Department of Materials Science and Engineering

Effects of Potential and Strain Rate on the Cracking Behavior of Alloy 182 Weld in Hydrochloric Acid Solution

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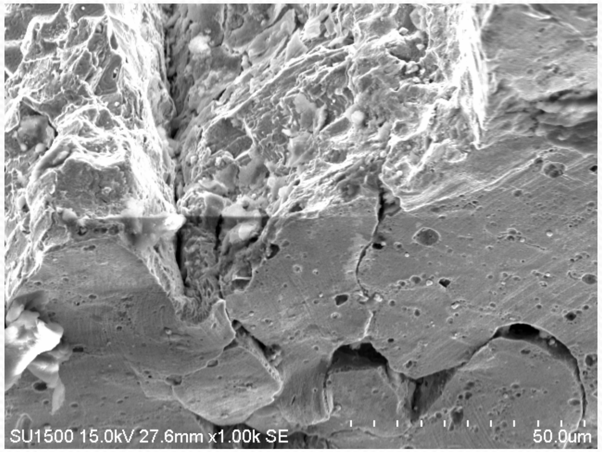
Background Information

- The incidence of **primary water stress corrosion cracking (PWSCC)** in Alloy 182 weld in nuclear power plant
- The possibility of the occurrence of **environmentally-assisted cracking (EAC)** during shut-down and start-up period
  -- *low temperature condition*
- The effect of **contaminants**, such as SO_4^{2-} and Cl^-
- The effect of solidification microstructure and microchemistry

Top view of cavity

DBNPS VHP Nozzle NO.3 Degradation Cavity

EAC of Alloy 182 weld in Sulfuric Acid Solution



- The experimental results showed that the as-welded Alloy 182 was most susceptible to EAC in 0.05 M H_2SO_4 solution at potentials in the active-to-passive transition region.
- At anodic potentials, the slow strain rate test results also demonstrated that EAC susceptibility increased with decreasing strain rate in 0.05M H_2SO_4 solution, indicating the involvement of HAC in the cracking process.

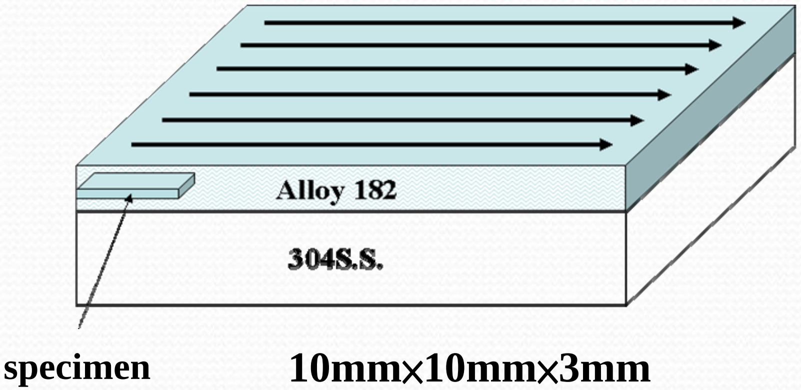
Subjects of investigation

- Susceptibility of Alloy 182 weld to ***EAC*** in hydrochloric acid solution (HCl) at room temperature
  - *under applied potential conditions*
  - *at different strain rates*

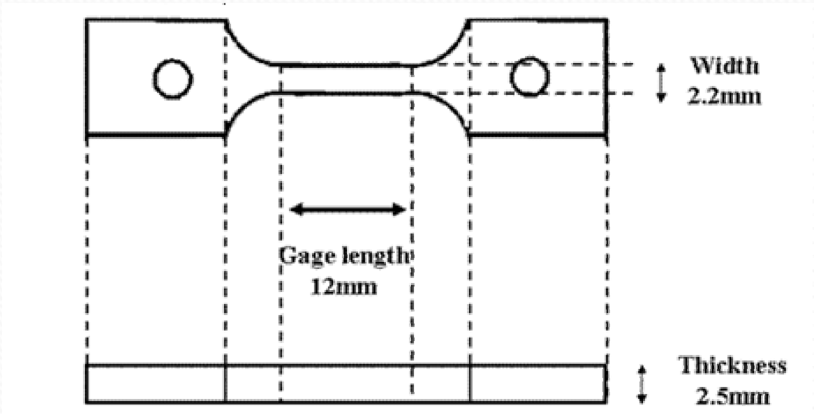
- The effect of solidification microstructure and microchemistry

Specimens Preparation

Material : Alloy 182 weld metal
Submerged arc welding (SMAW) : 23 V and at a traveling of 150 mm/min



Optical observation, electrochemical tests



Tensile specimens for SSRTs

Grinding with SiC paper to #2000 and polishing with 0.3 μm Al_2O_3 powder.

Chemical composition of Alloy 182

chemical composition	Wt %								
	Ni	Cr	Fe	C	Mn	Si	Cu	Ti	Nb
Alloy 182	Bal.	14.12	7.25	0.028	7.16	0.42	0.01	0.41	1.72

SSRT

Test environment : (Room Temperatue)

- **Air**
- **0.05 M HCl solution**

Effect of applied potential

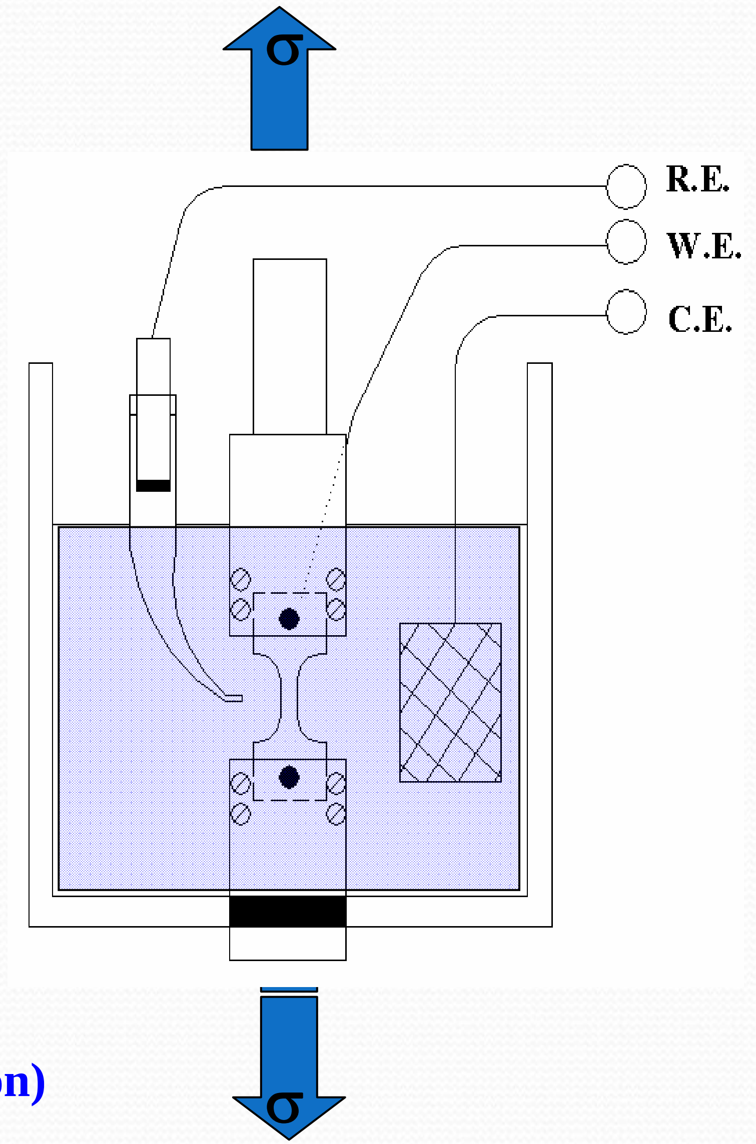
Strain rate : 8.3×10^{-7} s^{-1}

Potential : Open circuit potential, cathodic,
active-to-passive transition,
passive, transpassive potentials

Effect of strain rate

Potential : -50 mV_{SCE} (active-to-passive transition)

