Pacific Northwest
NATIONAL LABORATORY

Investigating the role of LASER Surface Processing (LSP) on Corrosion of an Al-Mg-Si Alloy

July 30, 2026

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Aashish Rohatgi

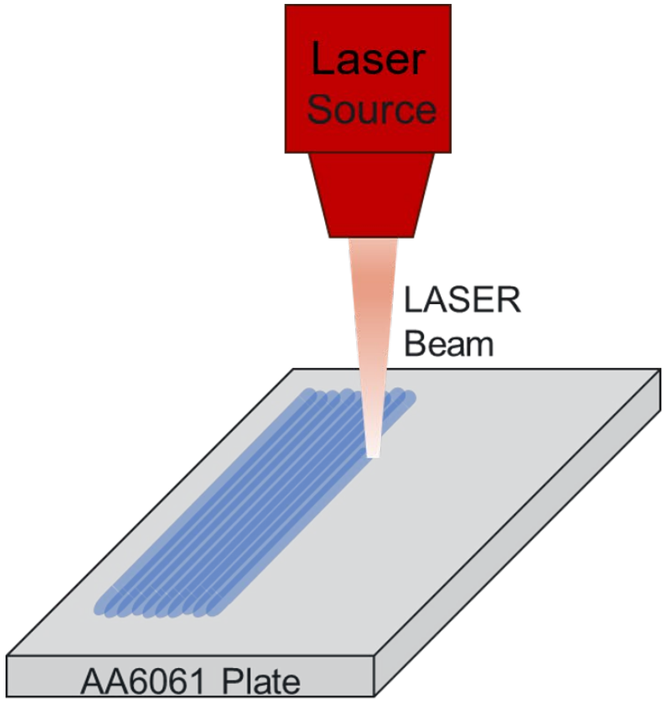
U.S. Department of ENERGY BATTELLE

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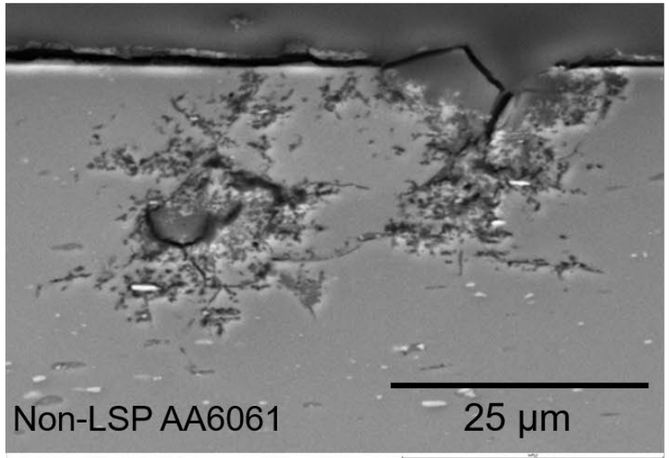


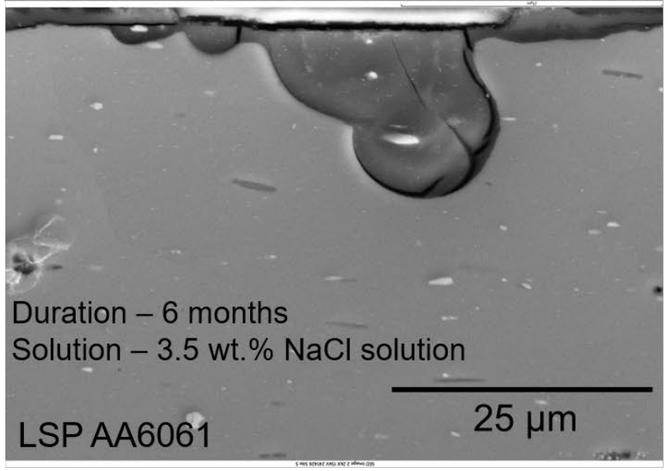
Summary / Abstract

Laser Surface Processing (LSP)

