Crevice Corrosion Propagation Behavior of Alloy 22 in Extreme Environments

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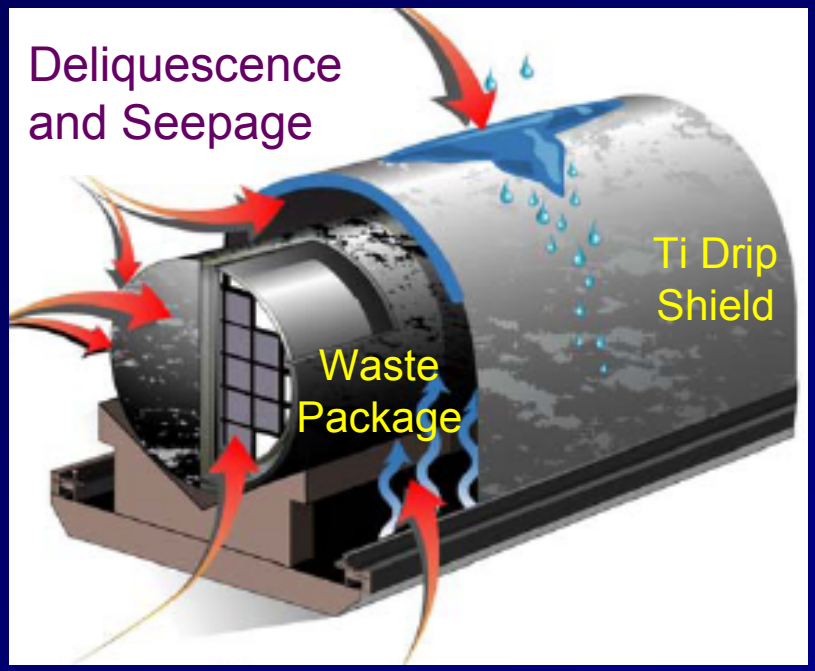
Outline

- Background
- Objectives
- Experimental Setup
- Experimental Results on Alloy 22 Crevice Corrosion

Background: U.S. Department of Energy Potential Engineered Barrier System for Yucca Mountain Repository

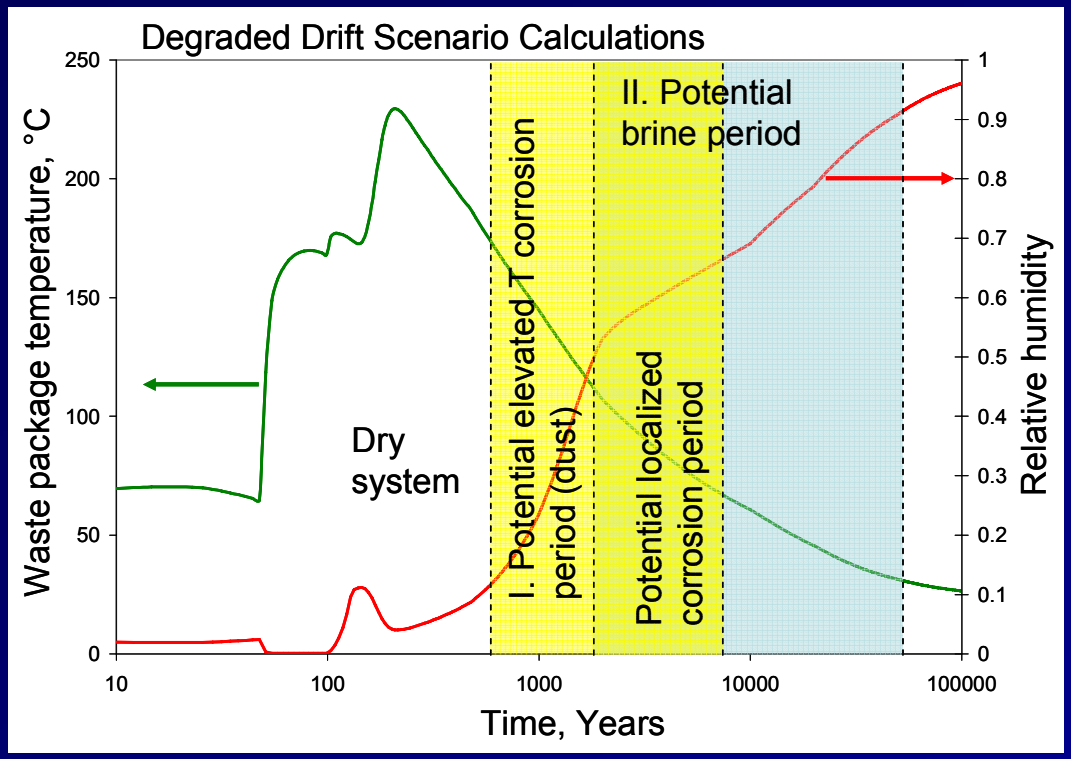


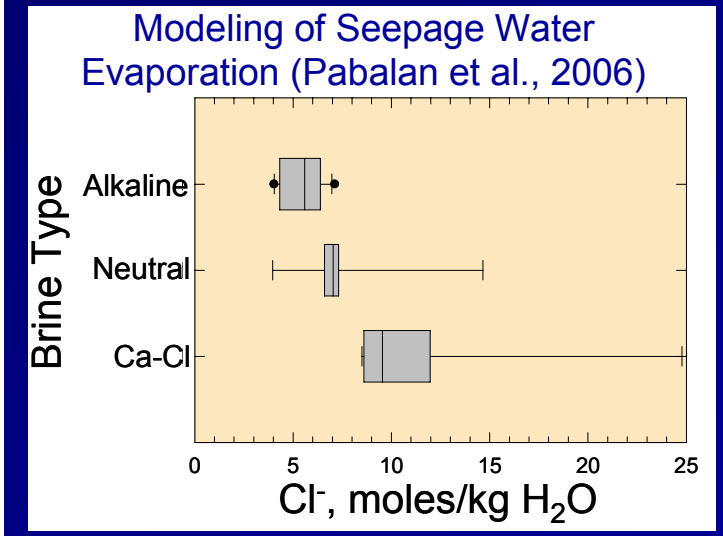
(Modified from U.S. Department of Energy, 2006)