Strain rate : 8.3×10^{-6} s^{-1} ~ 8.3×10^{-8} s^{-1}



Optical microscopy observation

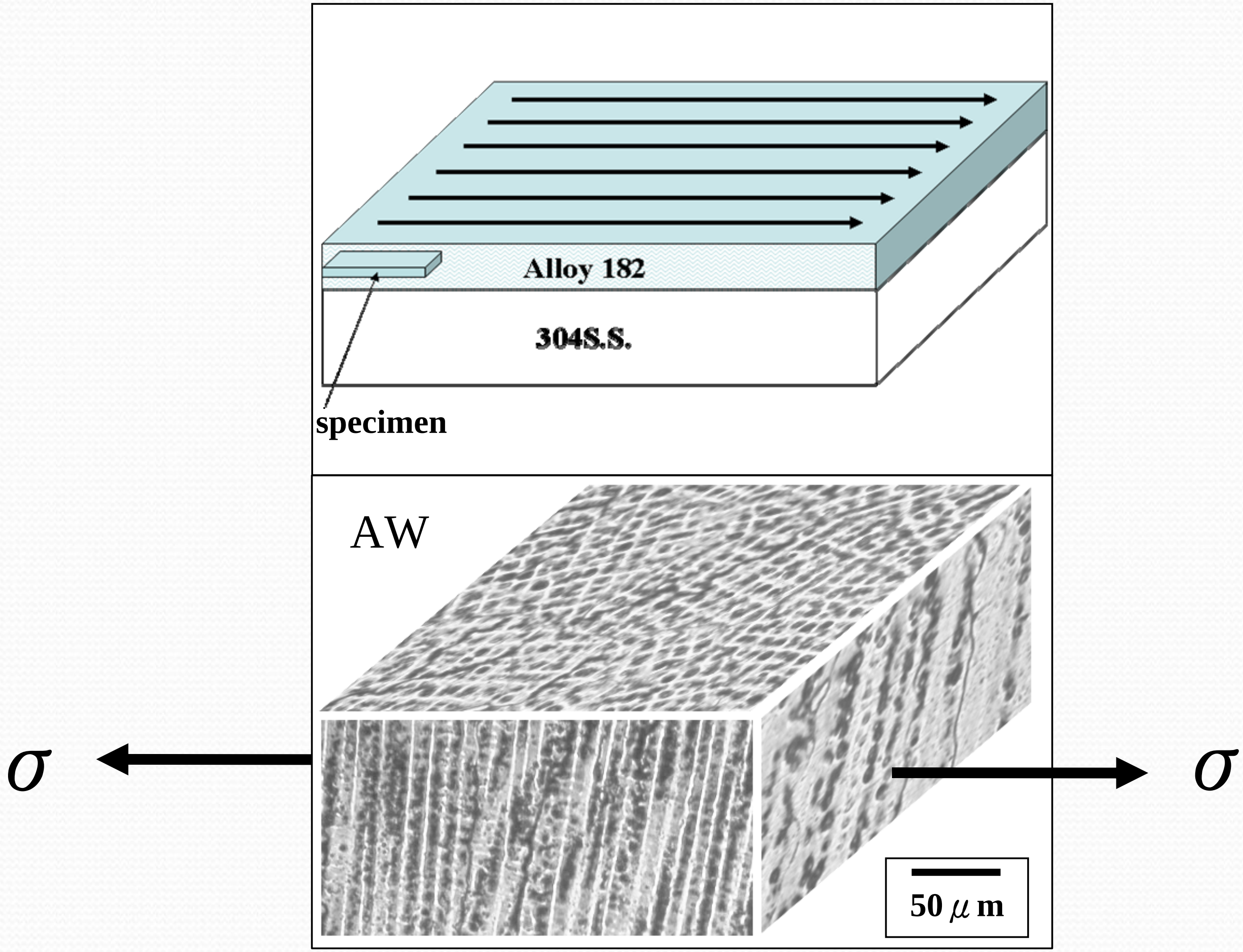


Fig. Three dimensional microstructure of Alloy 182 weld and the direction of applied stress

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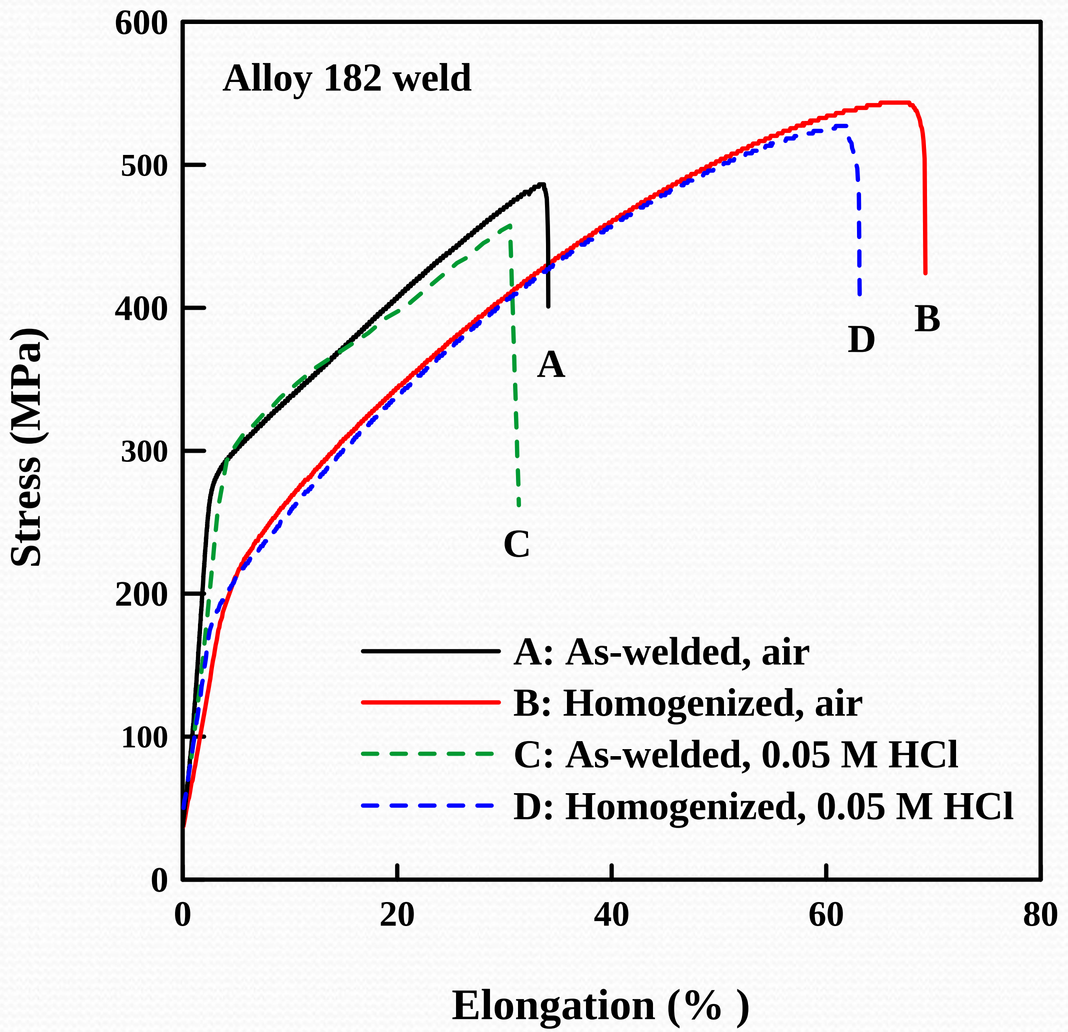
Effect of heat treatment

SSRT in Air and at OCP in 0.05 M HCl solution ($8 \times 10^{-6}\ s^{-1}$)

