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SURFACE ANALYSES OF ALLOY 22 UNDER CONDITIONS THAT PROMOTE STRESS CORROSION CRACKING

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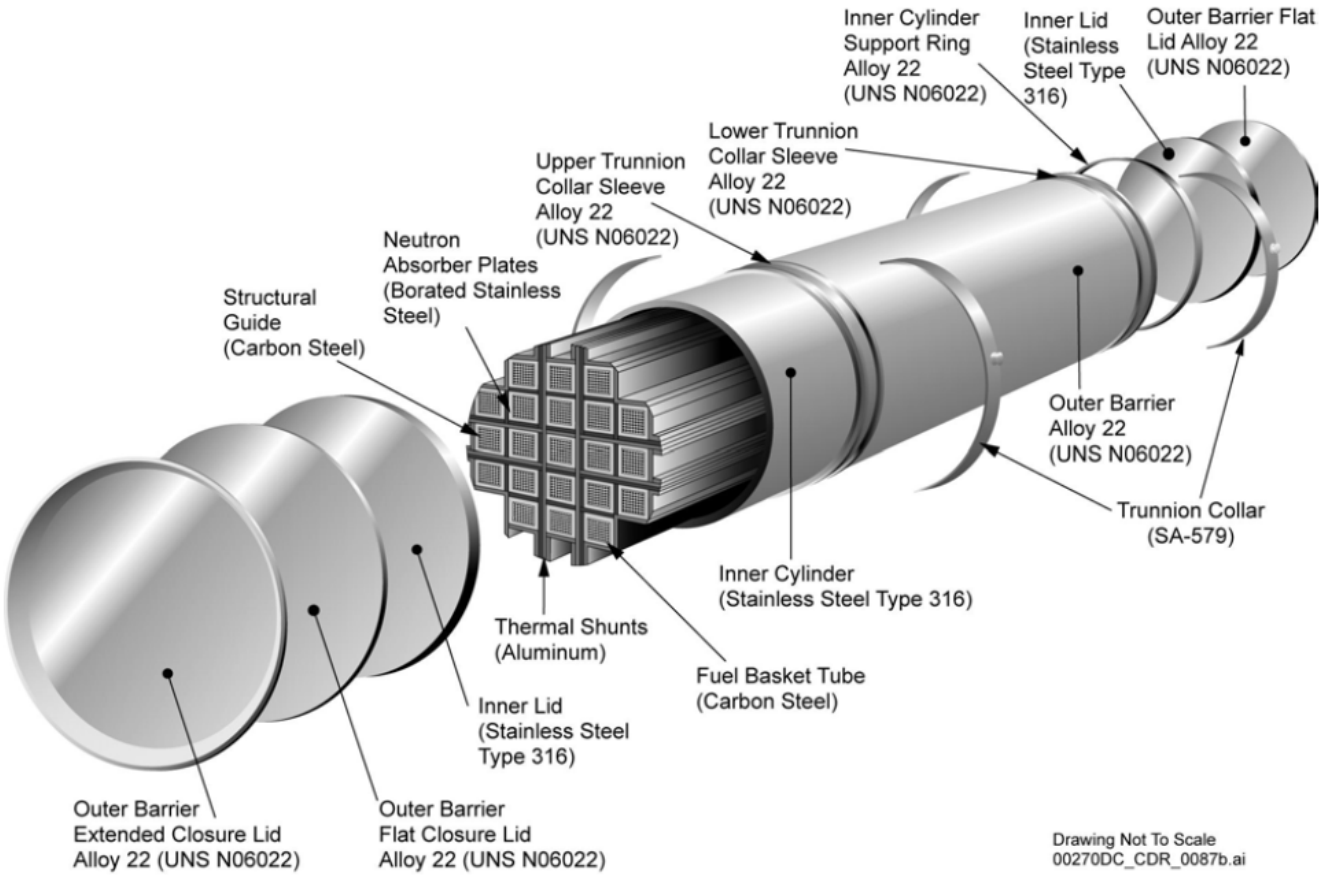
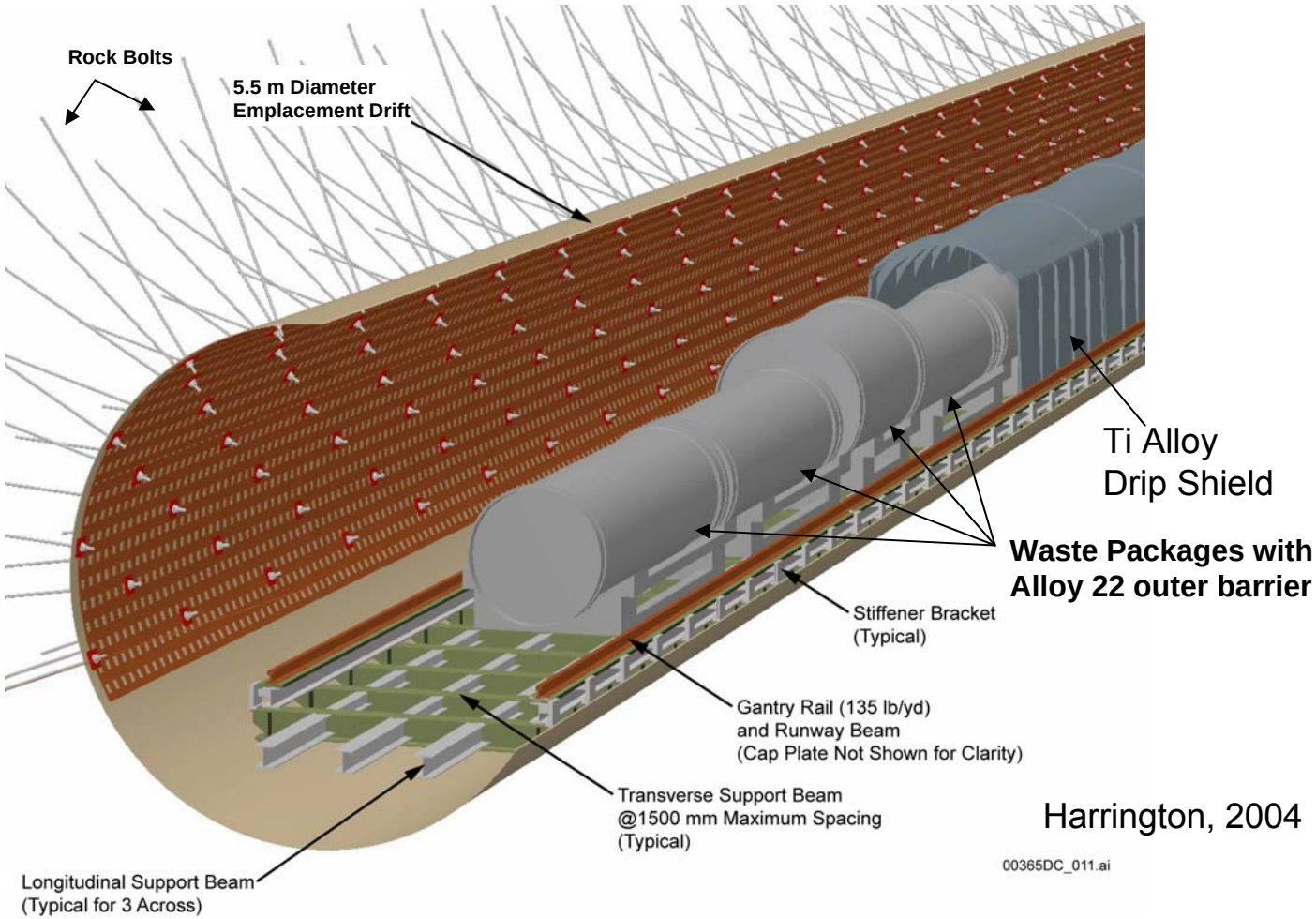
Potential Waste Package Design