Degradation processes with high to medium significance to waste isolation for the waste package outer container include:

- Persistence of a passive film (high)
- Waste package failure mode (medium)
  - General corrosion
  - Localized corrosion
  - Microbially influenced corrosion
- Stress corrosion cracking (medium)

Background: Thermal Periods

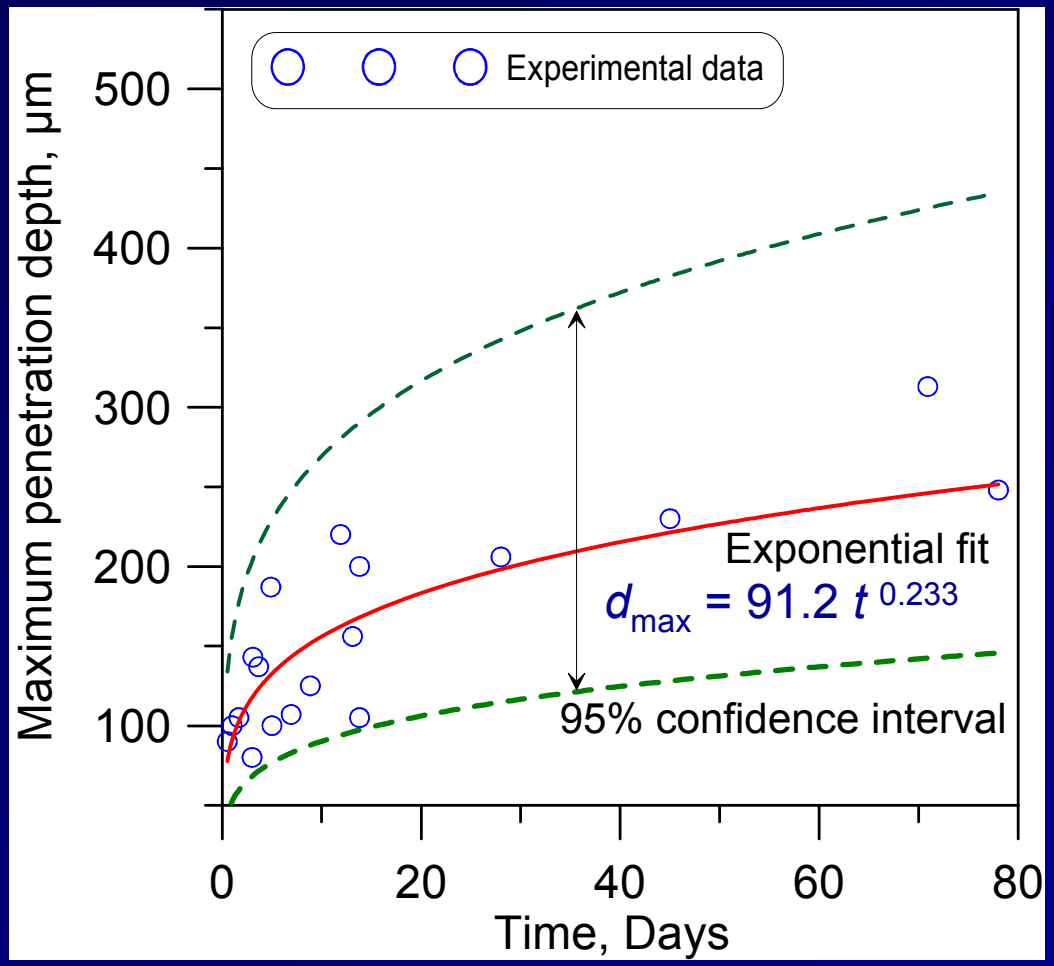




- Region I: No seepage (elevated temperature)
- Region II: Evaporation rate > seepage rate. Brine formation if seepage contacts waste packages

- Brines formed by seepage water evaporation are rich in chloride (based on thermodynamic modeling)

Background: Previous Work* on Alloy 22 Crevice Corrosion Propagation



- Tests conducted in 5 M NaCl + 2×10^{-4} M $CuCl_2$ (oxidant added to raise E_{corr}) at 95 °C
- Alloy 22 crevice corrosion propagation showed strong tendency to stifling and repassivation

