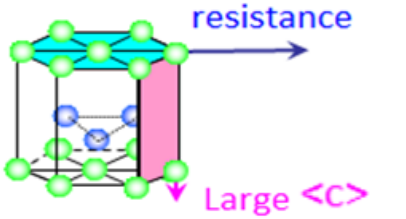
Basal <a> slip

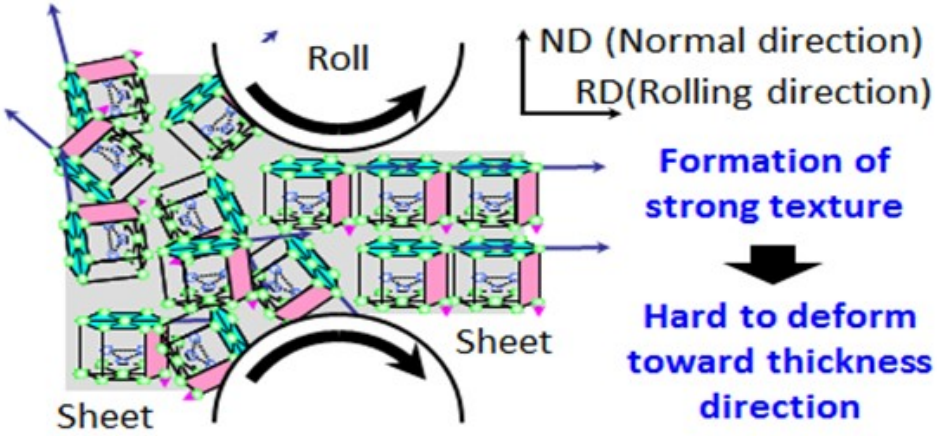
Prismatic <a> slip (cross slip)