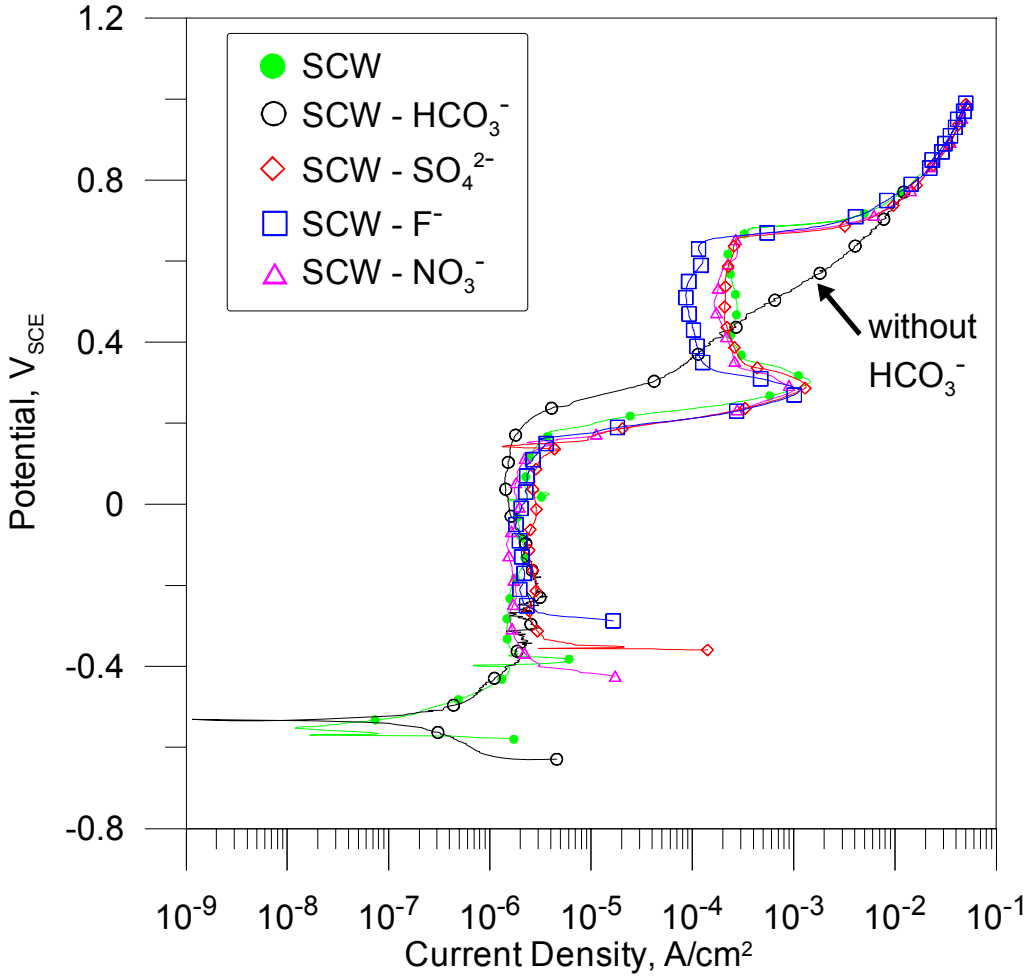
- Alloy 22 Outer Container
- Type 316 Nuclear Grade Stainless Steel Inner Container