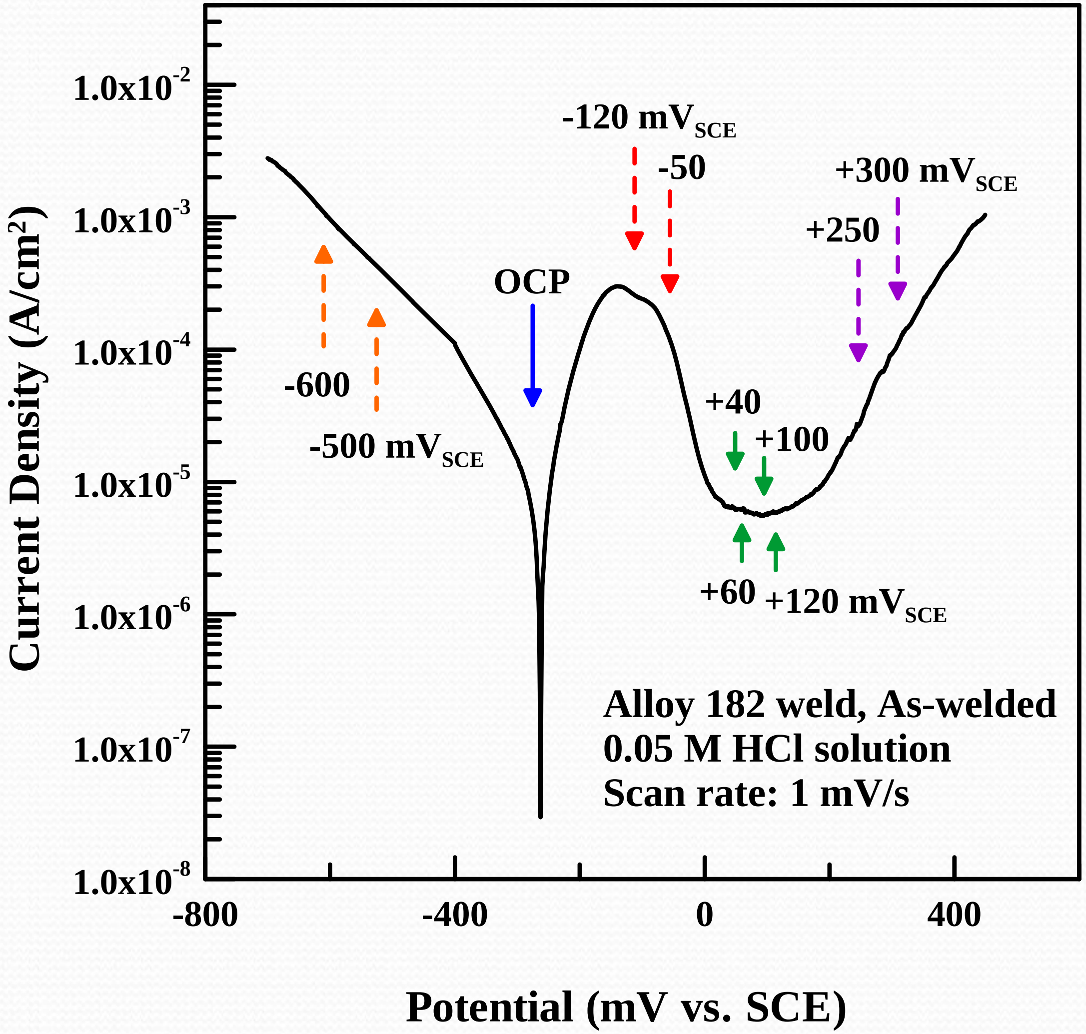


Part I.