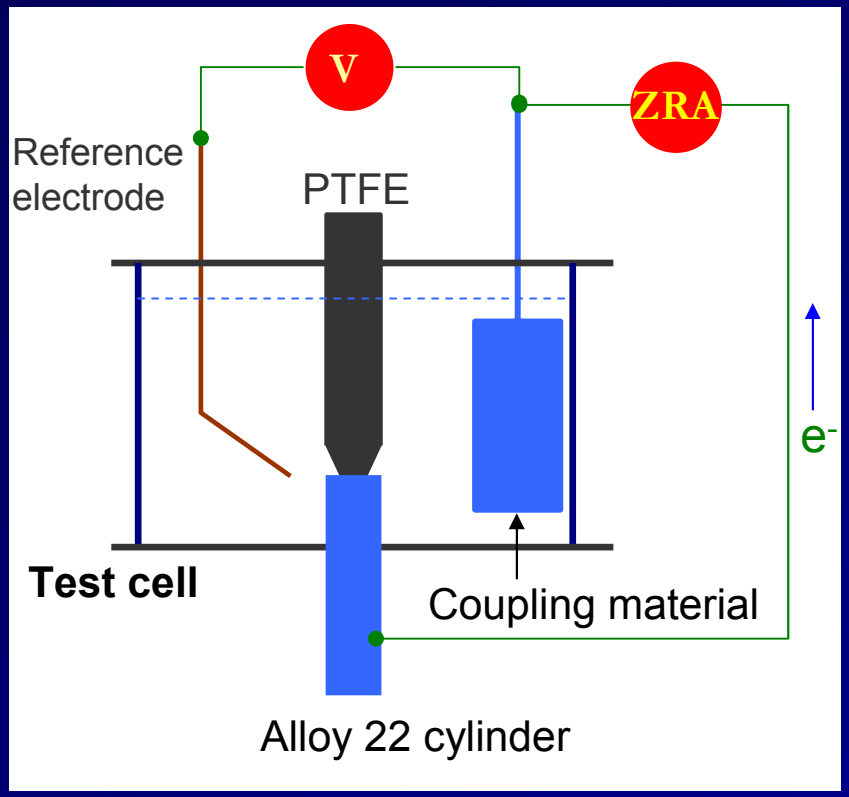
* NACE paper 06618, He et al., 2006

Objectives

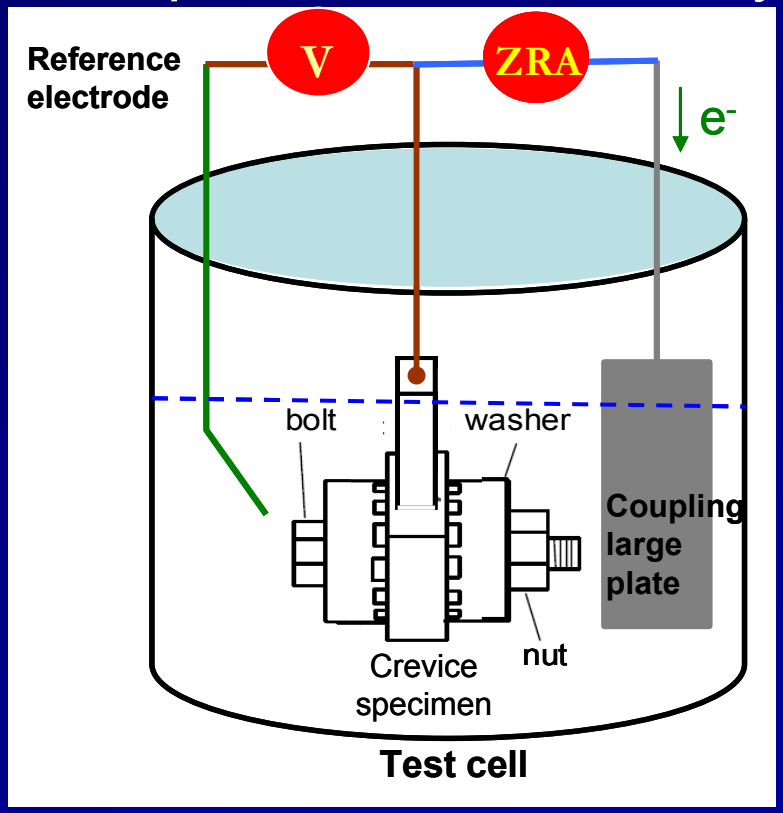
- Evaluate the crevice corrosion propagation behavior of Alloy 22 in chloride-rich solution at elevated temperatures
- Compare with crevice corrosion propagation behavior of Alloy 22 previously studied in 5 M NaCl solution at 95 °C
- Reduce the uncertainties in the current understanding of crevice corrosion stifling and repassivation processes
  - At higher temperatures
  - Under more aggressive chemical conditions

Galvanic Coupling Test Cell

Single Crevice Assembly



Multiple Crevice Assembly

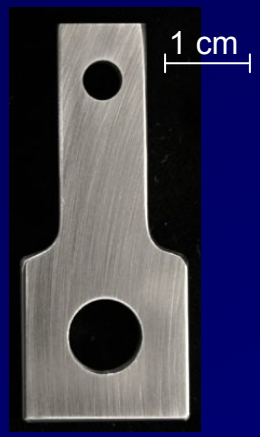


- Solutions: 4 M $MgCl_2$*, 4 M $CaCl_2$, or 5 M NaCl
- Temperatures: 95 °C or 110 °C
- Coupling materials: Alloy 22, Titanium Grade 7, or Platinum

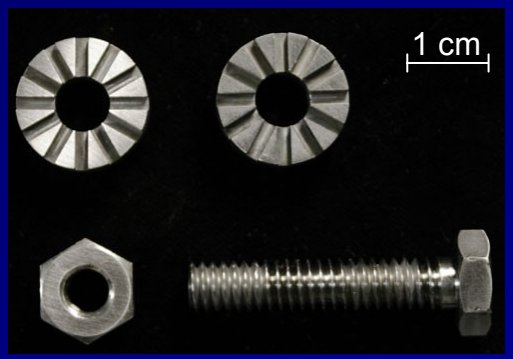
* $MgCl_2$ solution was used as an analog for $CaCl_2$

Alloy 22-to-Metal Crevice Assemblies and Chemical Composition of Materials (Weight Percent)