Anderson et al. 2003

Drift Emplacement



Anodic Polarization Test Results



- Slow Strain Rate Tests Show Bicarbonate Necessary for Stress Corrosion Cracking
- Similar Results in All Solutions Except in the Absence of Bicarbonate

Objectives

- Analyze the Composition of the Oxide Films on Alloy 22 Specimens as a Function of Solution Chemistry and Electrochemical Conditions

- Compare Oxide Film Compositions Formed Under Conditions that Are Known to Promote Stress Corrosion Cracking with Oxides Formed Under Benign Conditions

Material

Alloy 22 Composition

Material	Ni	Cr	Mo	W	Fe	Co	Si	Mn	V	P	S	C
Alloy 22 2277-3-3266	57.8	21.40	13.60	3.00	3.80	0.09	0.030	0.12	0.15	0.008	0.002	0.004

- Alloy 22 Test Specimens 19 × 13 × 4 mm [0.75 × 0.51 × 0.15 in] Machined From a 12.7-mm [0.5-in] Plate

- Specimens Were Polished to a 2,000 Grit Finish and Ultrasonically Cleaned in Acetone and Deionized Water

Approach

Specimen Preparation

- Alloy 22 specimens placed in standard electrochemical test cells
- Test solutions maintained at 95 °C [203 °F]
- Specimens potentiostatically polarized
- Solutions contained ratios of chloride and bicarbonate, which are known to be significant for stress corrosion cracking based on slow strain rate tests