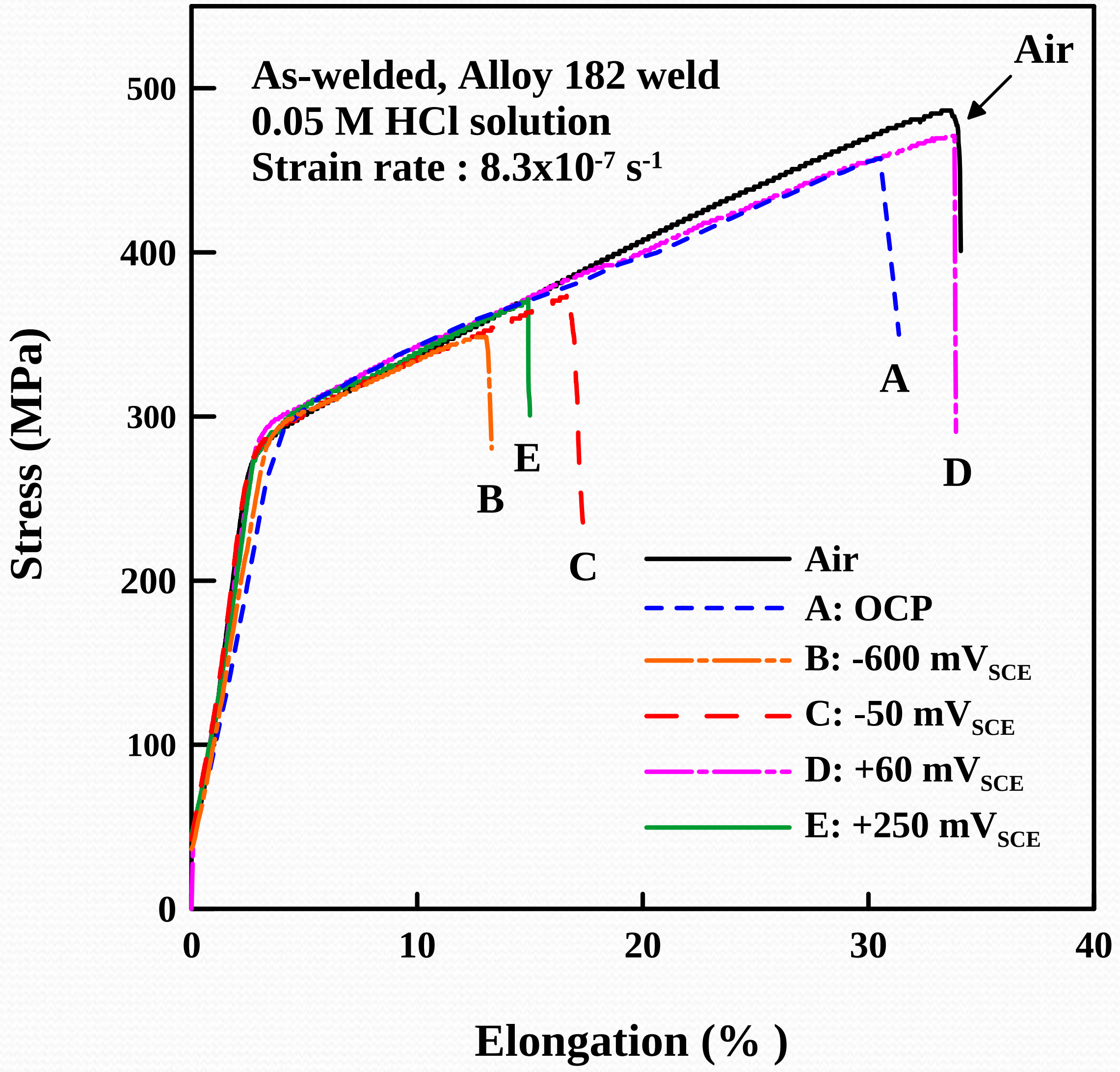
Effect of applied potential

Effect of applied potential *As-welded*

Potentiodynamic polarization curve in 0.05 M HCl solution

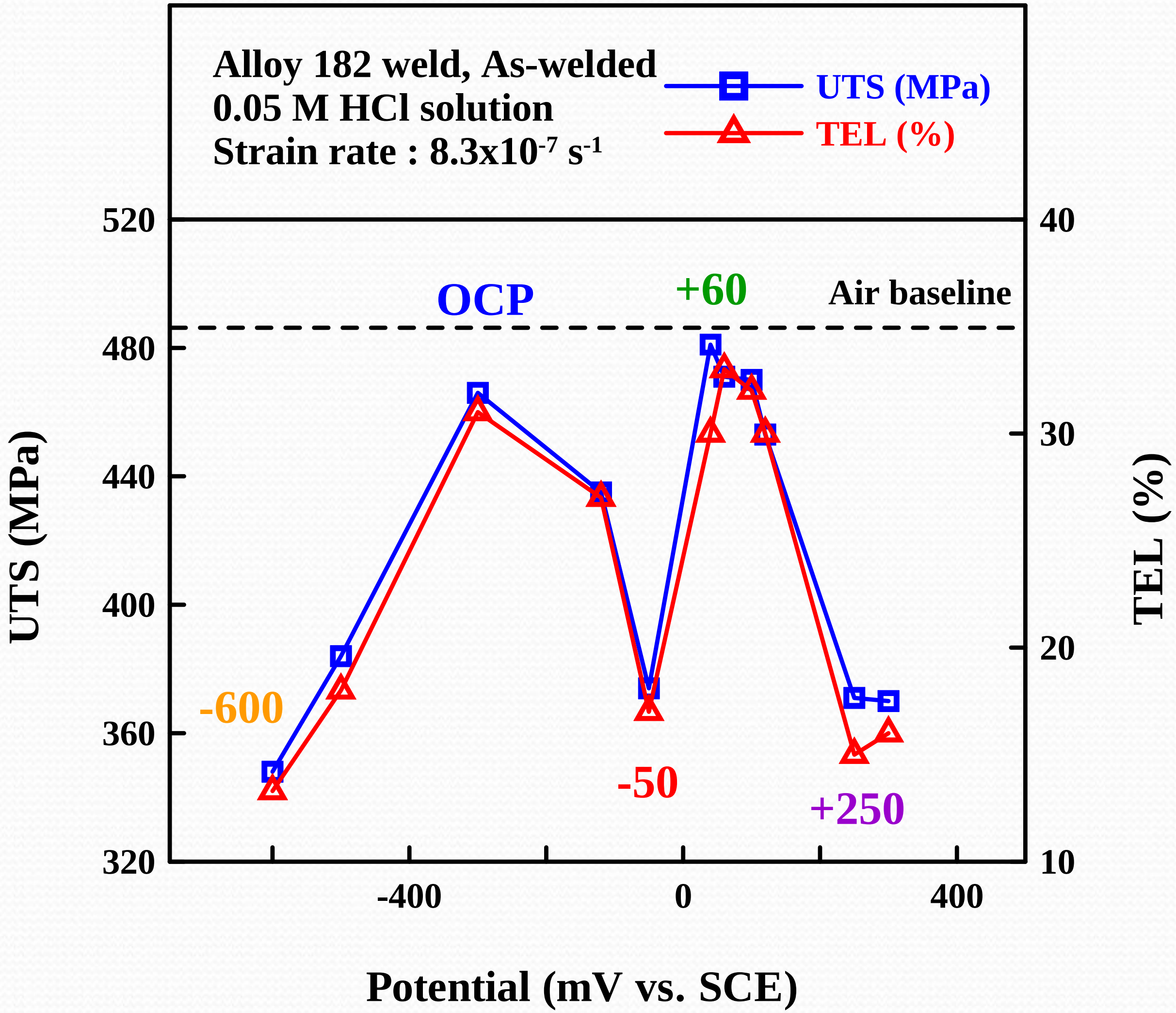


Slow strain rate test in 0.05 M HCl solution

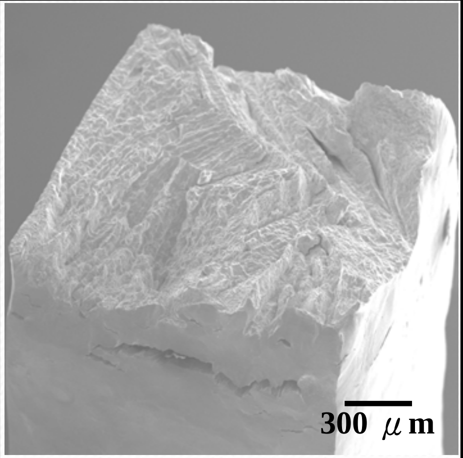
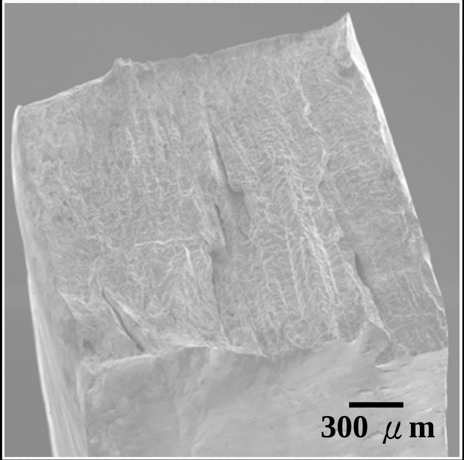
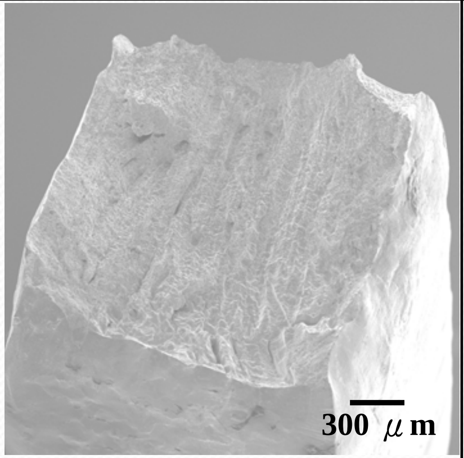
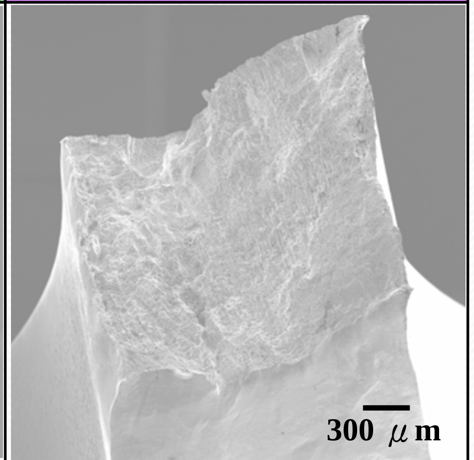
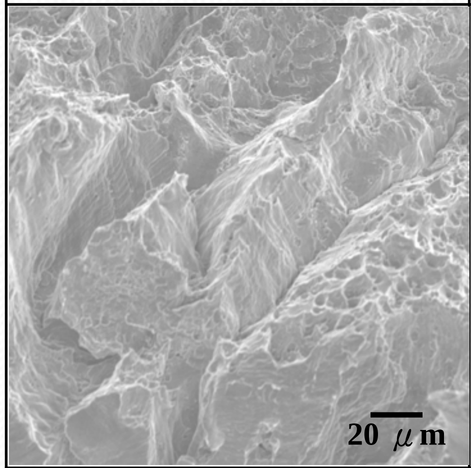
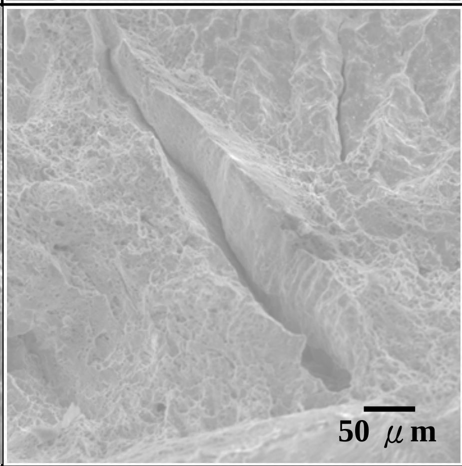
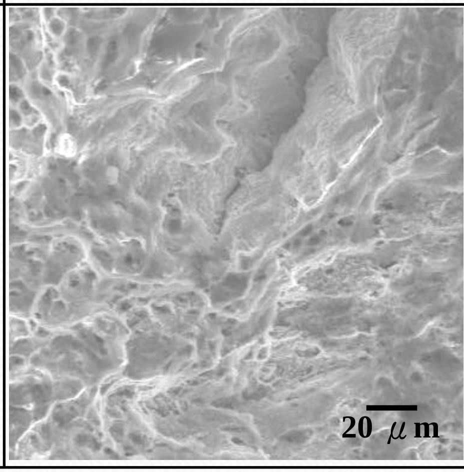
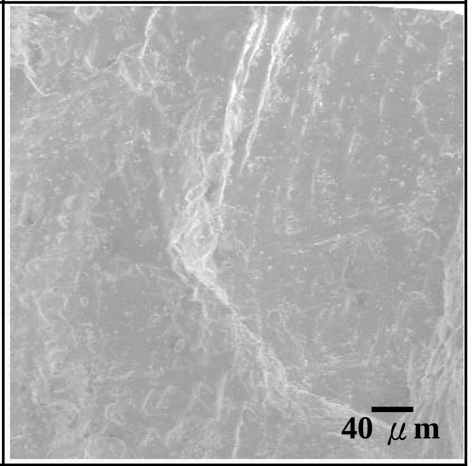