Crevice Specimen



Serrated Alloy 22 or Titanium Grade 7 Crevice Washer, Bolt, and Nut

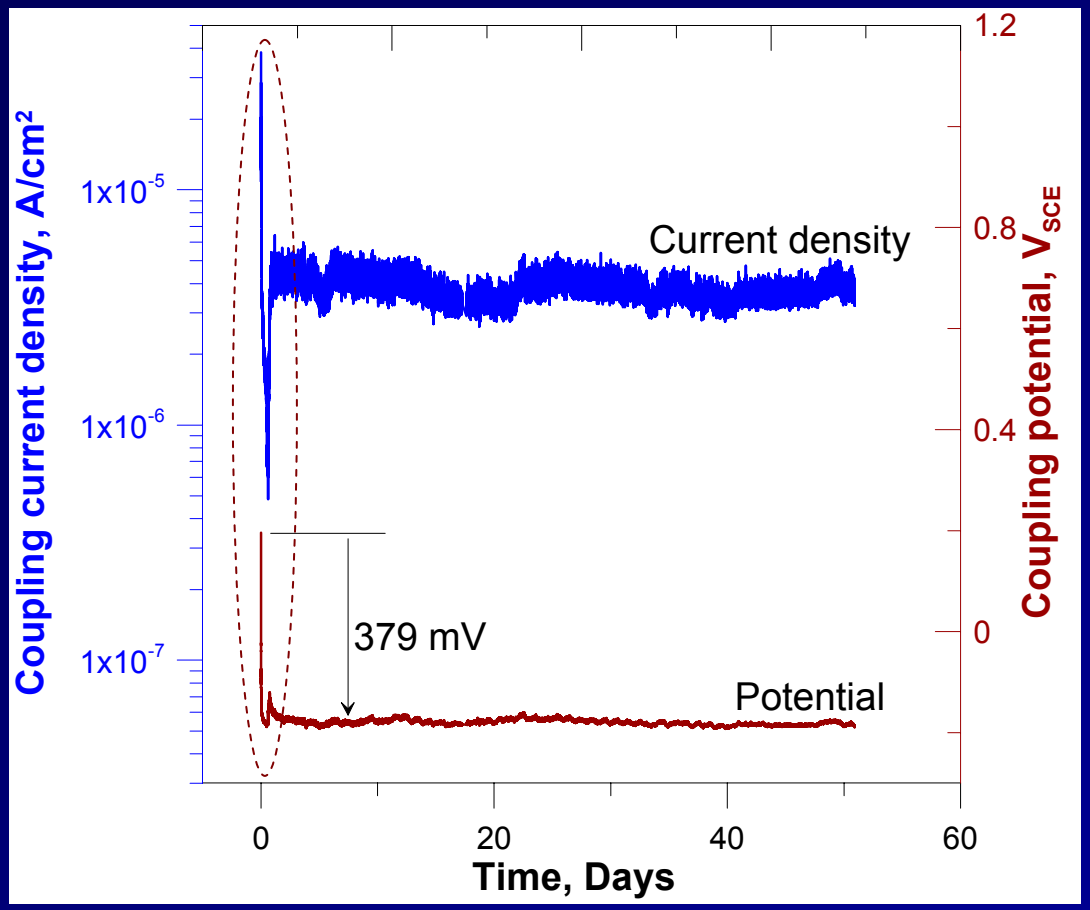


Torque used to assemble metal-to-metal crevices: 8.4 N·m

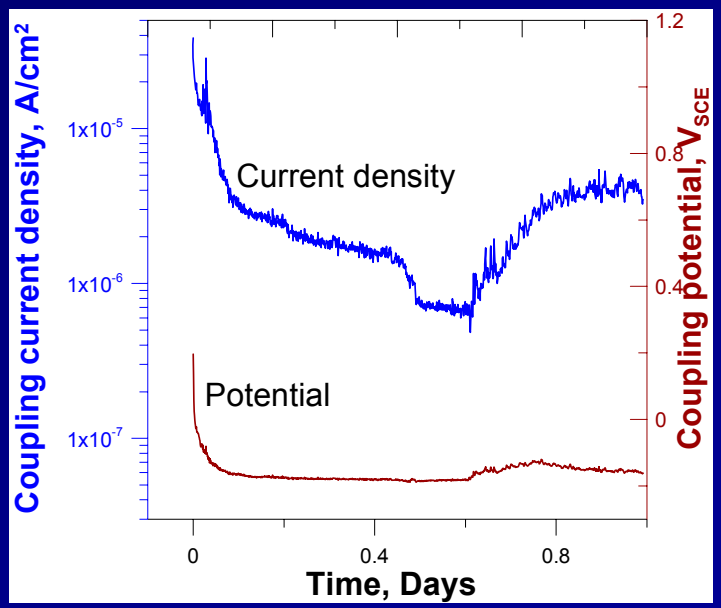
Material	Ni	Cr	Mo	W	Fe	Co	Si	Mn	V	P	S	C
Alloy 22 Heat 2277-3-3266	Bal	21.4	13.3	2.81	3.75	1.19	0.03	0.23	0.14	0.008	0.004	0.005