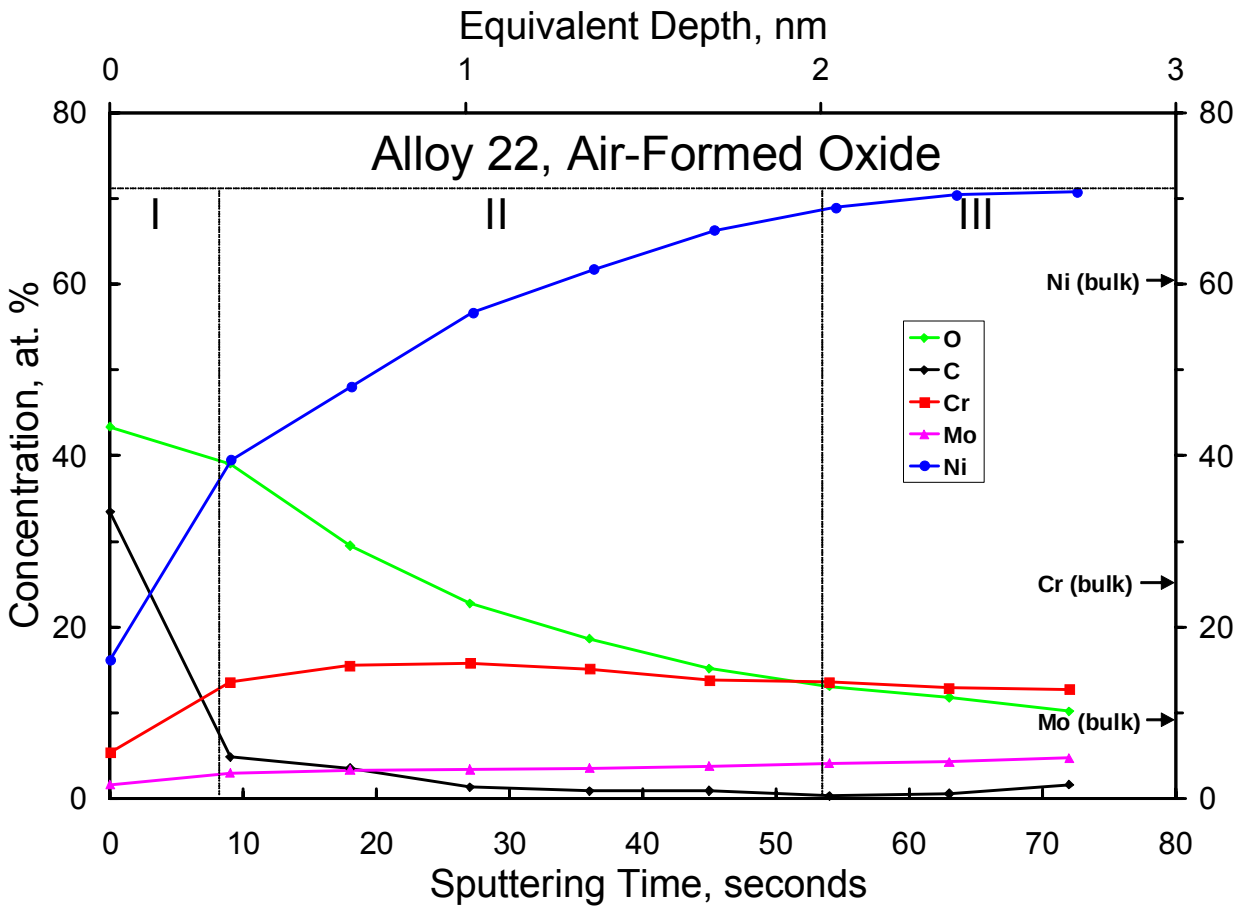
Surface Analyses

- Oxide films analyzed using X-ray photoelectron spectroscopy
- The sputtering rate was 2.27 nm/min [8.94×10^{-5} mil/min], obtained by sputtering an SiO_2 film

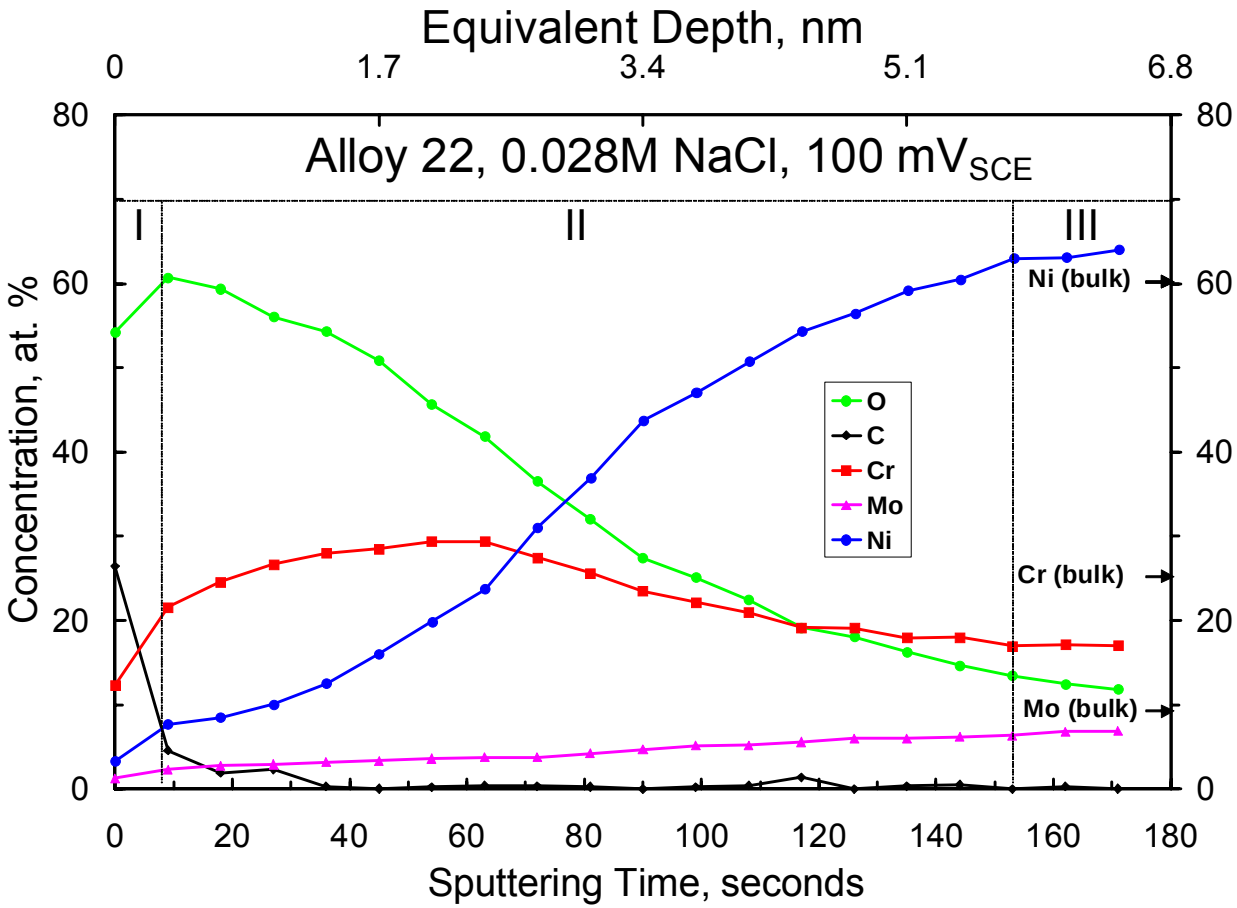
Composition of Simulated Concentrated Water (SCW)

Ion	K^+	Na^+	Mg^{2+}	Ca^{2+}	F^-	Cl^-	NO_3^-	SO_4^{2-}	HCO_3^-
Concentration (Molar)	0.09	1.78	<0.0004	<0.0003	0.074	0.19	0.10	0.17	1.14