Effect of applied potential *As-welded*

Slow strain rate test in 0.05 M HCl solution

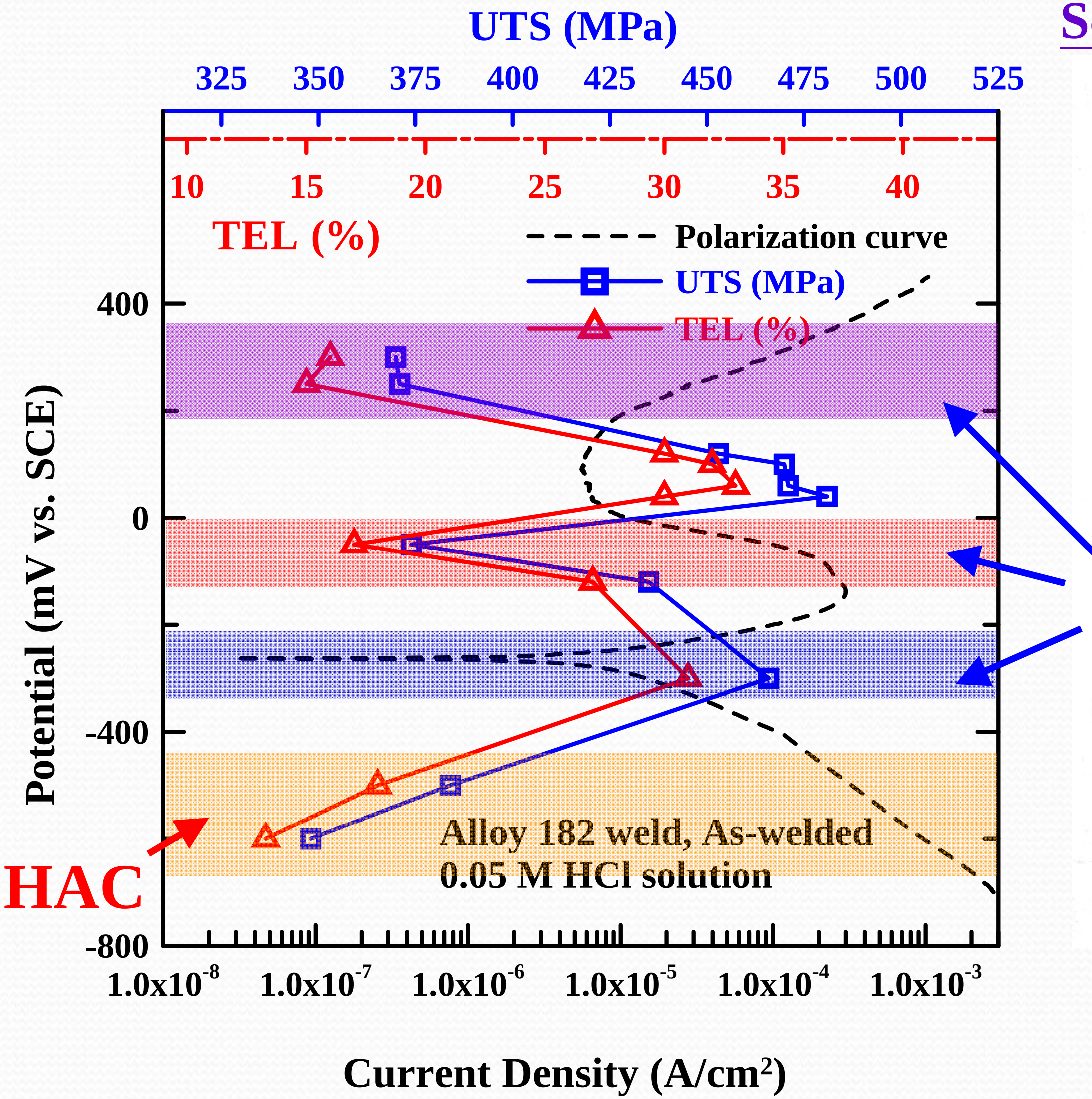


SSRT in 0.05M HCl solution at a strain rate of $8.3x10^{-7}$ s^{-1}

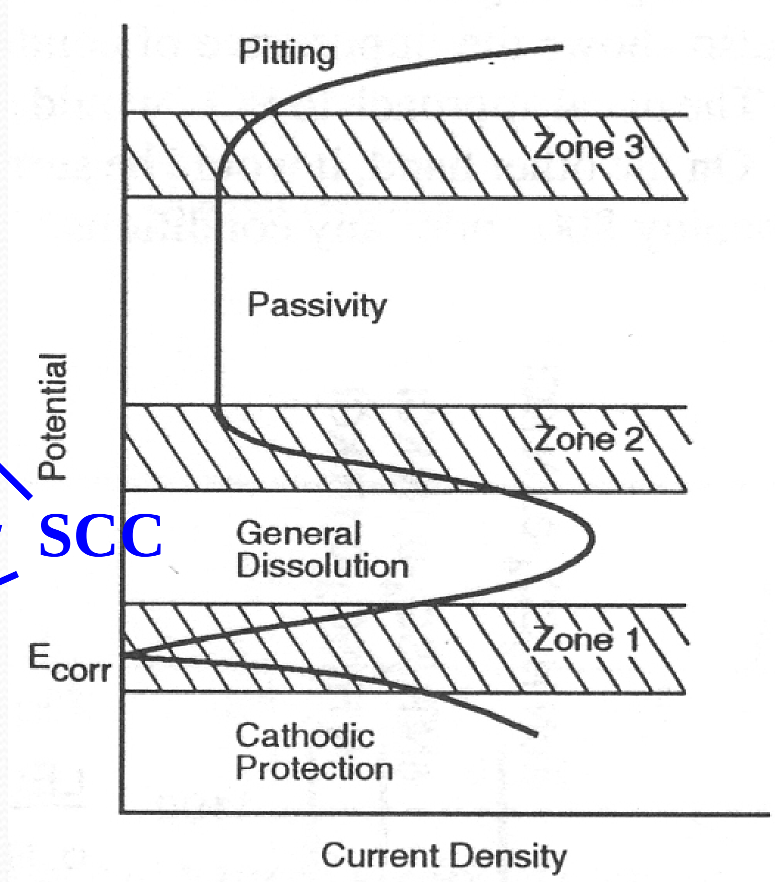
-600 mV_{SCE}	-50 mV_{SCE}	+60 mV_{SCE}	+250 mV_{SCE}
			
			

Effect of applied potential *As-welded*

Slow strain rate test in 0.05 M HCl solution



Schematic : SCC region of potentials



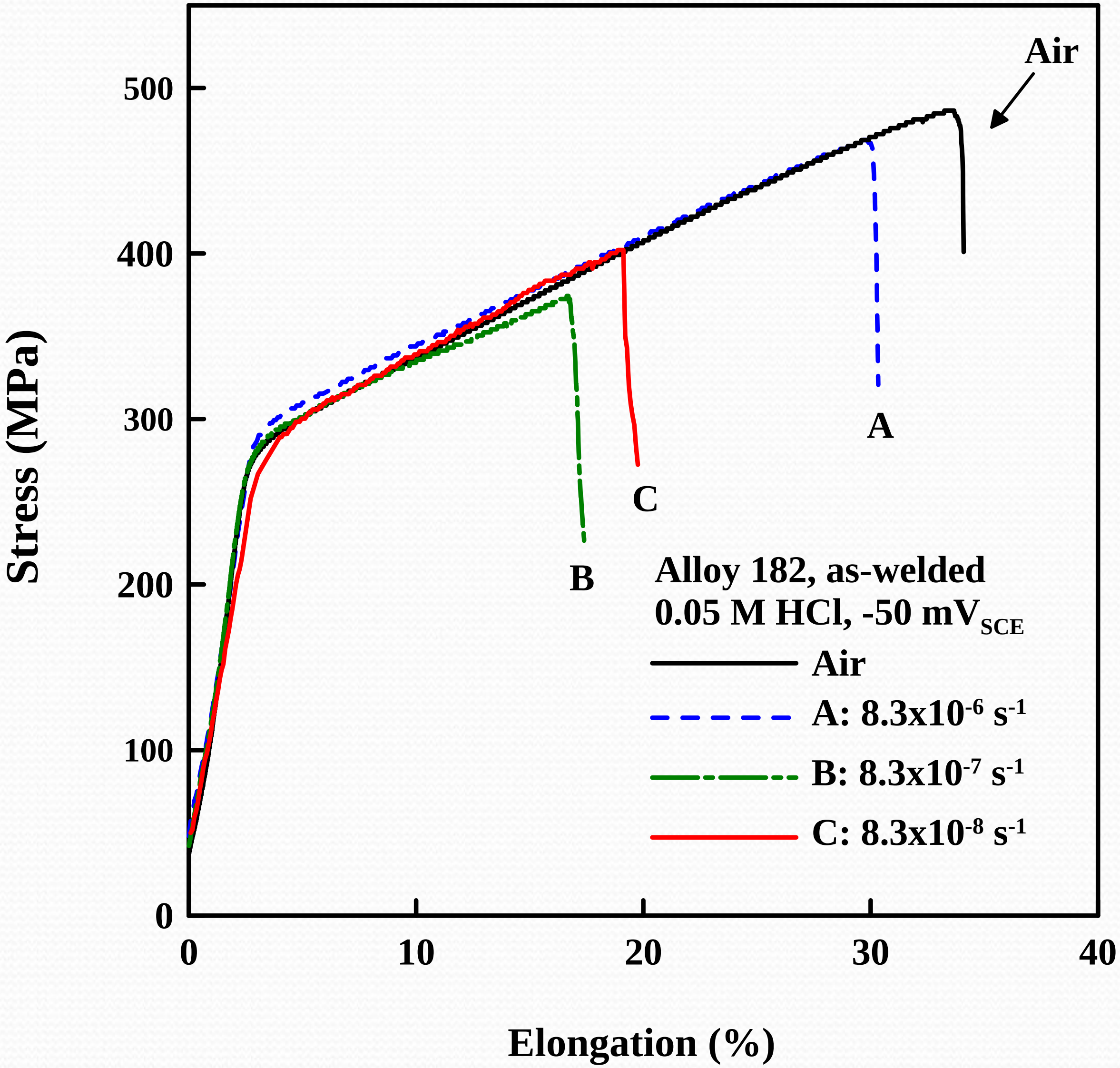
Ref. R. W. Staehle, "Stress Corrosion Cracking and Hydrogen Embrittlement of Iron Base Alloys", R. W. Staehle et al, eds., NACE-5, NACE, Houston, p. 193, 1973.