Prismatic <a> slip

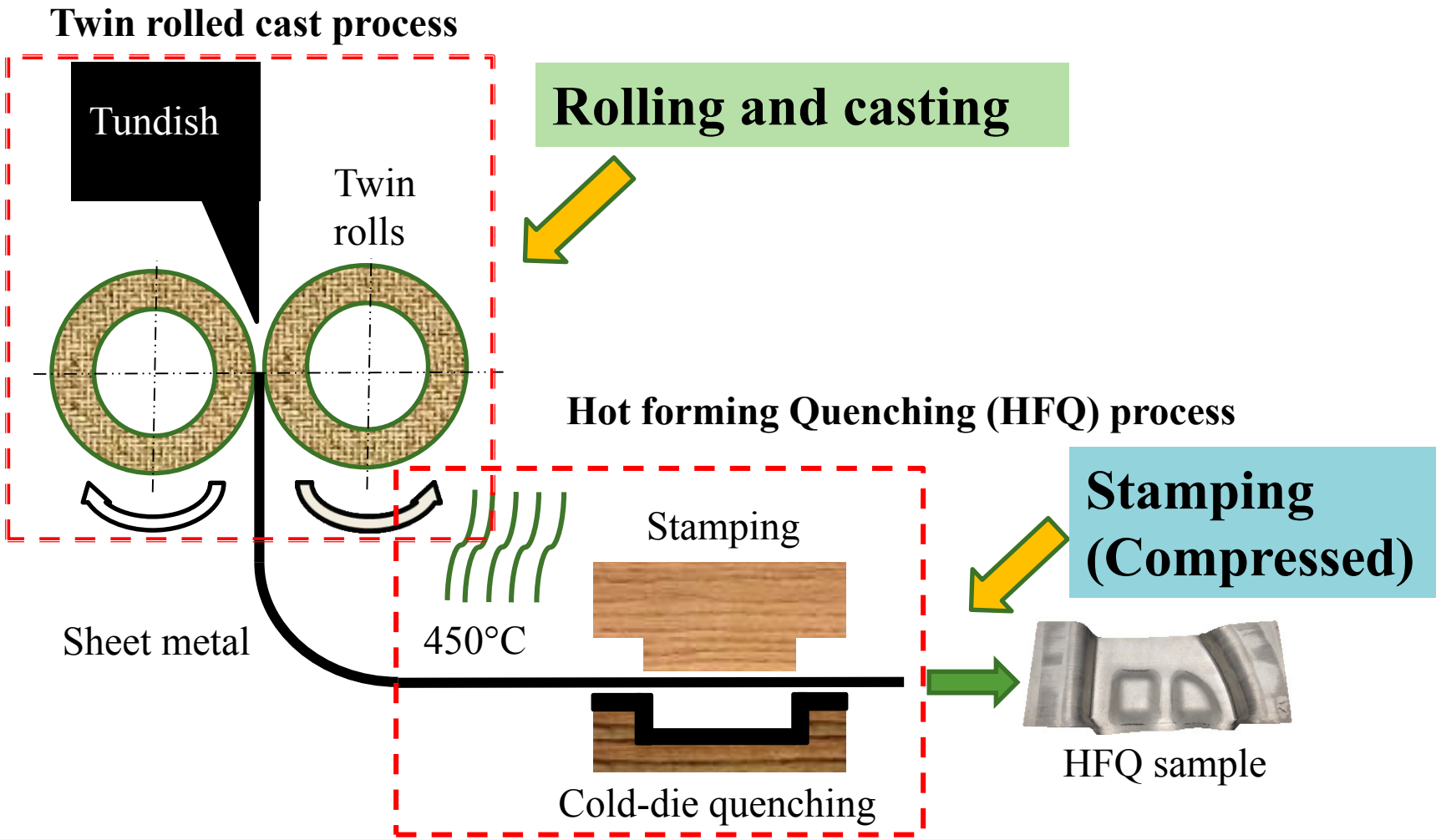
Pyramidal <c+a> slip

{10-12} twinning

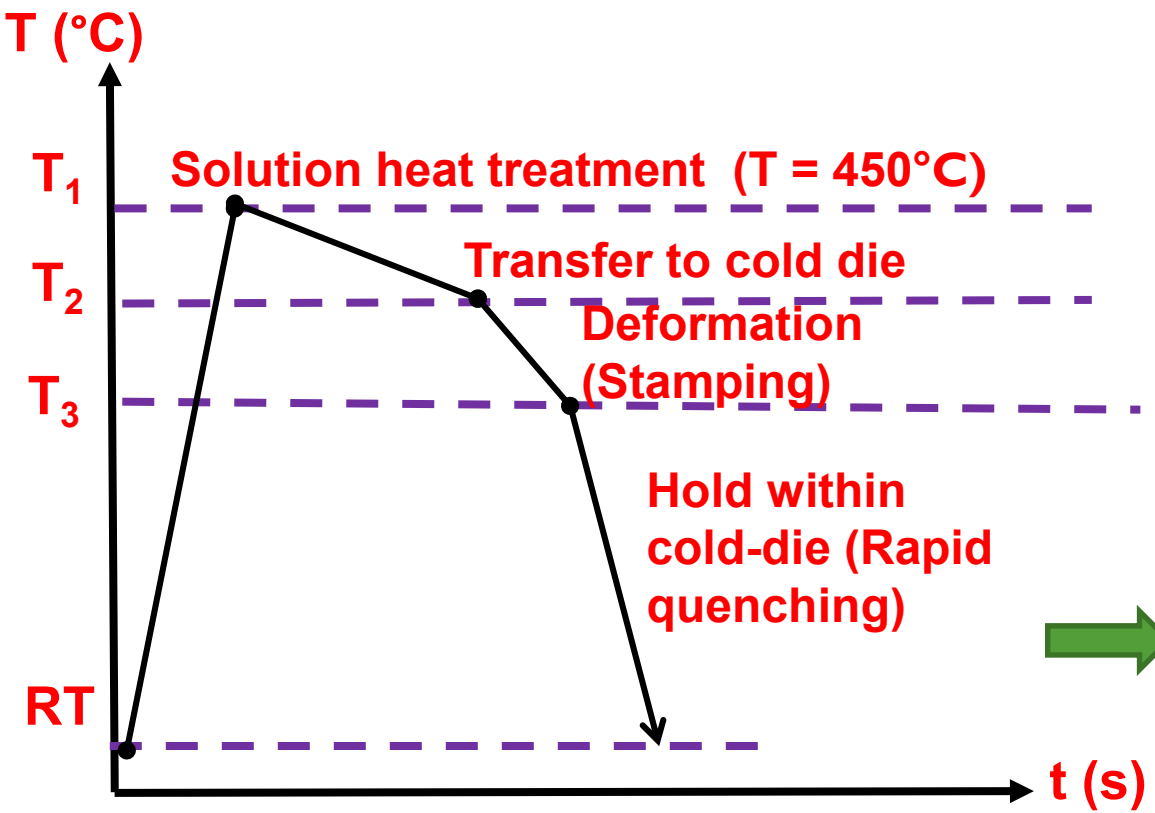


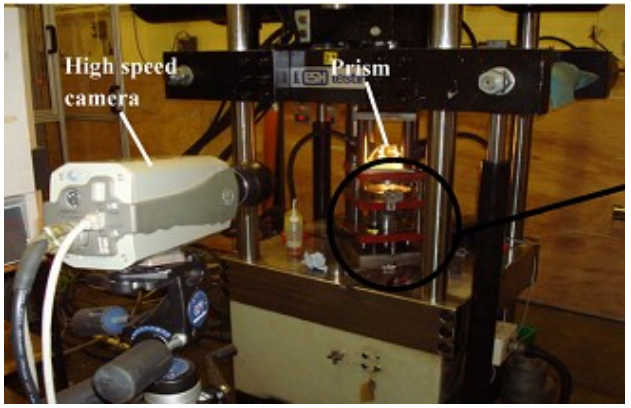


CASTING & HOT FORMING QUENCHING (HFQ)

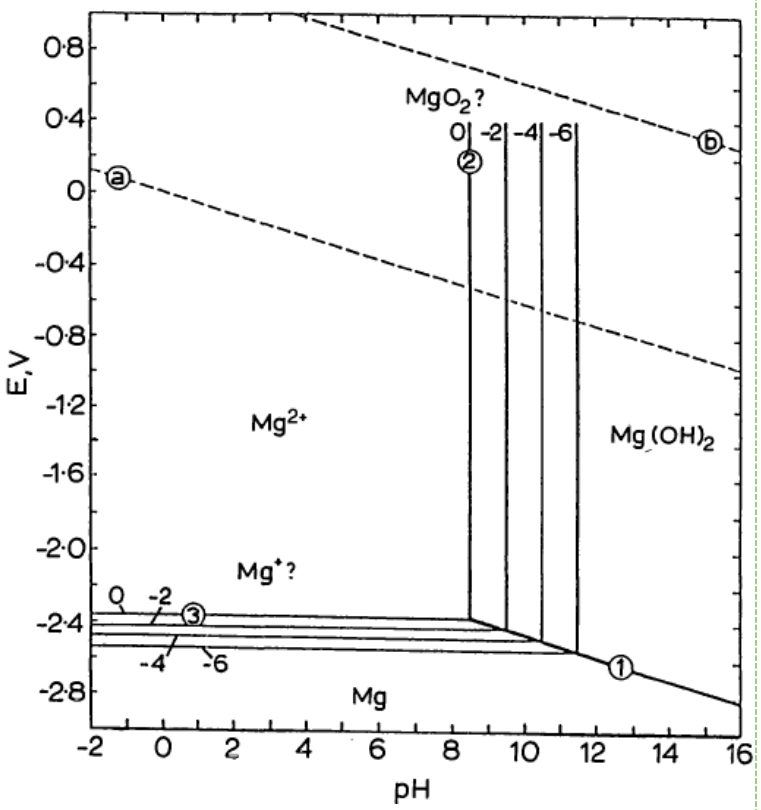


HFQ SCHEMATIC DIAGRAM





CORROSION OF MAGNESIUM



Magnesium alloy

- ✓ Standard electrode potential = -2.37 V, in aqueous solution = -1.67 V vs SCE

'Rapid corroding metal'

Chemical reaction :

$Mg \longrightarrow Mg^{2+} + 2e$ (Anodic reaction)

$2H_2O + 2e \longrightarrow 2OH^- + H_2$ (Cathodic reaction)

$Mg^{2+} + 2OH^- \longrightarrow Mg(OH)_2$ (product formation)

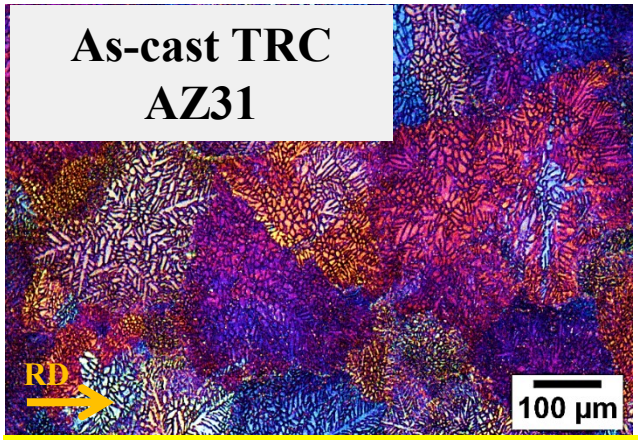
- ✓ Hydrogen evolution and corrosion rate increases, with increasing potential