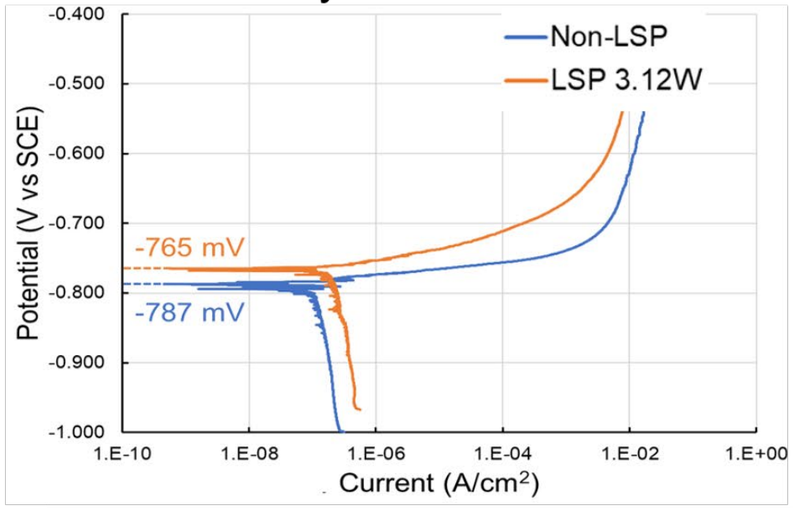


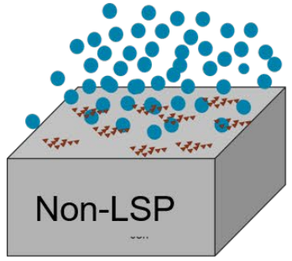
Immersion Corrosion

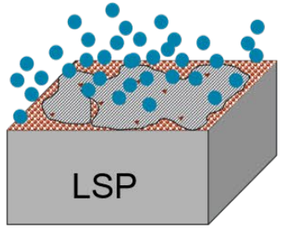


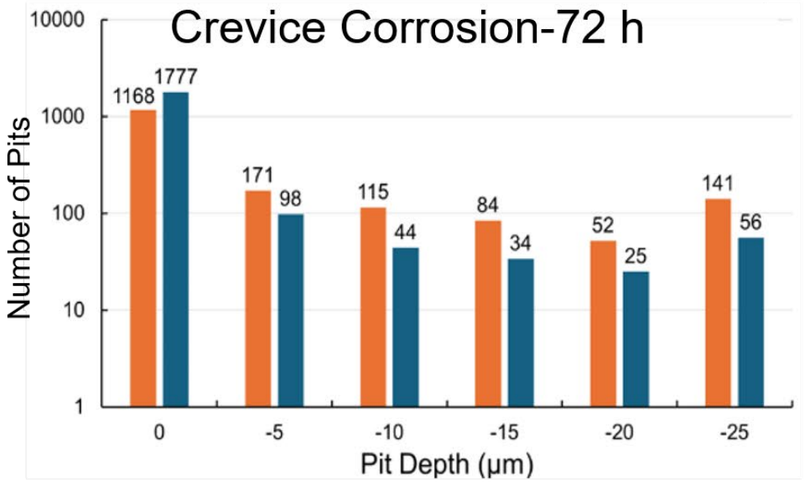


Potentiodynamic Polarization