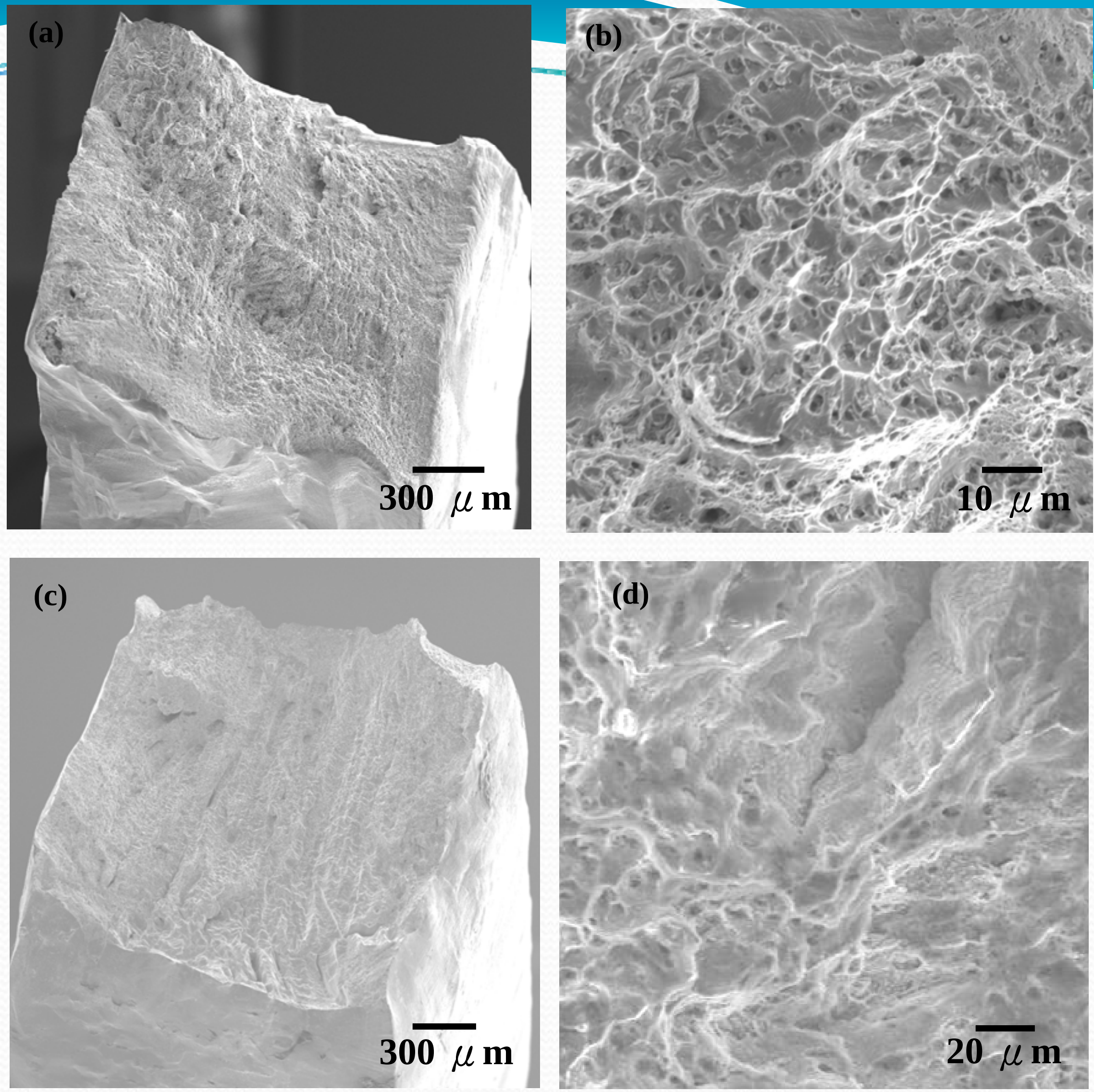
Part II.