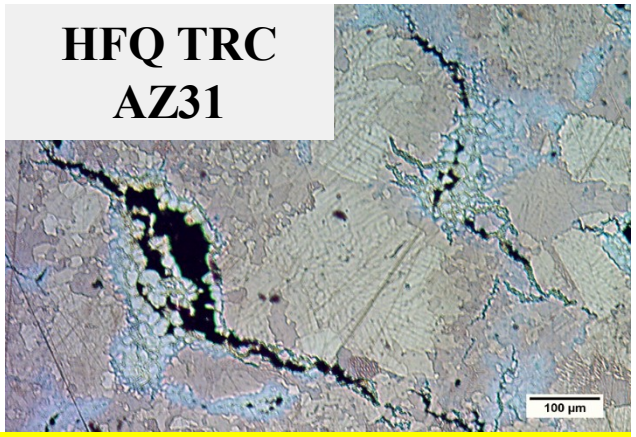
'Negative difference effect (NDE)'

EXPERIMENTAL WORK

Specimen preparation	• Mechanical grinding • Diamond polishing • Chemical etching
Microstructure characterization	• Optical micrograph • Field emission scanning electron microscopy (SEM)
Corrosion evaluation	• Hydrogen evolution experiment (immersion testing) • SEM, EDX and optical micrograph • Electrochemical measurement : Open circuit potential, potentiodynamic polarization

MICROSTRUCTURE EVOLUTION

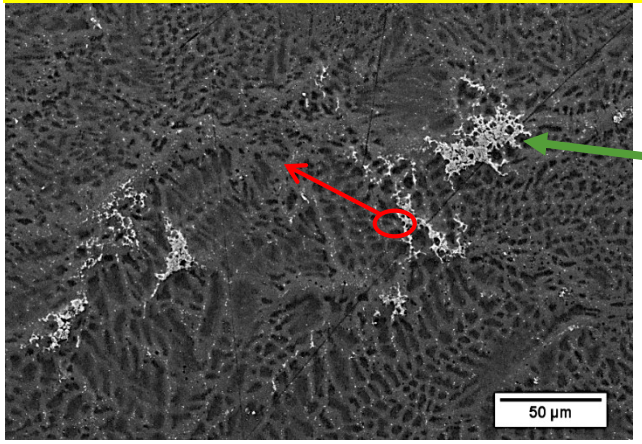


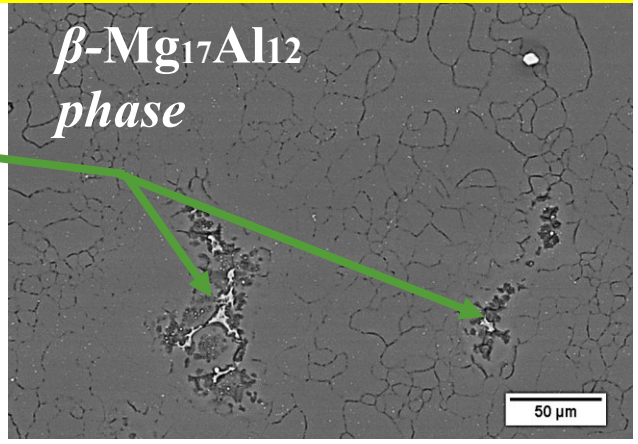


As-cast :

- Coarse dendrites
- Dendrite mean size = 200 µm
- Particle type = Continuous or network *β*-phase distribution

Rolled surface (RS)

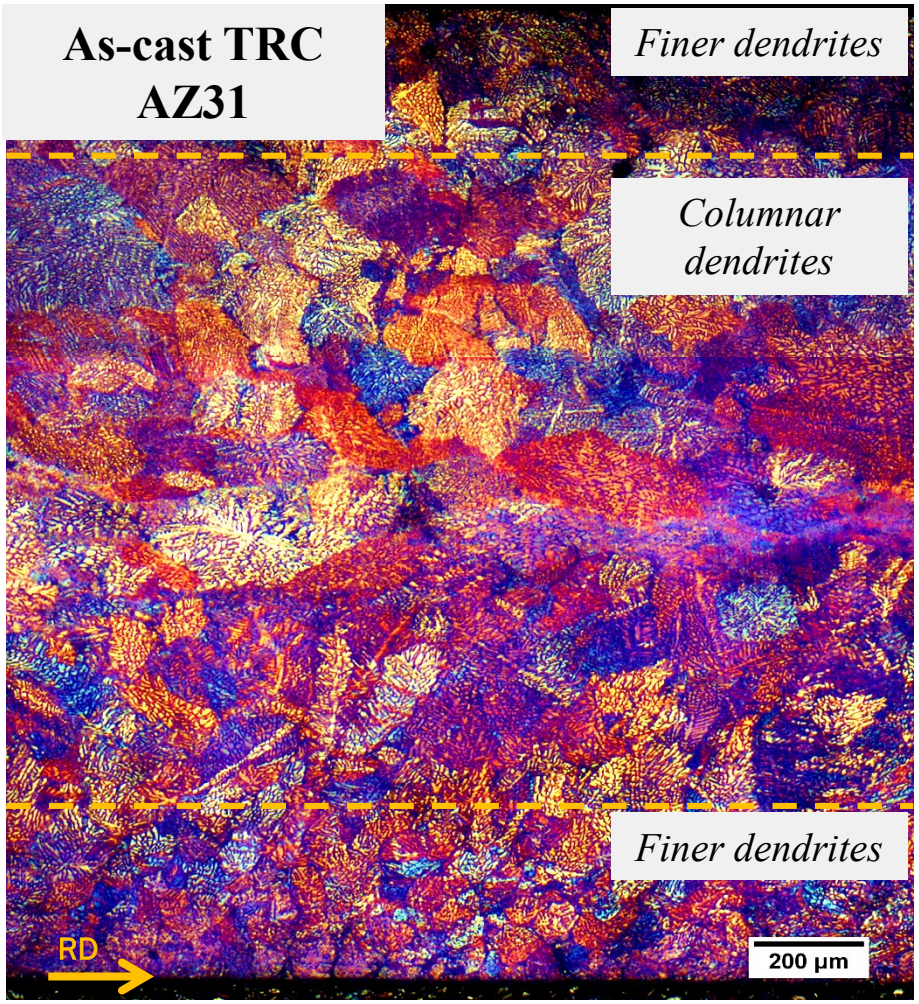


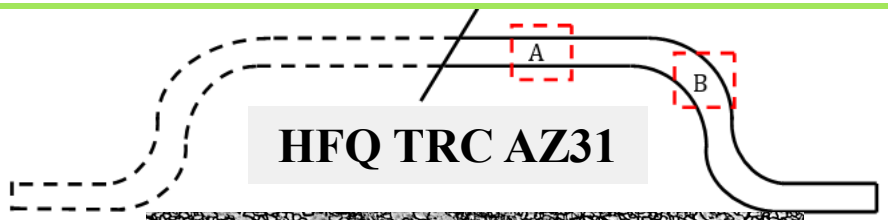


HFQ :