	Ti	Pd	Fe	C	N	O	H
Titanium Grade 7 Heat CN2775	Bal	0.16	0.08	0.01	0.01	0.13	0.001

Crevice Corrosion of Alloy 22 Coupled to Platinum in 4 M $MgCl_2$ at 110 °C

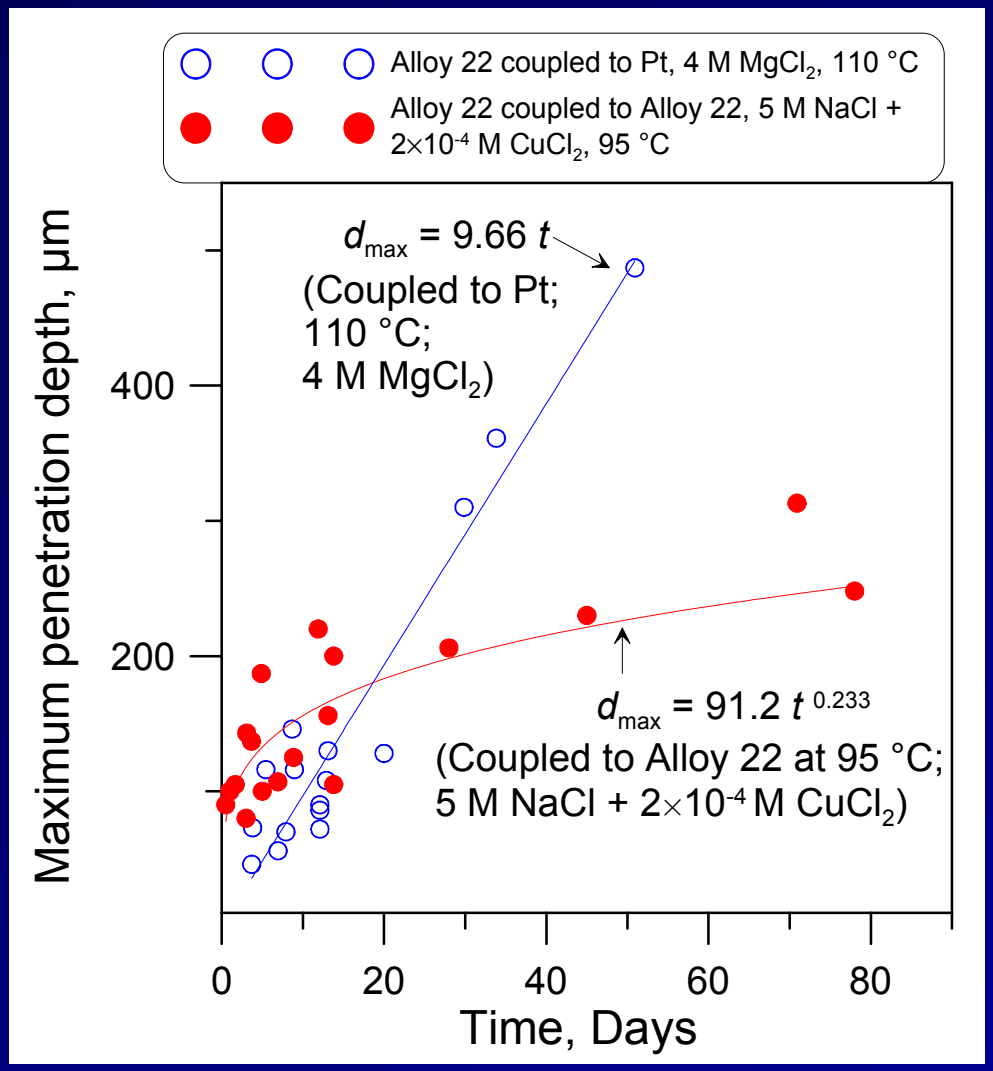


Early Period



- Crevice corrosion
  - Initiated instantaneously
  - Propagated steadily

Crevice Corrosion Penetration Depth of Alloy 22 Coupled to Platinum



- Fitted equation

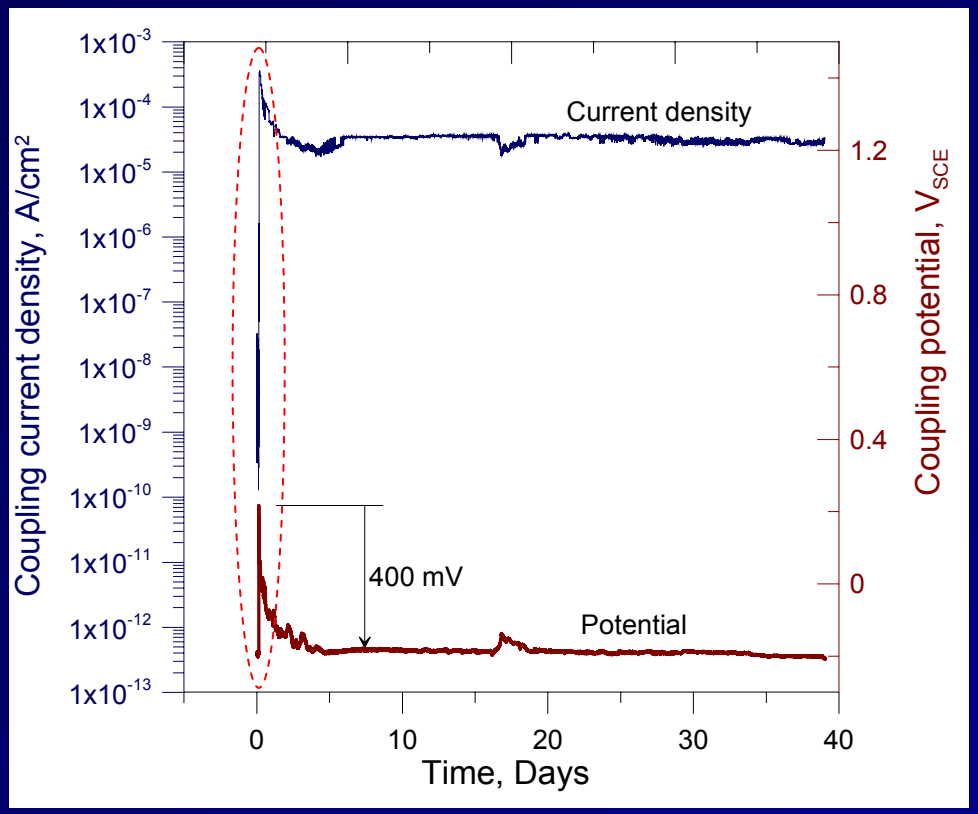
  $d_{max} = 9.66\ t$

  d_{max} — Maximum penetration depth (µm)