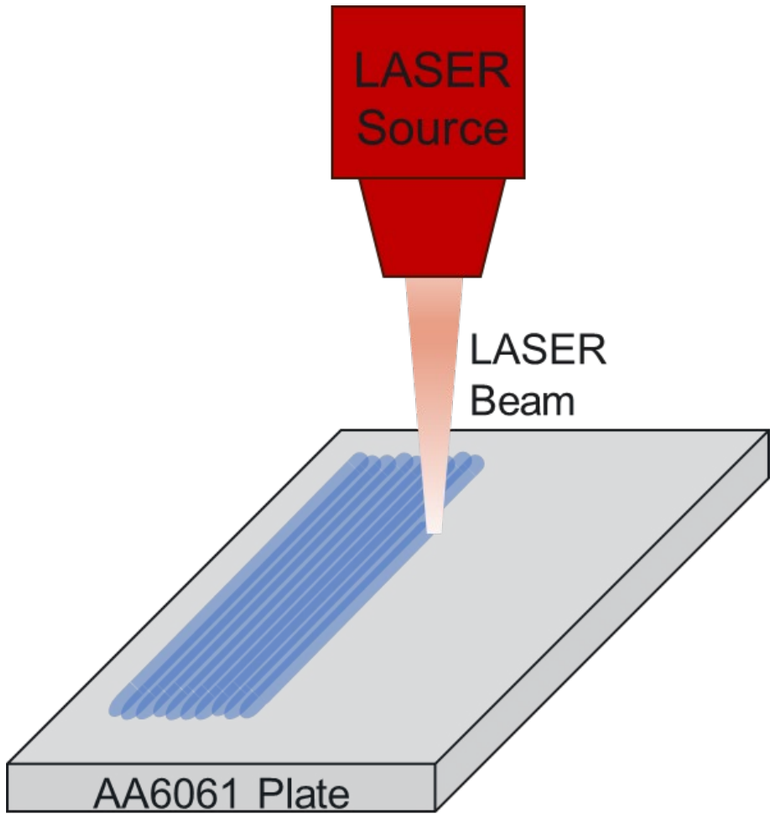




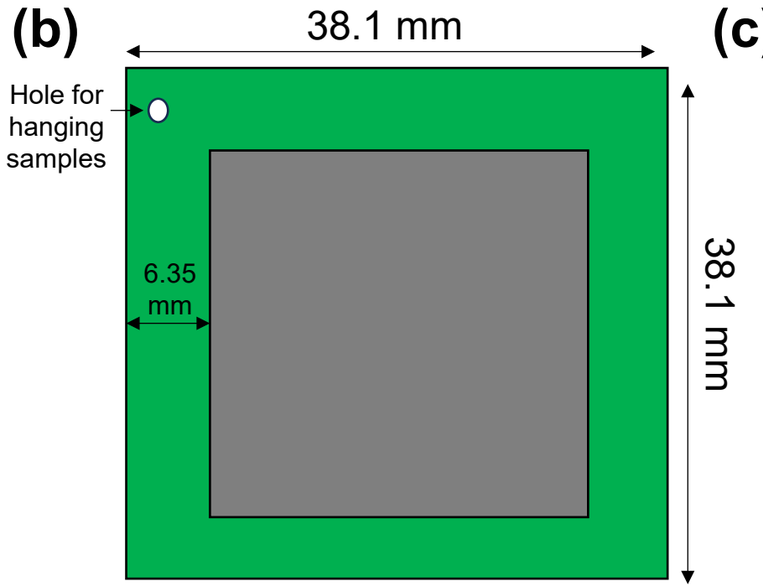
Methods Employed in this Study

(a)

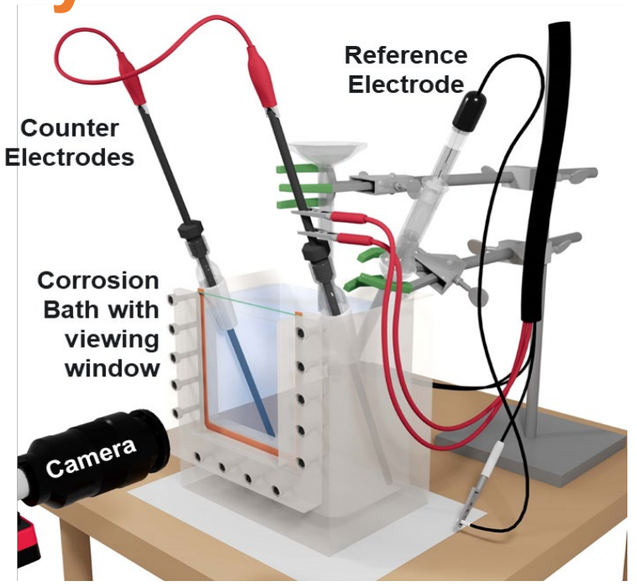
LASER Surface Processing (LSP)



(b)

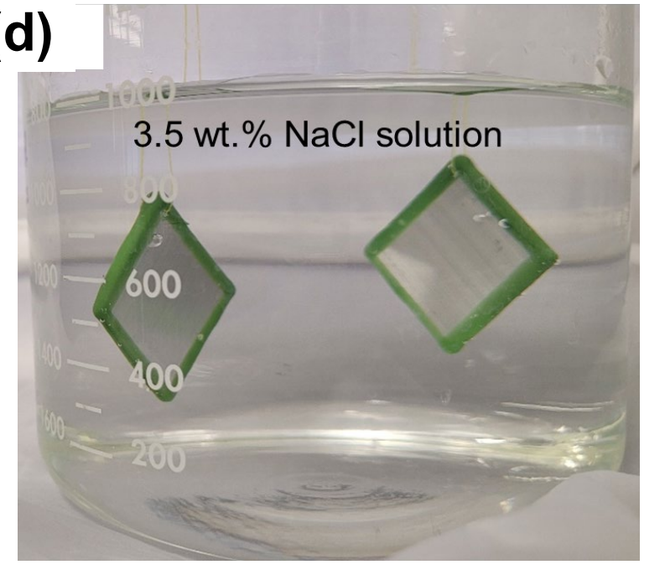


(c)