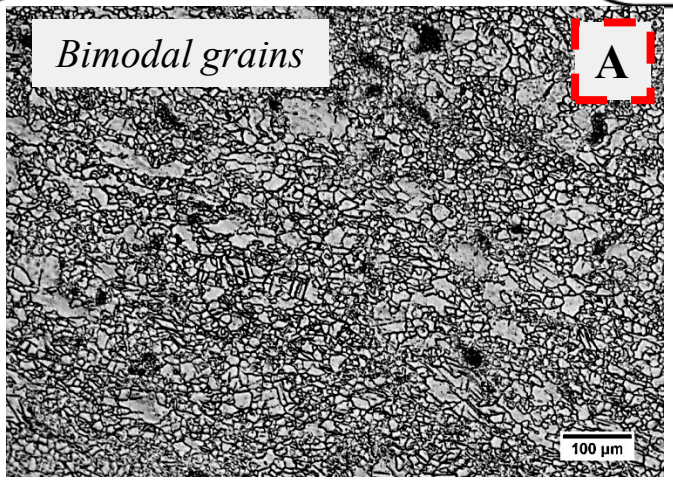
- Recystallized bimodal grain, dendrite morphology
- Range of grain size =1.7 – 100 µm
- Particle type = Discontinuous or random *β*-phase distribution