Air-Formed Oxide on Alloy 22

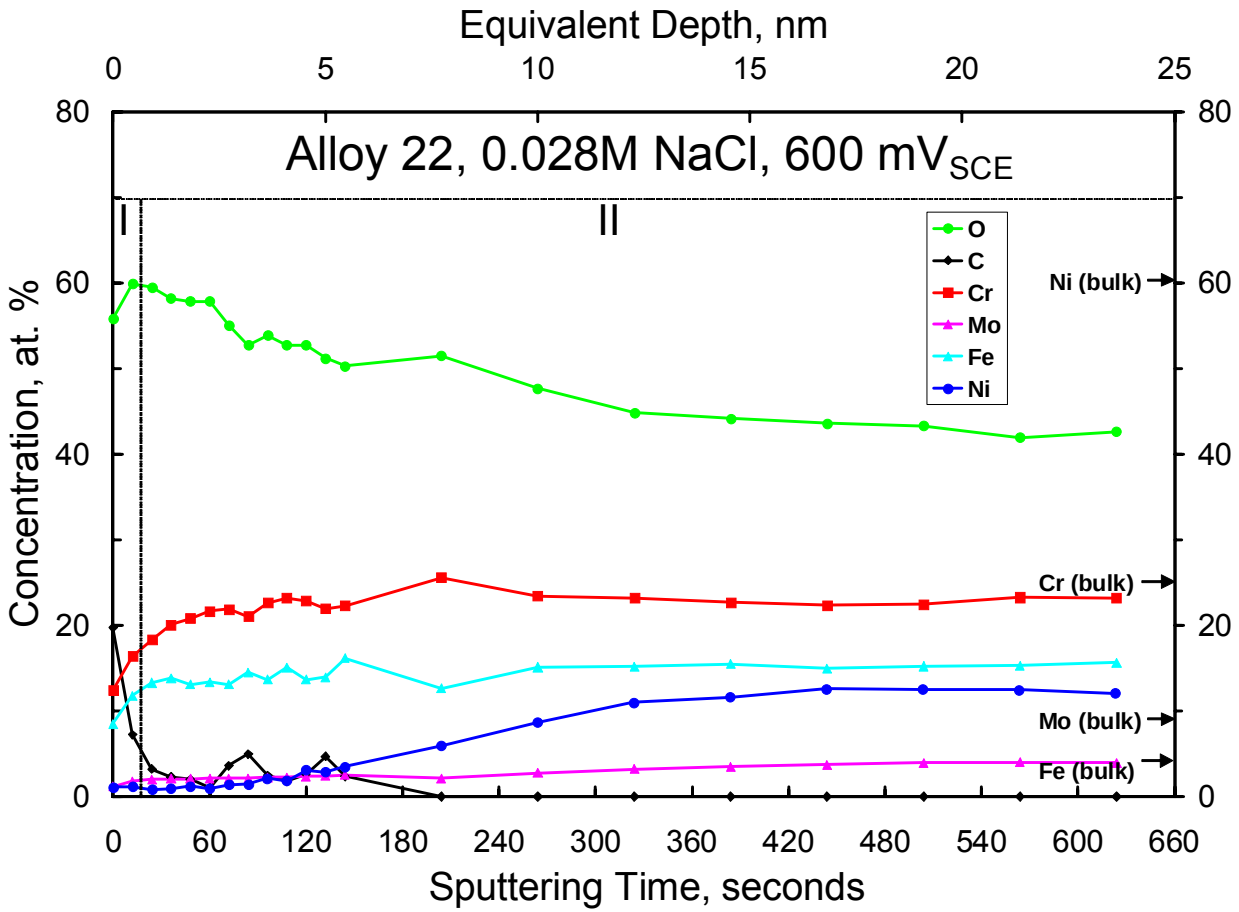


Passive Oxide Film



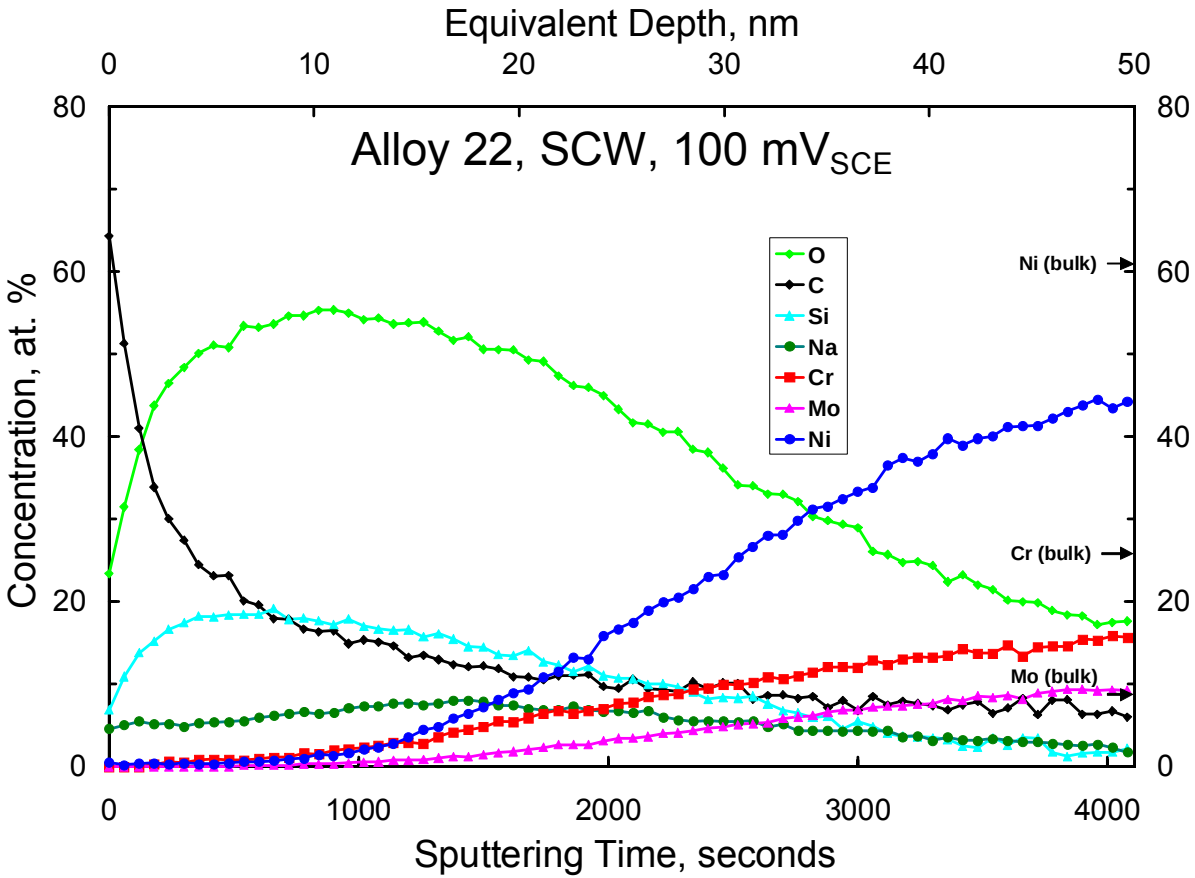
- Oxide Formed at 100 mV$_{SCE}$ in 0.028 M NaCl
- High Cr and Mo Concentrations in the Oxide