Effect of the strain rate

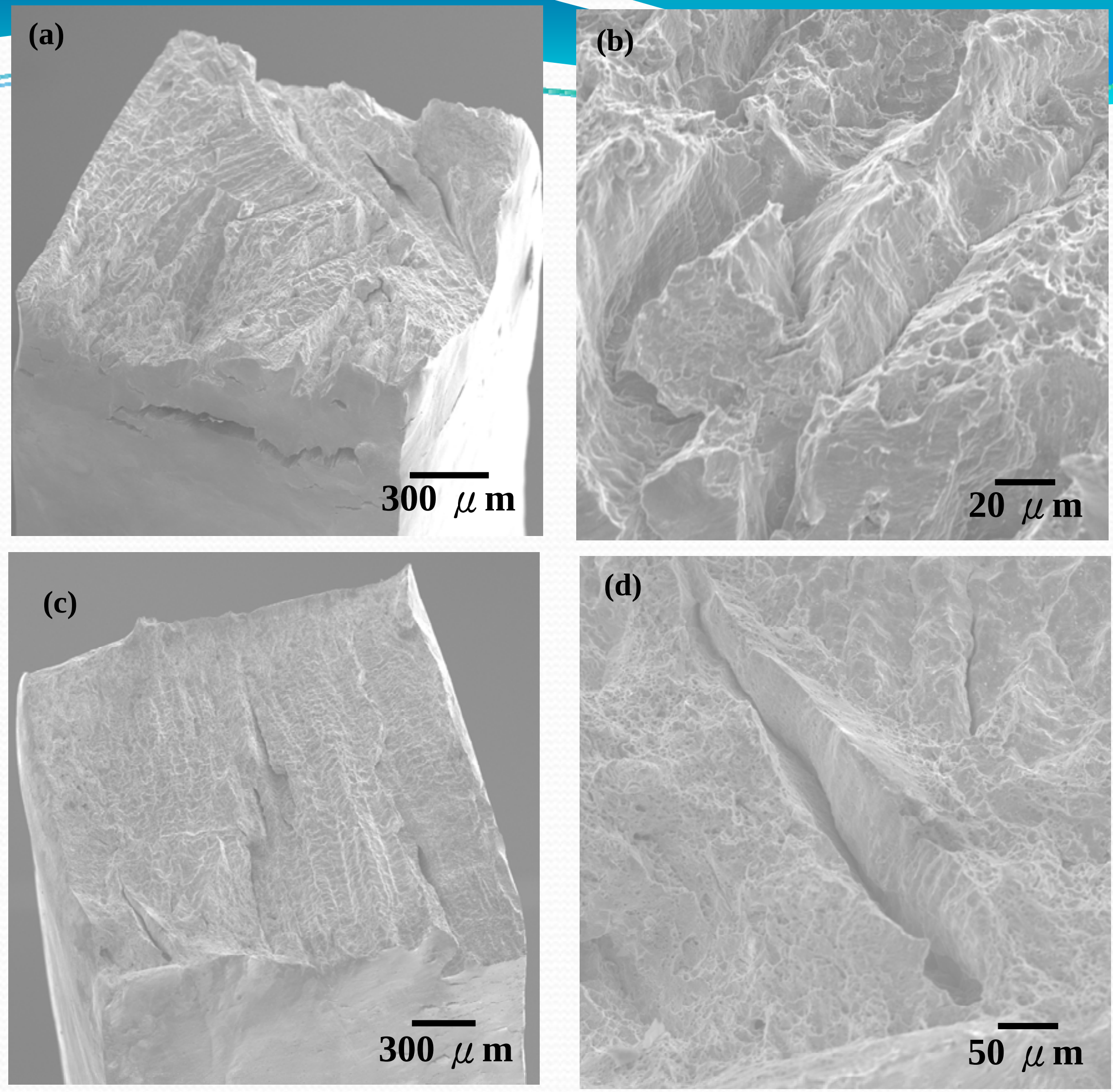
Effect of strain rate *As-welded*

Slow strain rate test in 0.05 M HCl solution

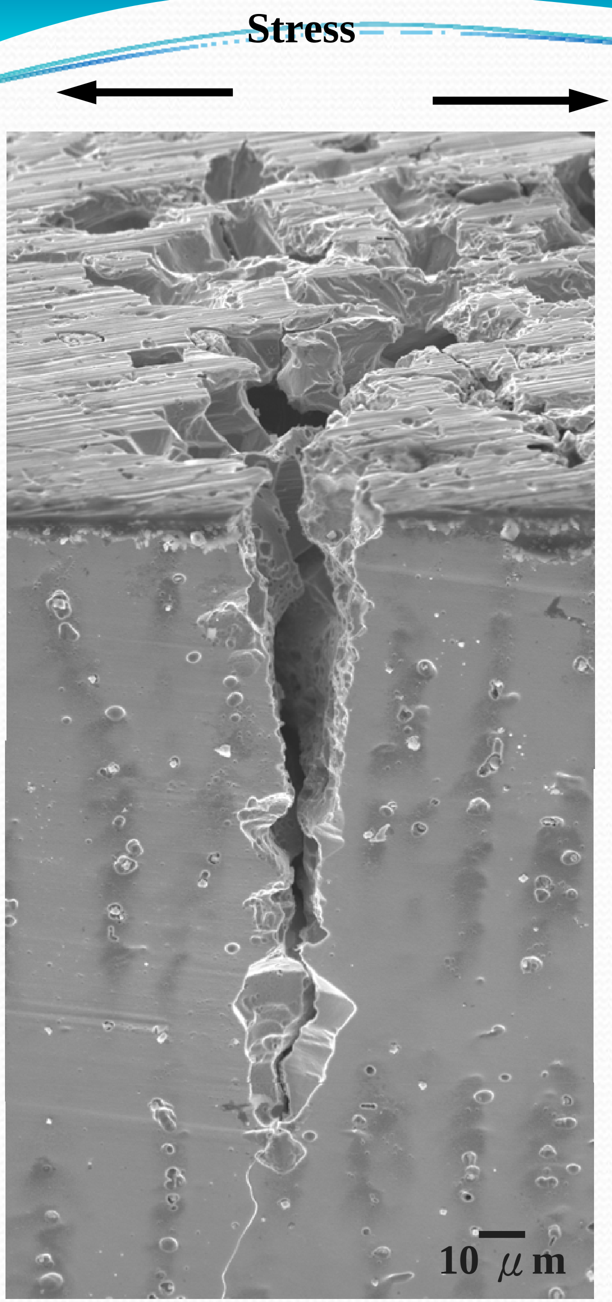




SEM micrographs showing the fracture surface morphologies for the as-welded Alloy 182 weld after SSRT in (a) air, and in 0.05 M HCl solution (c) at +60 mVSCE, respectively, at a strain rate of 8.3×10-7 s-1；(b) and (d) high magnification images for (a) and (c).

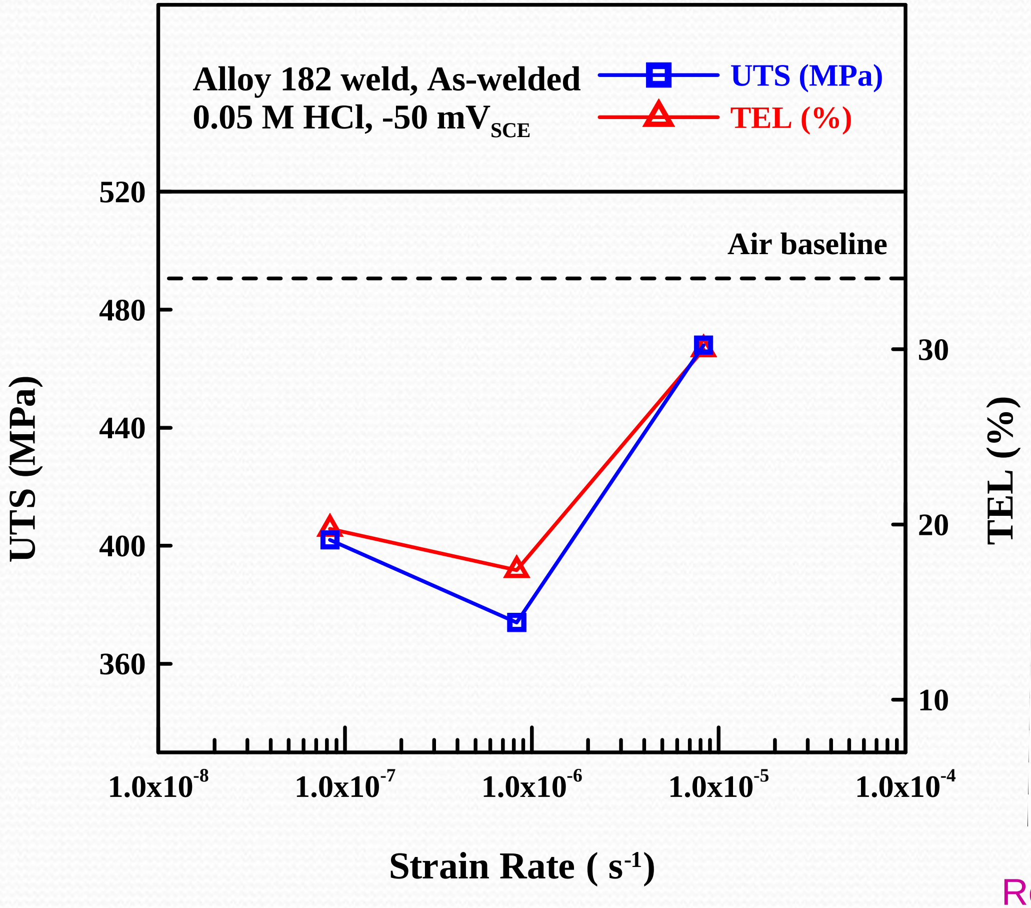


SEM micrographs showing the morphologies of the fracture surface for Alloy 182 weld after SSRT in 0.05 M HCl solution (a) at -600 mVSCE, and (c) -50 mVSCE, respectively, at a strain rate of 8.3×10-7 s-1；(b) and (d) high magnification images for (a) and (c).

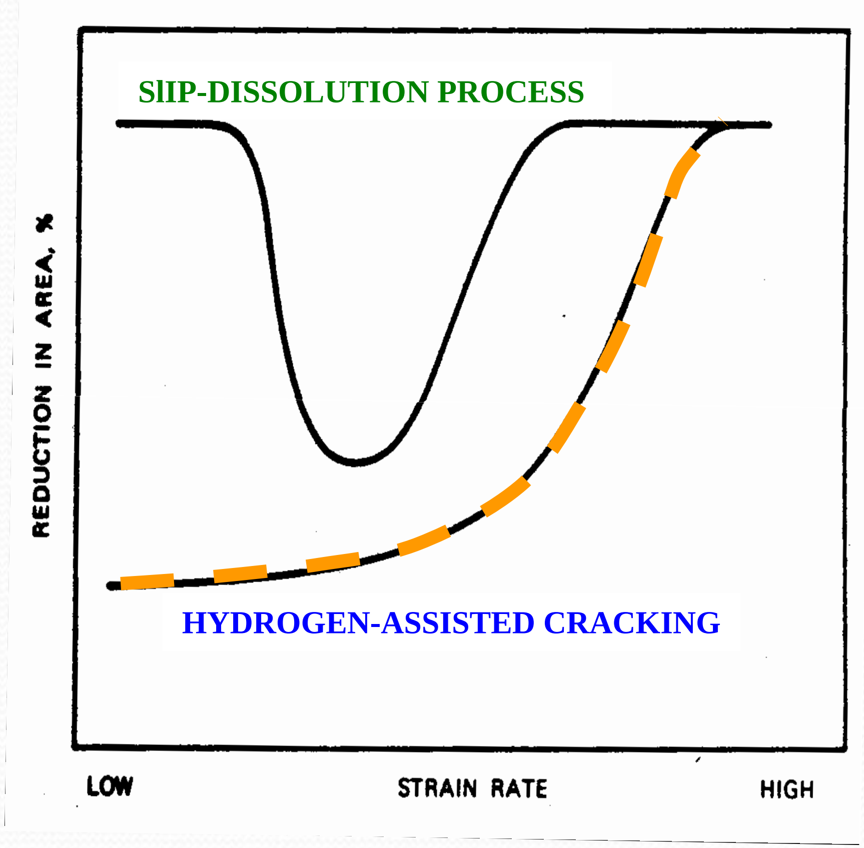


- Figure 9 - Cross section micrograph of Alloy 182 weld, showing the cracks after SSRT in 0.05 M HCl solution at -50 mVSCE at the strain rate of 8.3×10-7 s-1.