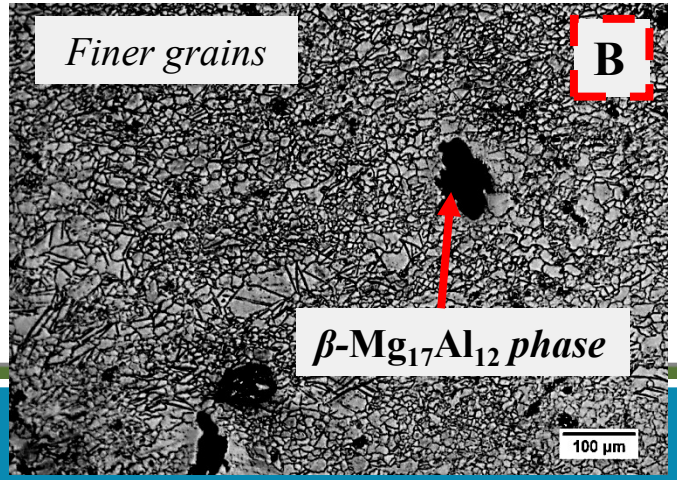
THROUGH THICKNESS MICROSTRUCTURE





HFQ TRC AZ31

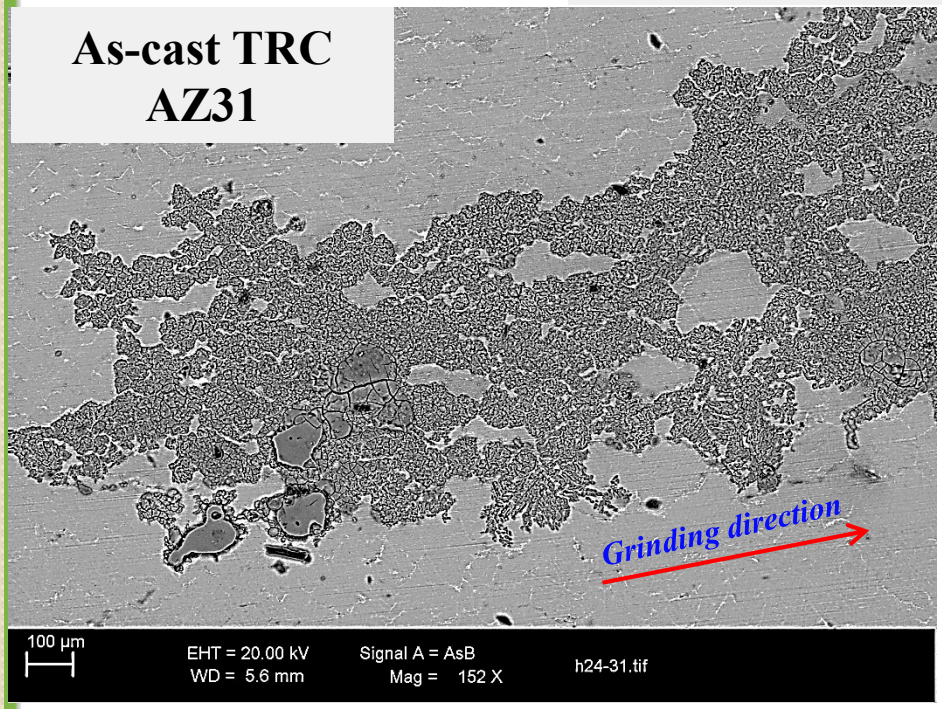




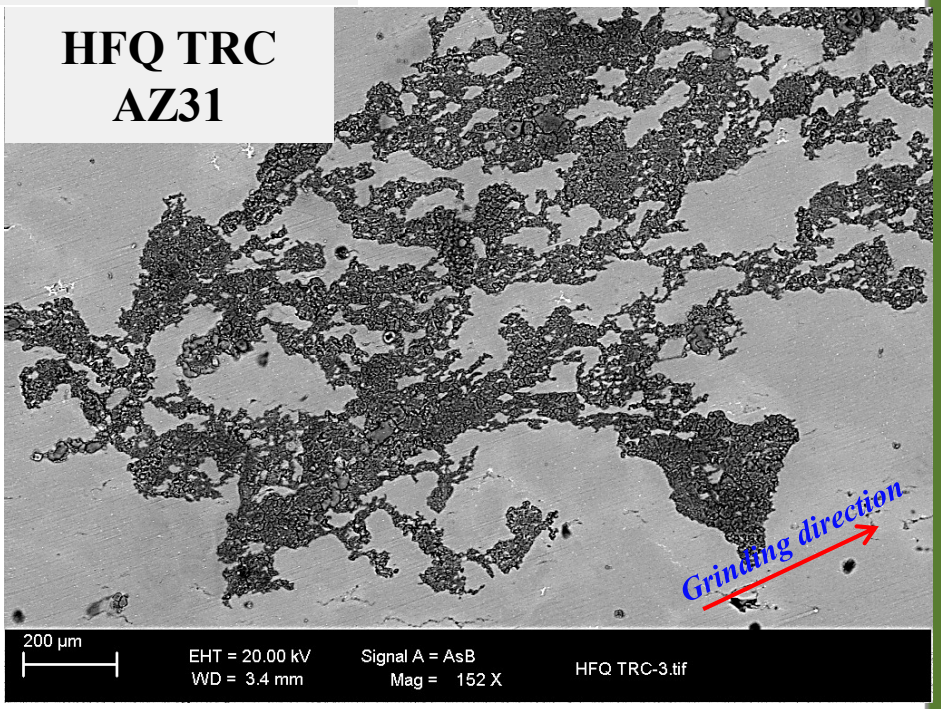
CORROSION MORPHOLOGY

'Filiform-like corrosion'

As-cast TRC AZ31

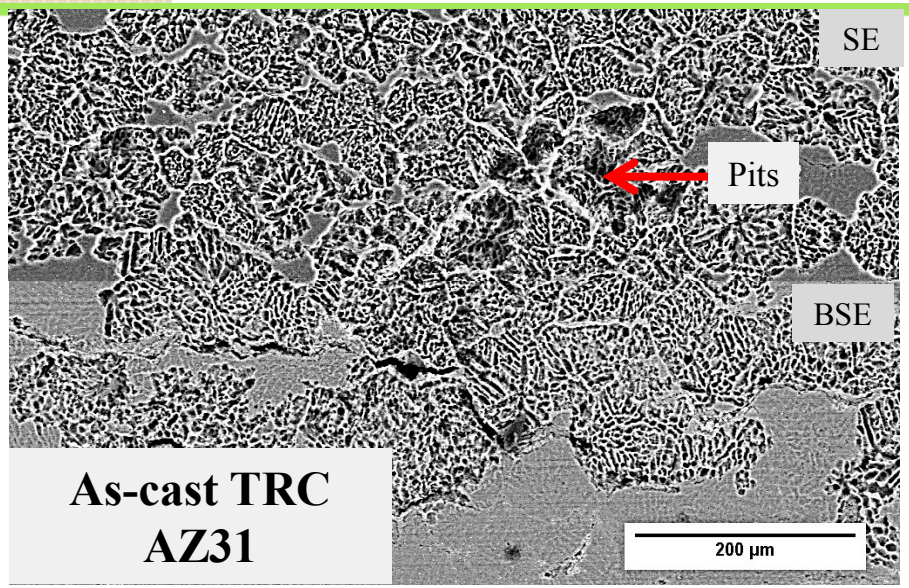


HFQ TRC AZ31

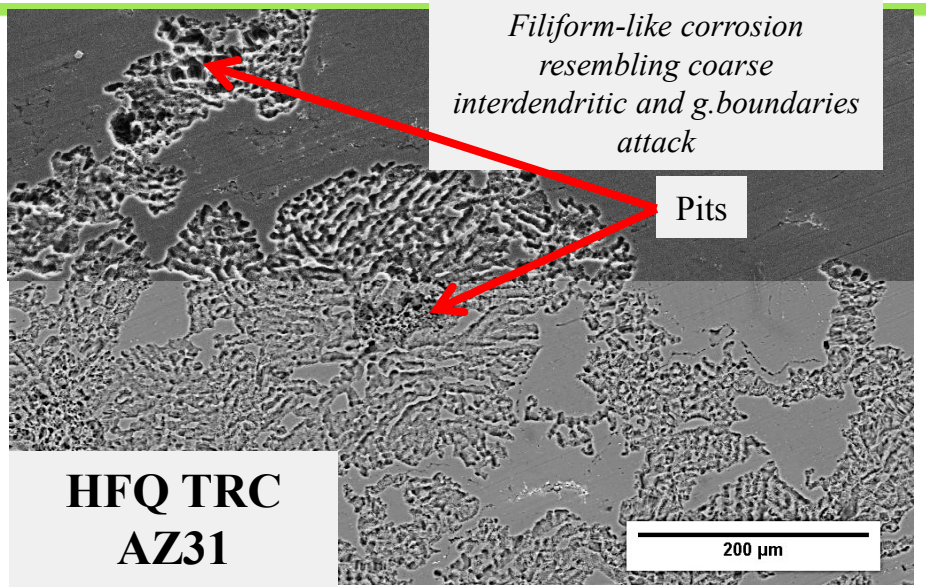


- ✓ *Propagation following grinding direction*
- ✓ *Corrosion features, resembling the grain structure attack*