Transpassive Conditions



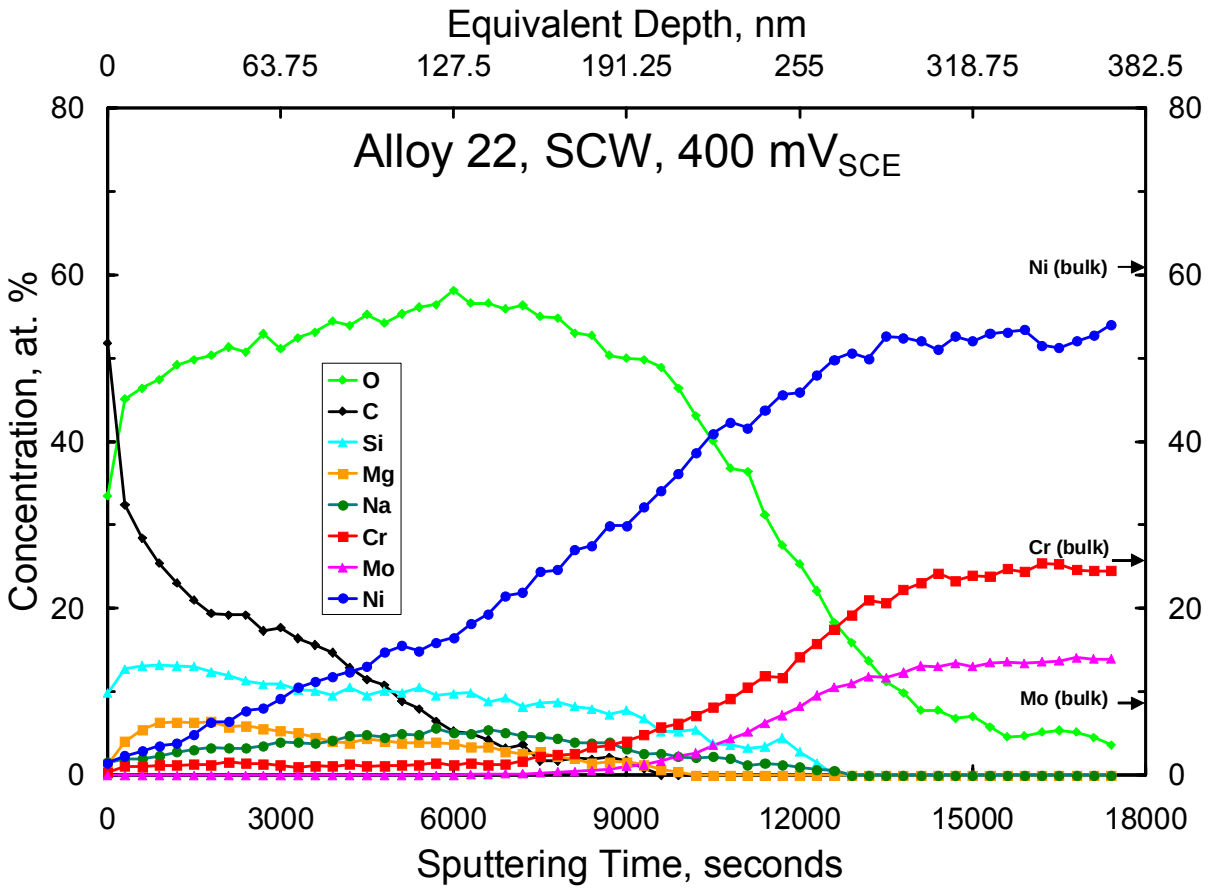
- Oxide Formed at 600 mV$_{SCE}$ in 0.028 M NaCl
- High Cr and Mo Concentrations in the Oxide