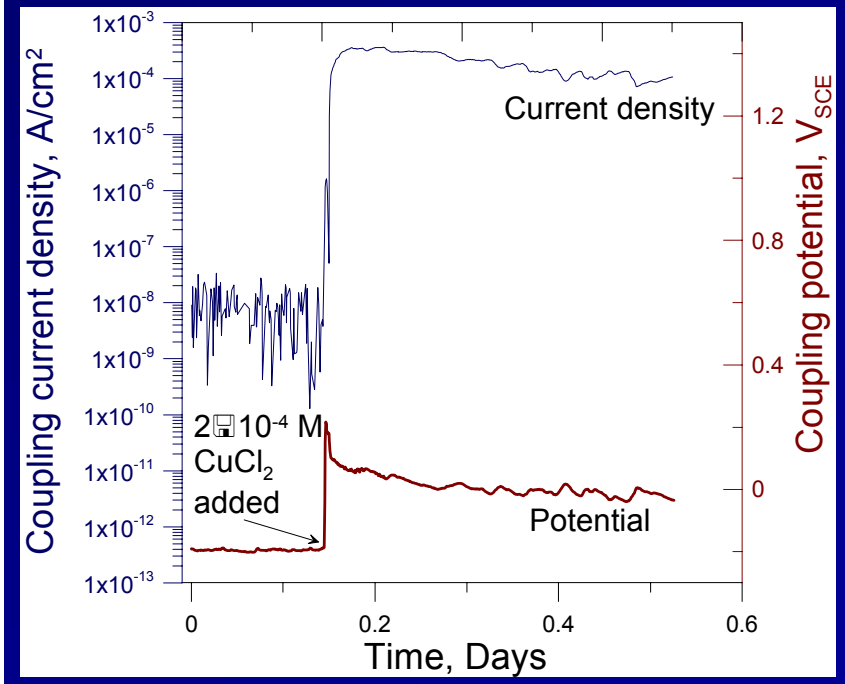
  t — time (days)