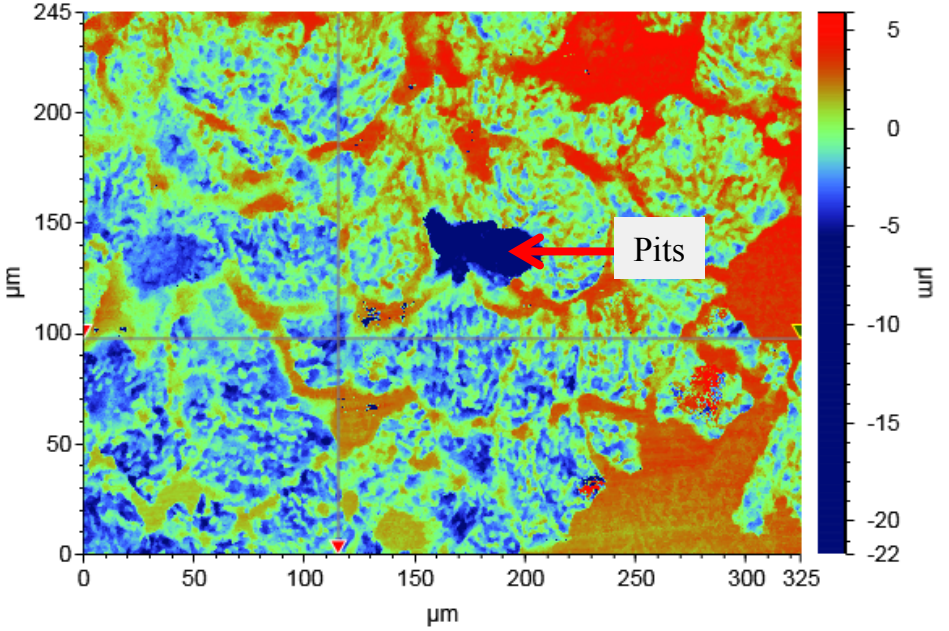
CORROSION ATTACK IN 5 HRS

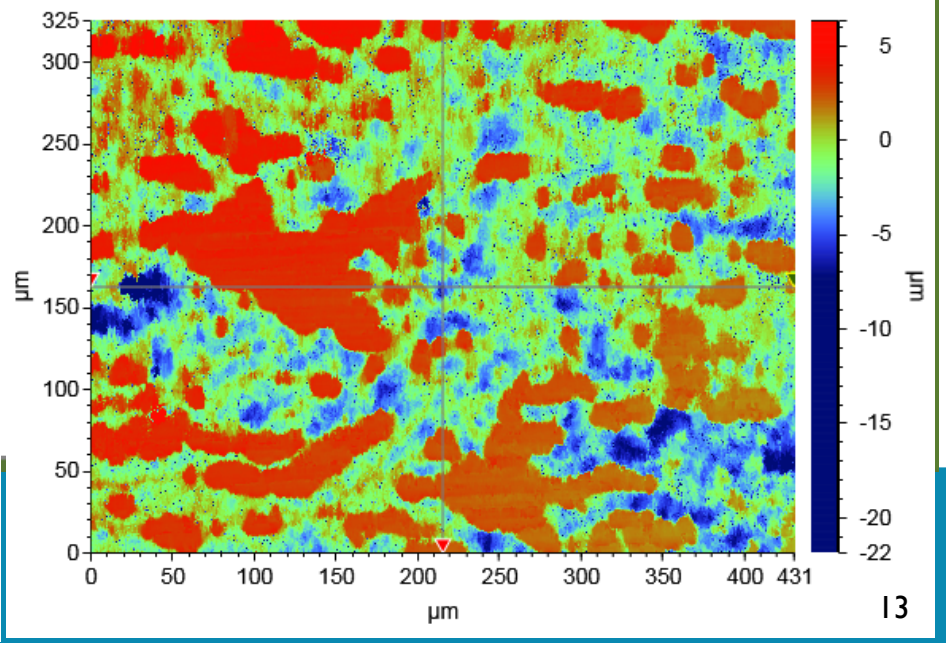


As-cast TRC AZ31

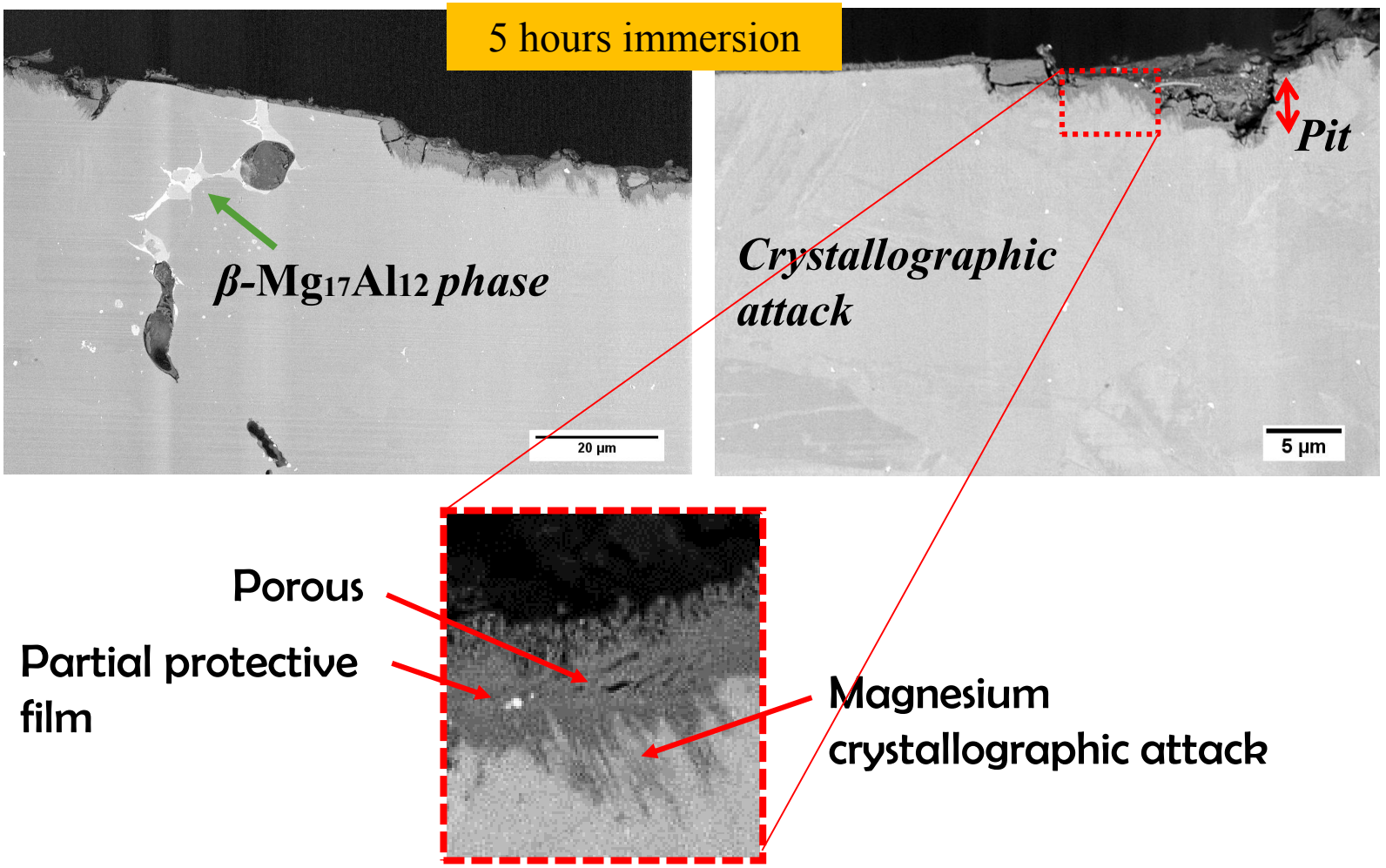


HFQ TRC AZ31



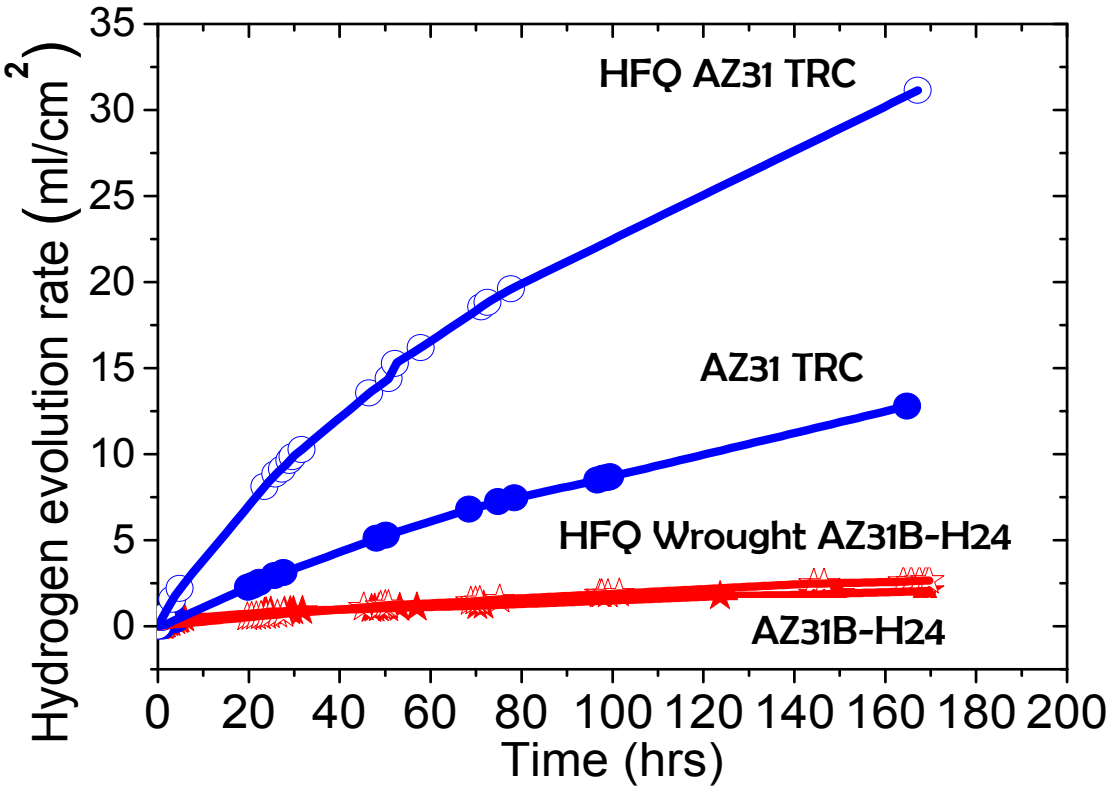