Simulated Concentrated Water



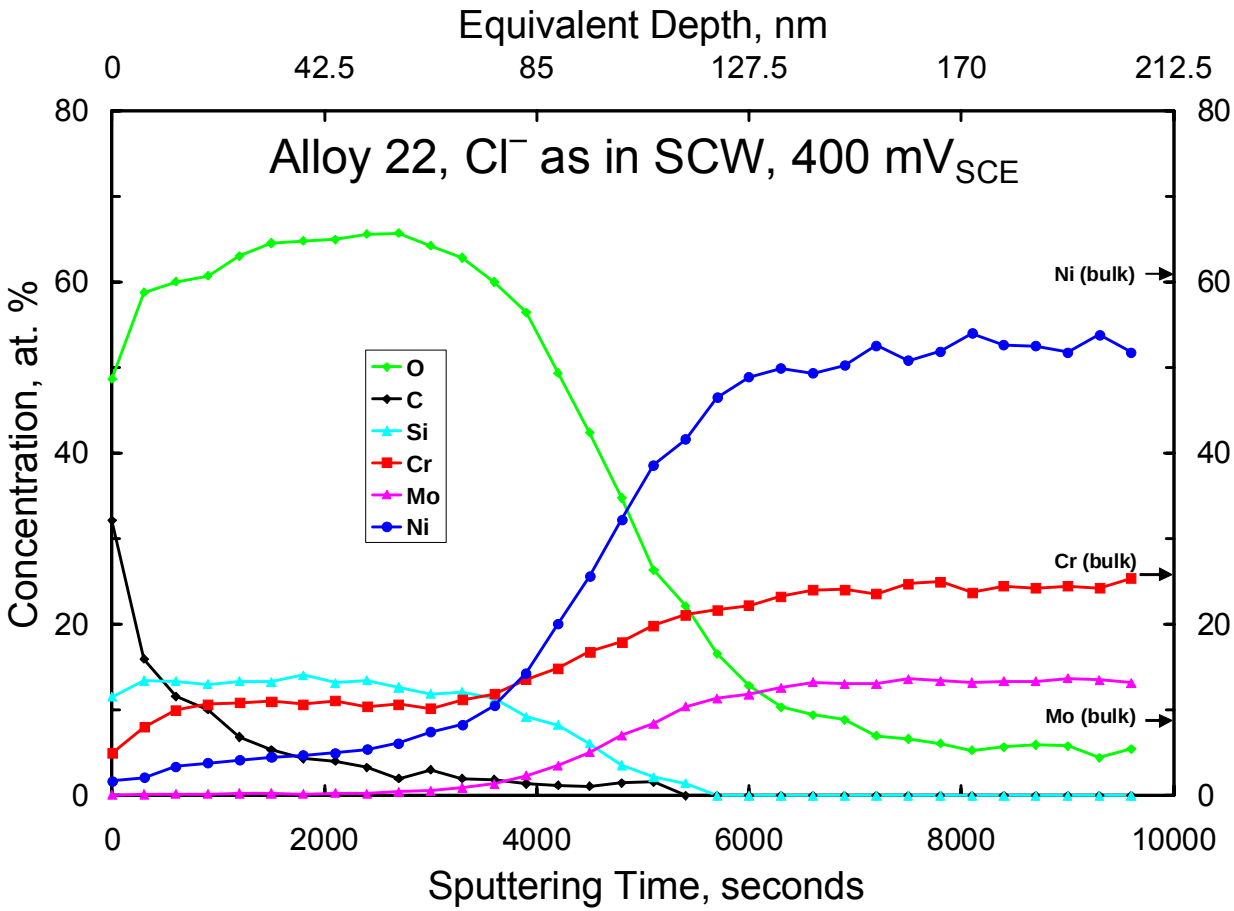
- Oxide Formed at 100 mV_{SCE} in Simulated Concentrated Water
- Low Cr and Mo Concentrations in the Oxide
- No Stress Corrosion Cracking Observed in Slow Strain Rate Tests

Simulated Concentrated Water (Continued)