- Faster propagation than when coupled to Alloy 22 in 5 M NaCl solution

Crevice Corrosion of Alloy 22 Coupled to Titanium Grade 7 in 5 M NaCl at 95 °C

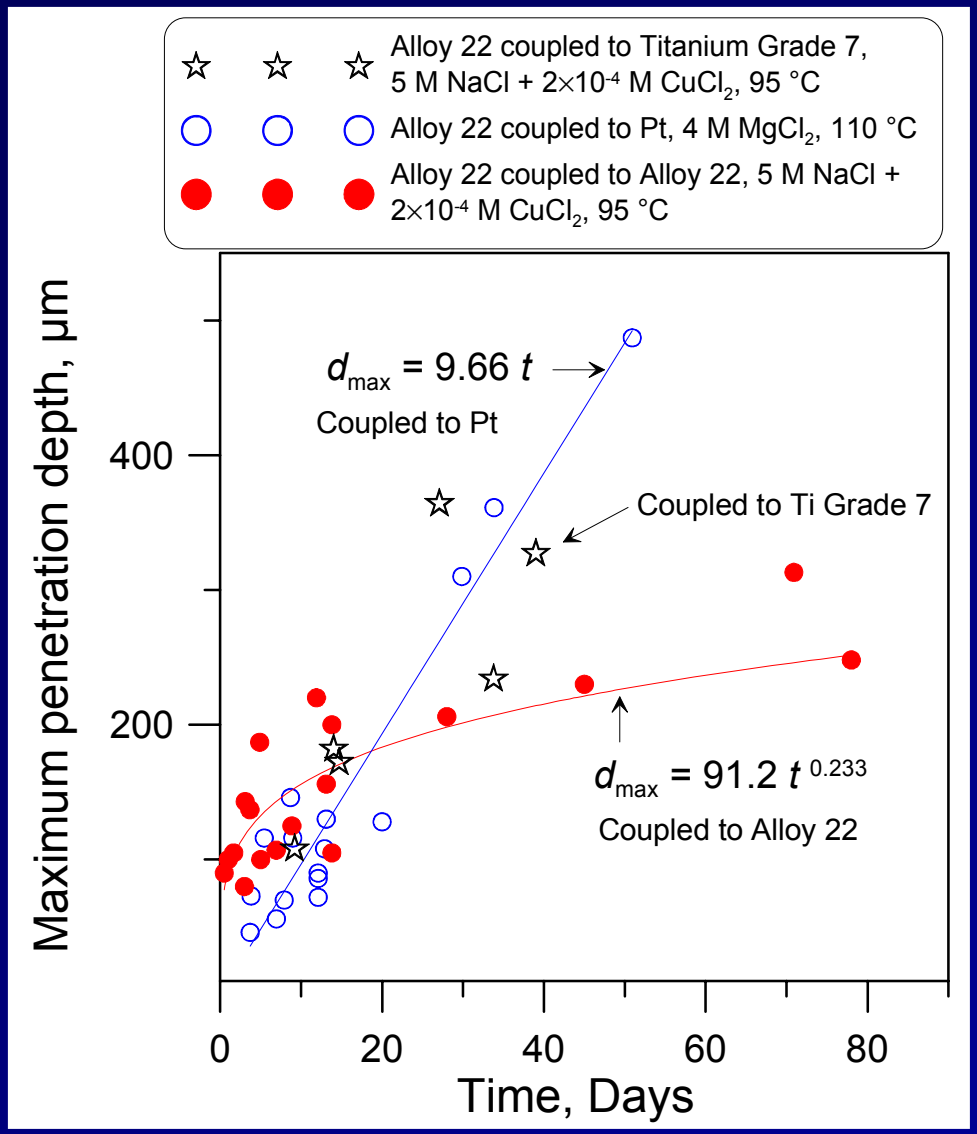


Early Period



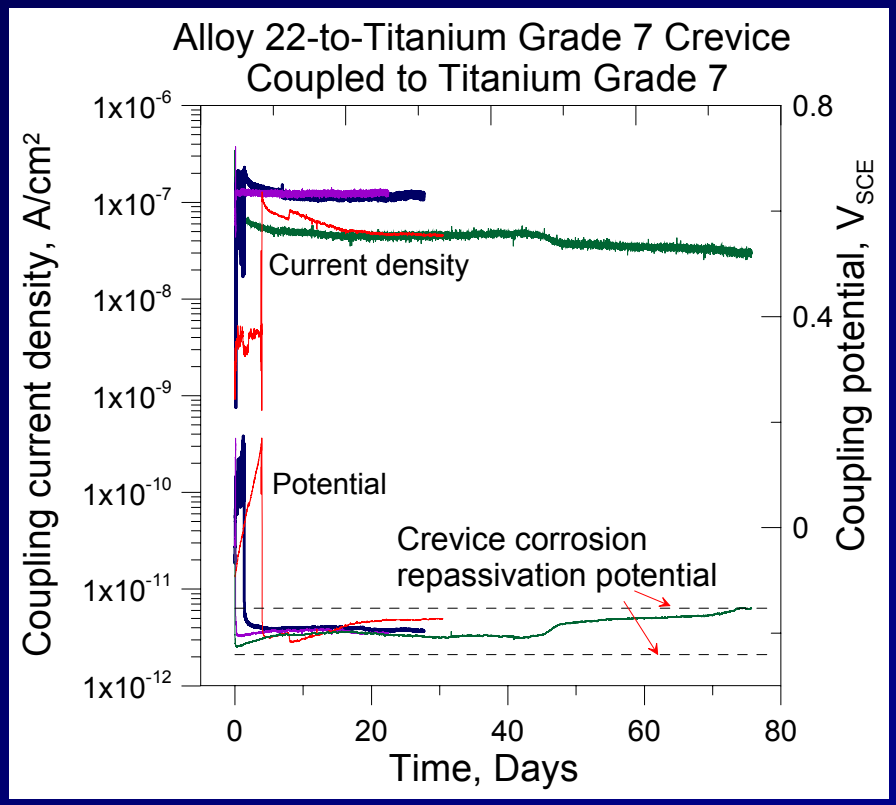
- Crevice corrosion initiated with the addition of 2×10^{-4} M $CuCl_2$ solution (oxidant added to raise E_{corr})
- After initiation, current dropped by 1–2 orders of magnitude

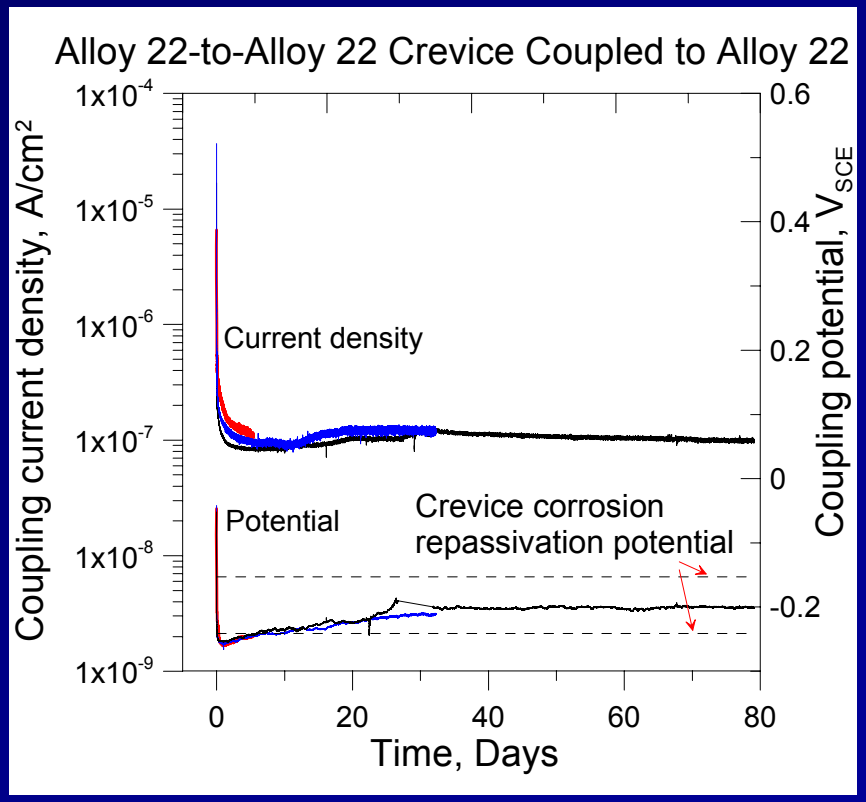
Crevice Corrosion Penetration Depth of Alloy 22 Coupled to Titanium Grade 7



- Limited data shows that coupling to Titanium Grade 7 resulted in deeper penetration than coupling to Alloy 22

Alloy 22-to-Metal Crevice Coupled to Alloy 22 or Titanium Grade 7 in 4 M $MgCl_2$ at 95 °C



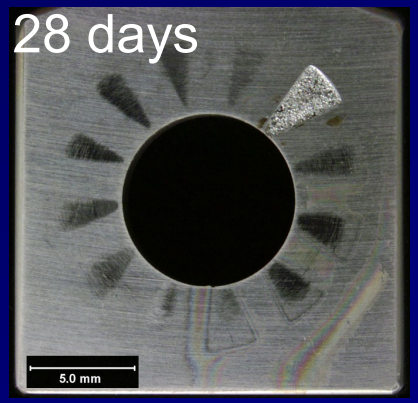


- Crevice corrosion initiated at open circuit and maintained steady propagation
- After initiation, current dropped by 1–2 orders of magnitude

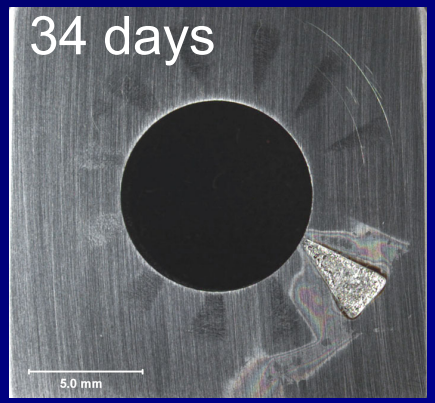
Alloy 22 Specimens from Alloy 22-to-Ti Grade 7 Crevice Coupled to Ti Grade 7