THROUGH-THICKNESS CHARACTERIZATION



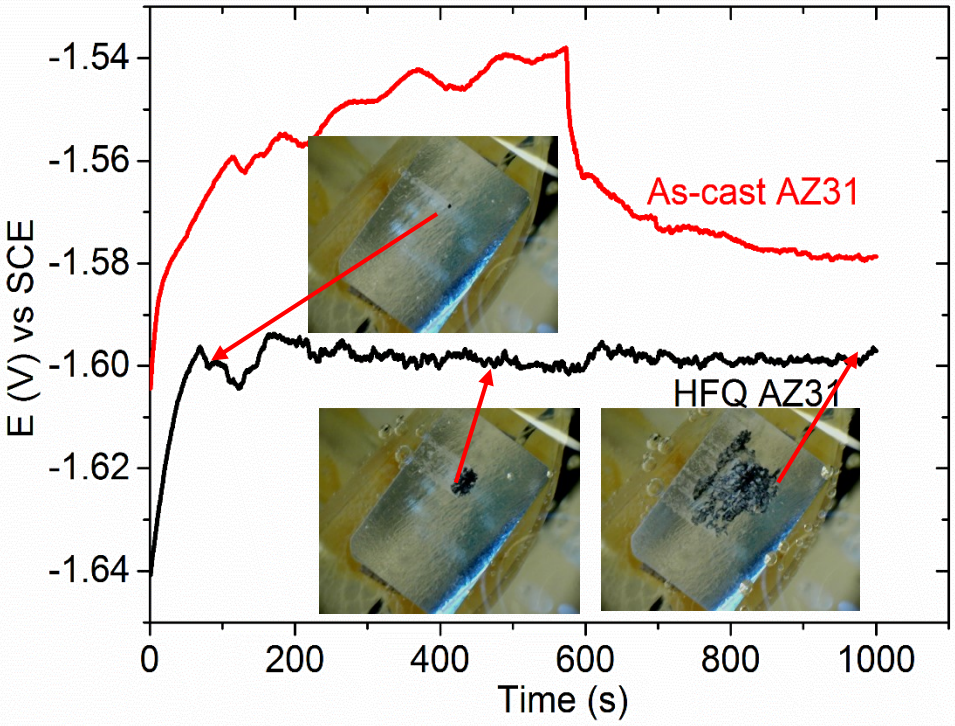
HYDROGEN EVOLUTION EXPERIMENT

- Experiment to quantify degradation rate (corrosion rate) of magnesium alloy
- One mole of H_2 evolved = one mole of Mg dissolved