Slow strain rate test in 0.05 M HCl solution

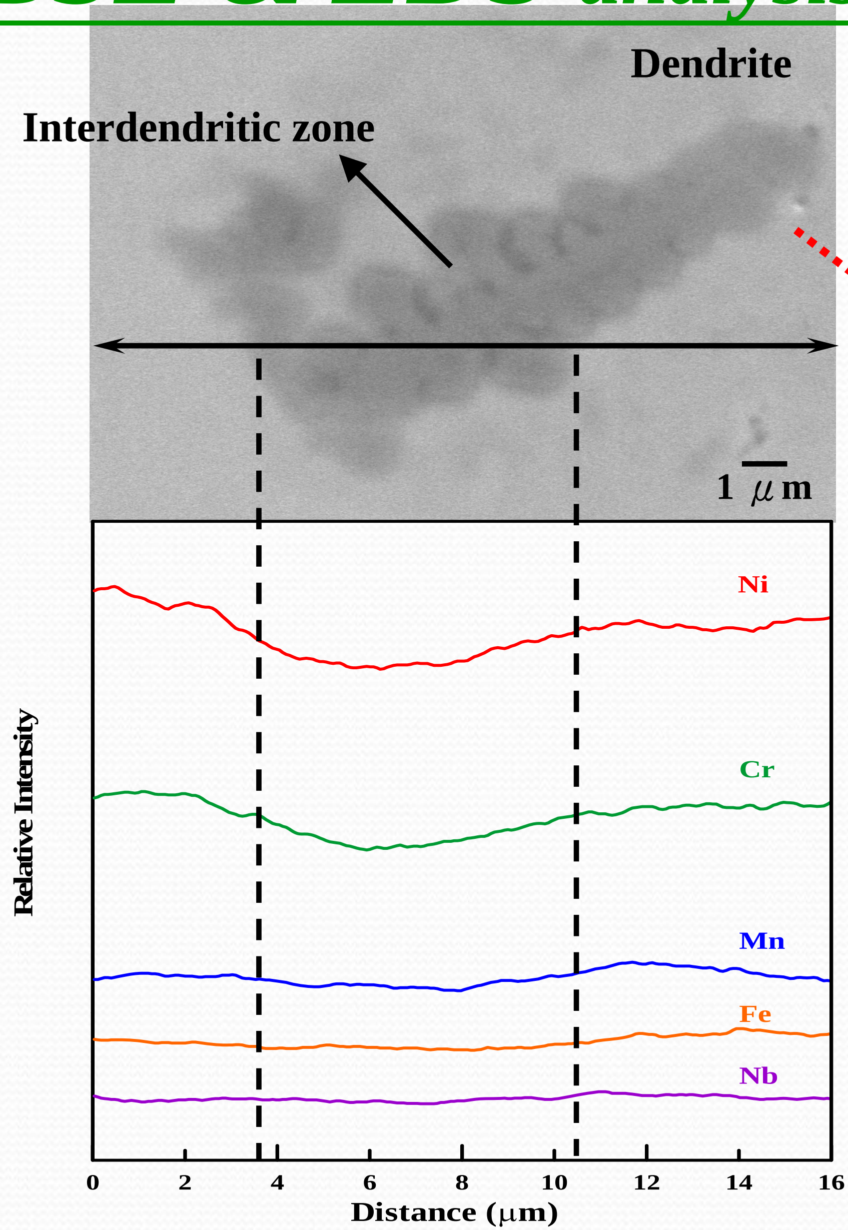


Environmentally-assisted cracking

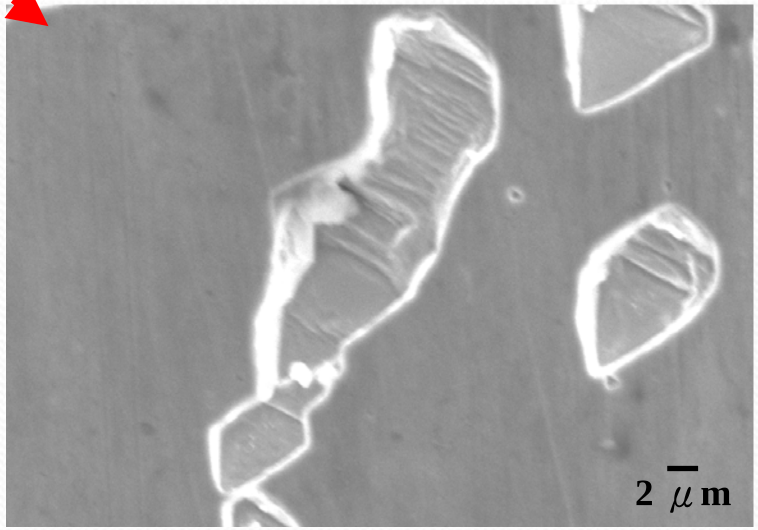


Ref. C. D. Kim and B. E. Wilde, Stress Corrosion Cracking - The Slow Strain Rate Technique, STP 665, G. M. Ugiansky and J. H. Payer, ED., ASTM, p. 97, 1979.

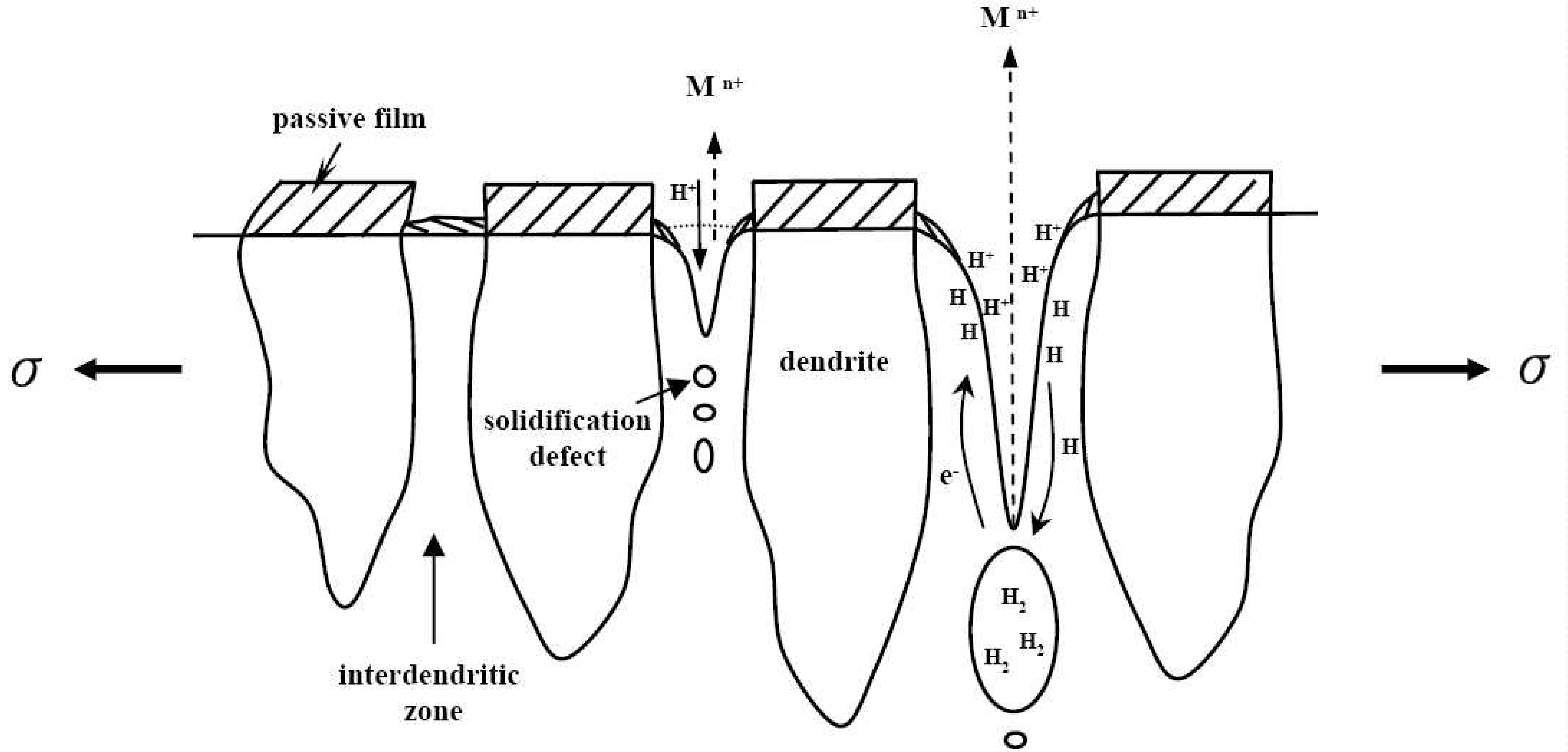
BSE & EDS analysis



0.05 M HCl, 4 Days



Schematic diagram of cracking process



1. composition induced difference in passivity
→ crack initiation
2. anodic polarization assisted local reduction of H^+
3. defects and/or tri-axial stress state assisted H absorption
4. H_2 trapped in inter-dendritic zone
→ decohesion along dendrite boundary
→ long parallel crack

Conclusions

- 1. The as-welded Alloy 182 was more susceptible to EAC in 0.05 M HCl solution at potentials in the active-to-passive transition region as well as transpassive potentials, as compared with those at open circuit potential and at passive potential. Under cathodic polarization condition, the ductility of Alloy 182 weld decreased substantially as the applied potential decreased, indicating the high susceptibility to HAC. In 0.05 M HCl solution and at active-to-passive potential, the SSRT results demonstrated that EAC susceptibility increased with decreasing strain rate, indicating the involvement of HAC in the cracking process.
- 2. A difference in chemical composition was noted between the dendrite and the interdendritic zone of the Alloy 182 weld. The interdendritic zone was less resistant to corrosion in the acidic solution and was the most favorable site for crack initiation and propagation.

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Acknowledgements

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Thank you for your attention!