In 4 M $MgCl_2$ at 95 °C

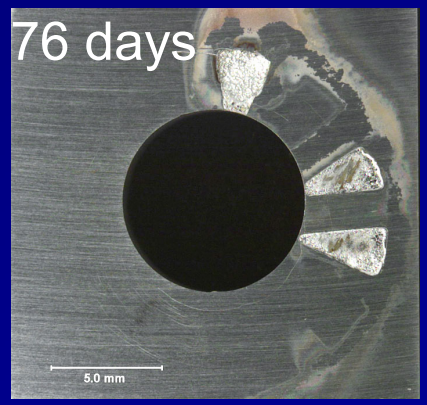
d_{max} = 130 µm



d_{max} = 155 µm



d_{max} = 77 µm

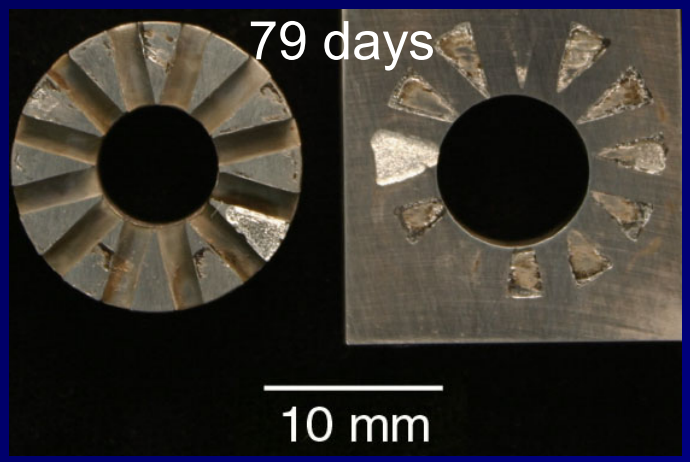


d_{max} = 277 µm

- No crevice corrosion was observed on Titanium Grade 7
- Limited crevice sites (1–3 out of 24 sites) were initiated on Alloy 22 crevice specimens

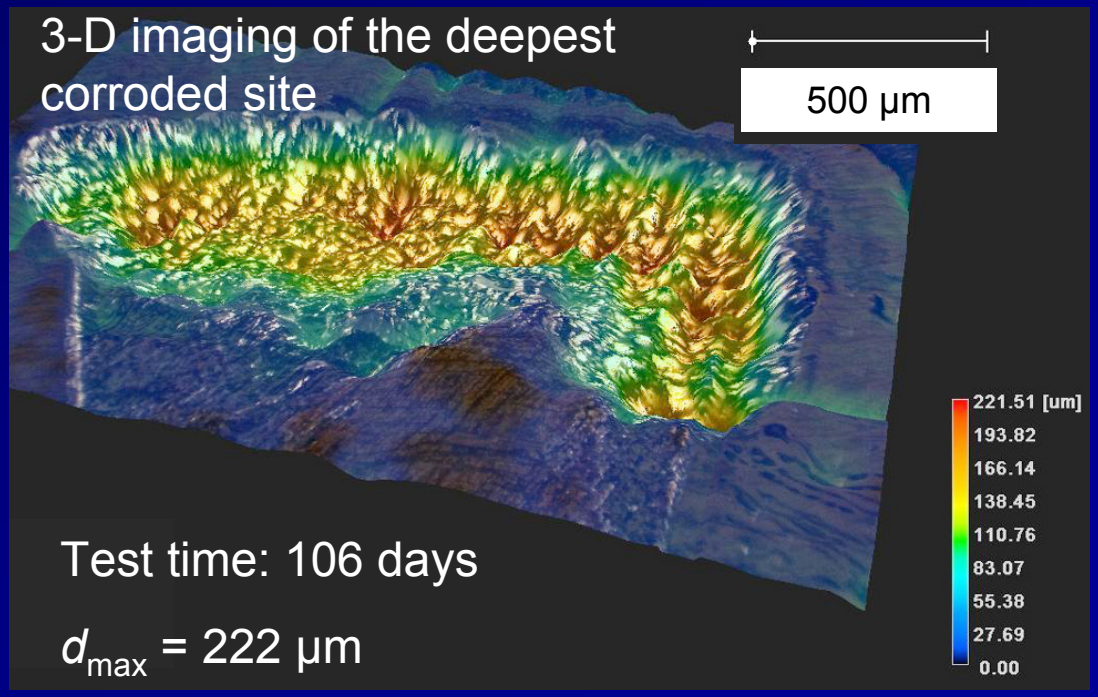
Alloy 22 Specimens from Alloy 22-to-Alloy 22 Crevice Coupled to Alloy 22

In 4 M $MgCl_2$ Solution at 95 °C



d_{max} = 245 µm

One Test in 4 M $CaCl_2$ Solution at 95 °C



- Most sites were corroded; however, the penetration depth was limited, and the deepest penetration was confined to a small area

Summary and Conclusions

- Crevice corrosion of Alloy 22-to-metal (Alloy 22 or Titanium Grade 7) crevices in 4 M $MgCl_2$ solution at 95 °C
  - Initiated under open circuit
  - Propagated without repassivation
- Crevice corrosion of Alloy 22 appears to propagate faster under more extreme conditions
  - Coupled to Platinum in 4 M $MgCl_2$ solution at 110 °C
  - Coupled to Titanium Grade 7 in 5 M NaCl + 2×10^{-4} M $CuCl_2$ solution at 95 °C
- Although crevice corrosion was observed under aggressive conditions, the corroded area and the deep penetration area with respect to the crevice area are limited

Summary and Conclusions (continued)

- Crevice corrosion initiation and propagation of Alloy 22 strongly depends on the solution composition and coupling material
- In chloride-rich solution, crevice corrosion of Alloy 22
  - Initiated instantaneously by coupling
  - Resulted in deeper penetration by coupling to Titanium Grade 7 than coupling to Alloy 22
- Stifling and repassivation may not occur under extreme conditions

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