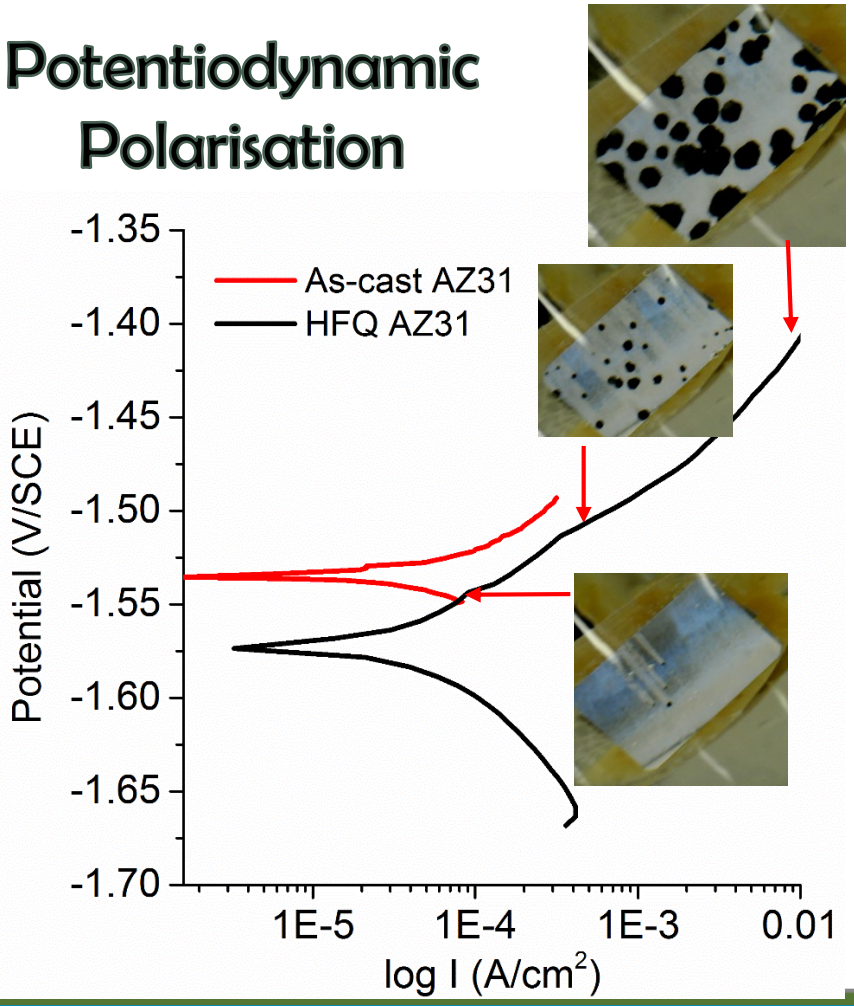


ELECTROCHEMICAL MEASUREMENT

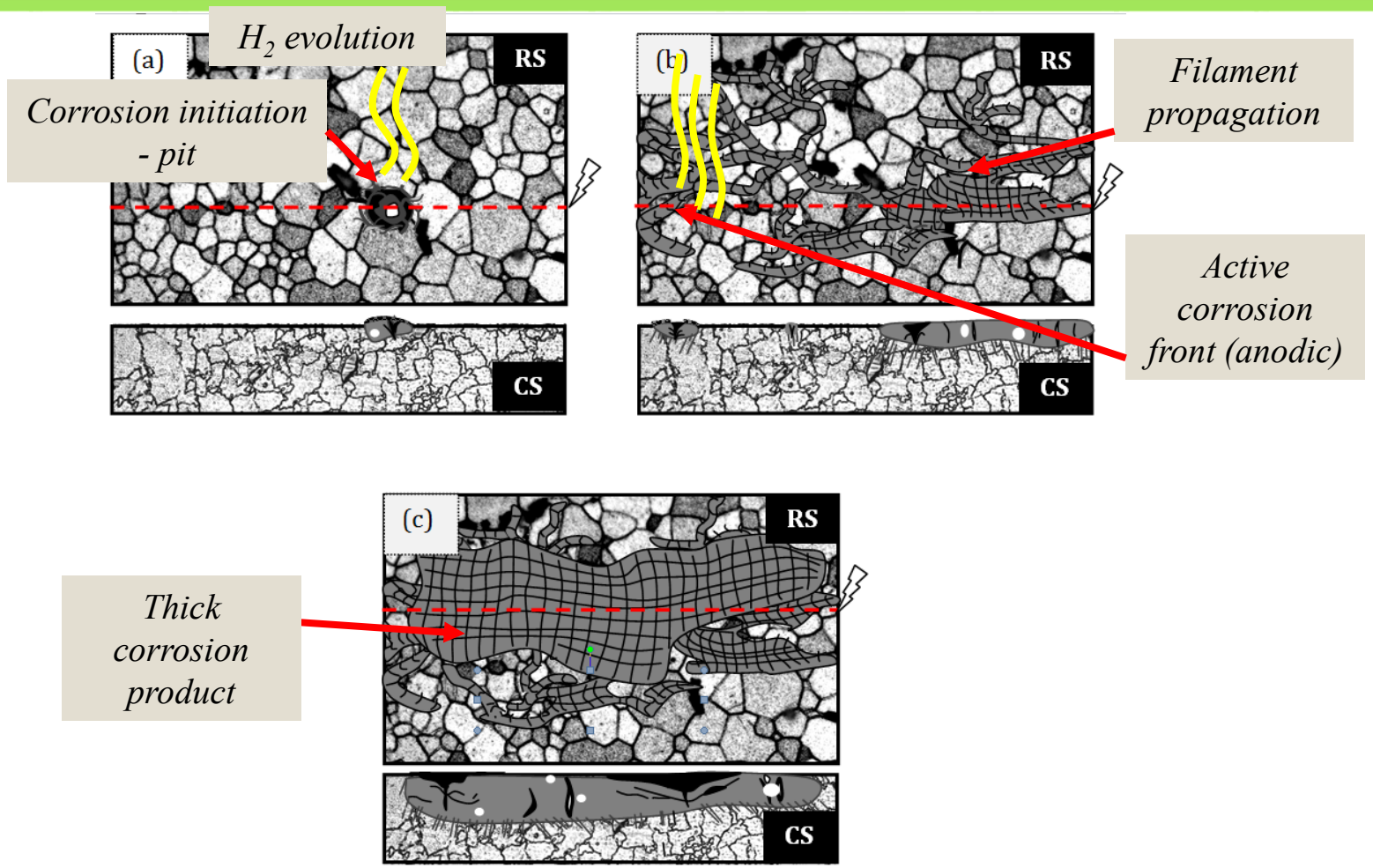
Open circuit potential



Potentiodynamic Polarisation



Corrosion Mechanism (schematic diagram)



CONCLUSION

- Microstructure evolution after HFQ
  - HFQ TRC AZ31 = Recrystallised bimodal grains with coarse dendrite morphology, discontinuous distribution of β-$Mg_{17}Al_{12}$ phase.
- Corrosion behaviour of as-cast and HFQ AZ31 Magnesium alloys
  - Corrosion feature = Filiform-like corrosion depending on the grain structure (Shallow pit and filament track)
  - As-cast TRC AZ31 alloy = interdendritic attack, HFQ TRC alloy = filament propagation resembling interdendritic and grain boundary attack
  - 2nd Corrosion propagation = Thick corrosion product (pit growth and propagation)
  - Discontinuous β-$Mg_{17}Al_{12}$ phase = Cathodic reaction = increase hydrogen evolution rate
  - HFQ process = Ruling the corrosion propagation appearance according to the grains structure, influenced by second phase distribution