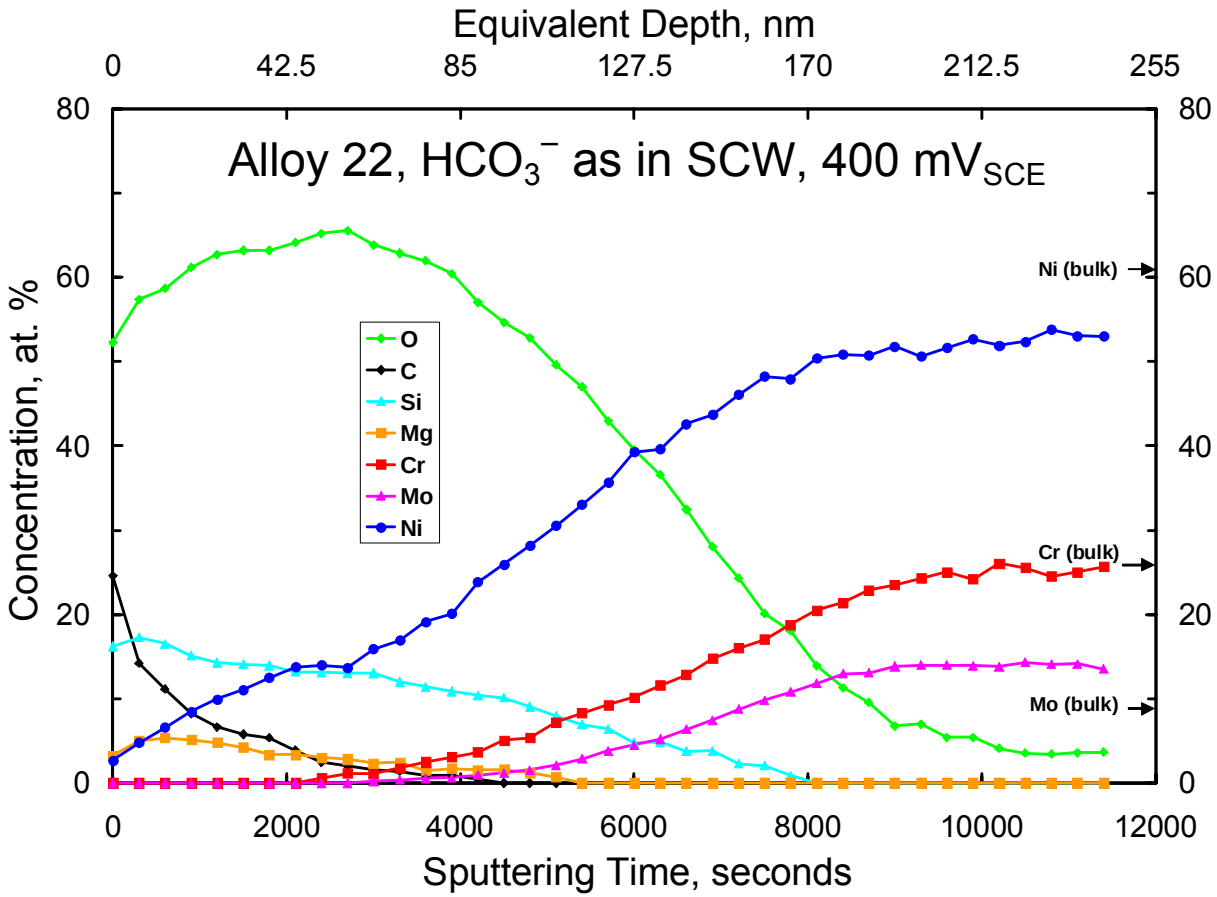
- Oxide Formed at 400 mV$_{SCE}$ in Simulated Concentrated Water
- Low Cr and Mo Concentrations in the Oxide
- Stress Corrosion Cracking Observed in Slow Strain Rate Tests

Chloride Solution



- Oxide Formed at 400 mV$_{SCE}$ in Solution with a Chloride Concentration the Same as in Simulated Concentrated Water
- Significant Cr Concentration in the Oxide
- No Stress Corrosion Cracking Observed in Slow Strain Rate Tests

Bicarbonate Solution



- Oxide Formed at 400 mV_{SCE} in a Bicarbonate Solution with the Same Concentration as Simulated Concentrated Water
- Reduced Cr and Mo Concentrations in the Oxide
- No Stress Corrosion Cracking Observed in Slow Strain Rate Tests

Results Summary

Solution	Potential, mV_{SCE}	SCC Expected?	Observations
None (Air-Formed Oxide)	None	No	Thin oxide with Cr, Ni, and Mo
0.028 M NaCl	100	No	Thin oxide with Cr, Ni, and Mo
	600	No	Oxide with Cr, Ni, and Mo
Simulated Concentrated Water	100	No	Thick oxide with reduced Cr concentration
	400	Yes	Very thick oxide with reduced Cr and Mo concentrations
0.19 M NaCl	400	No	Oxide with Cr, Ni, and Mo
1.14 M $NaHCO_3$	400	No	Thick oxide with reduced Cr and Mo concentrations

Conclusions

- The Air-Formed Oxide on Alloy 22 Is a Thin Compact Layer That Contains Ni, Cr, and Mo in Similar Proportion to the Base Alloy
- In Aqueous Solutions, the Alloy 22 Oxide Layer Thickness and Composition are Dependent on Applied Potential and Solution Chemistry
- Oxide Films Formed Under Conditions that Promote SCC Are Significantly Thicker and Have Reduced Cr Concentrations Compared to the Air-Formed Oxide Film
- Oxide Films Formed at Anodic Potentials in Solutions With HCO_3^- Ions Have Reduced Concentrations of Cr
- At Anodic Potentials in Solutions Containing Only Cl^-, No SCC of Alloy 22 Is Observed, and the Oxide Films Produced Under These Conditions Have Significant Cr Concentrations

Future Considerations

- Time Dependent Changes in Oxide Film Composition
- Spatial Variation of Oxide Film Composition
- Electrochemical Characterization of the Oxides Formed Under Similar Conditions
- Analyses of Eh-pH Calculations for Alloy 22 in Chloride and Bicarbonate Containing Solutions
- Evaluation of Other Ni-Cr and Ni-Cr-Mo Alloys

Acknowledgments

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