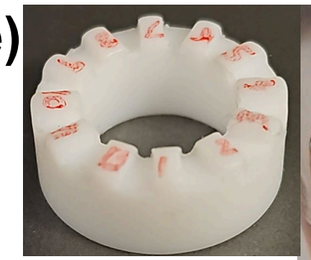
Accelerated Corrosion in 3.5 wt.% NaCl solution

(d)

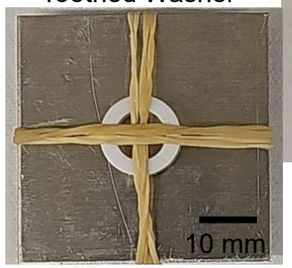


6-month Immersion in 3.5 wt.% NaCl solution

(e)



Toothed Washer



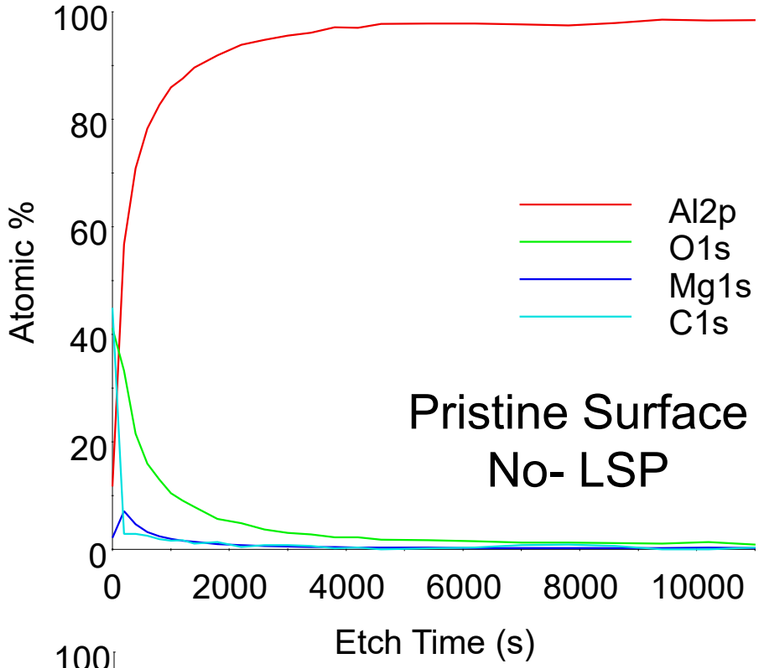
Assembled Sample

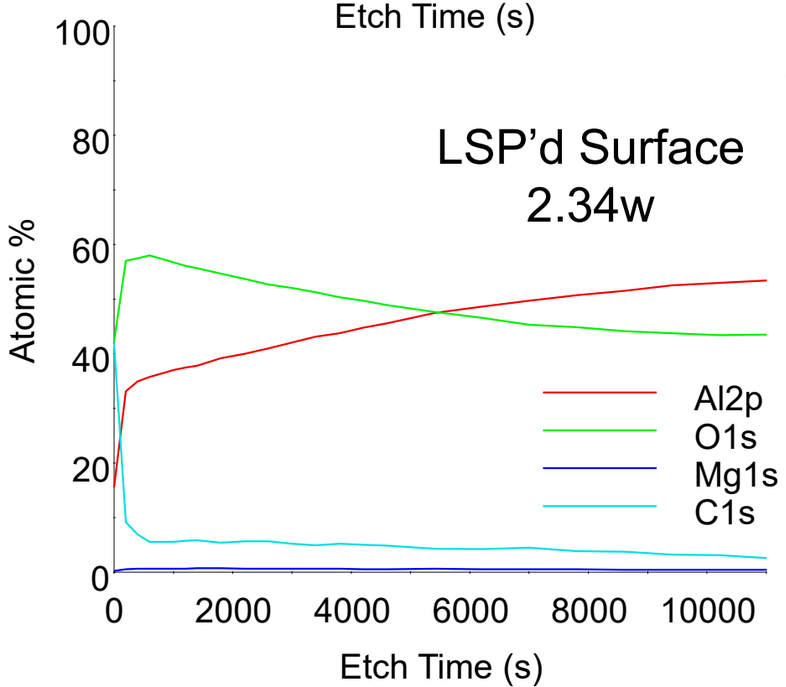


Assembled samples immersed into a beaker containing $FeCl_3$ solution

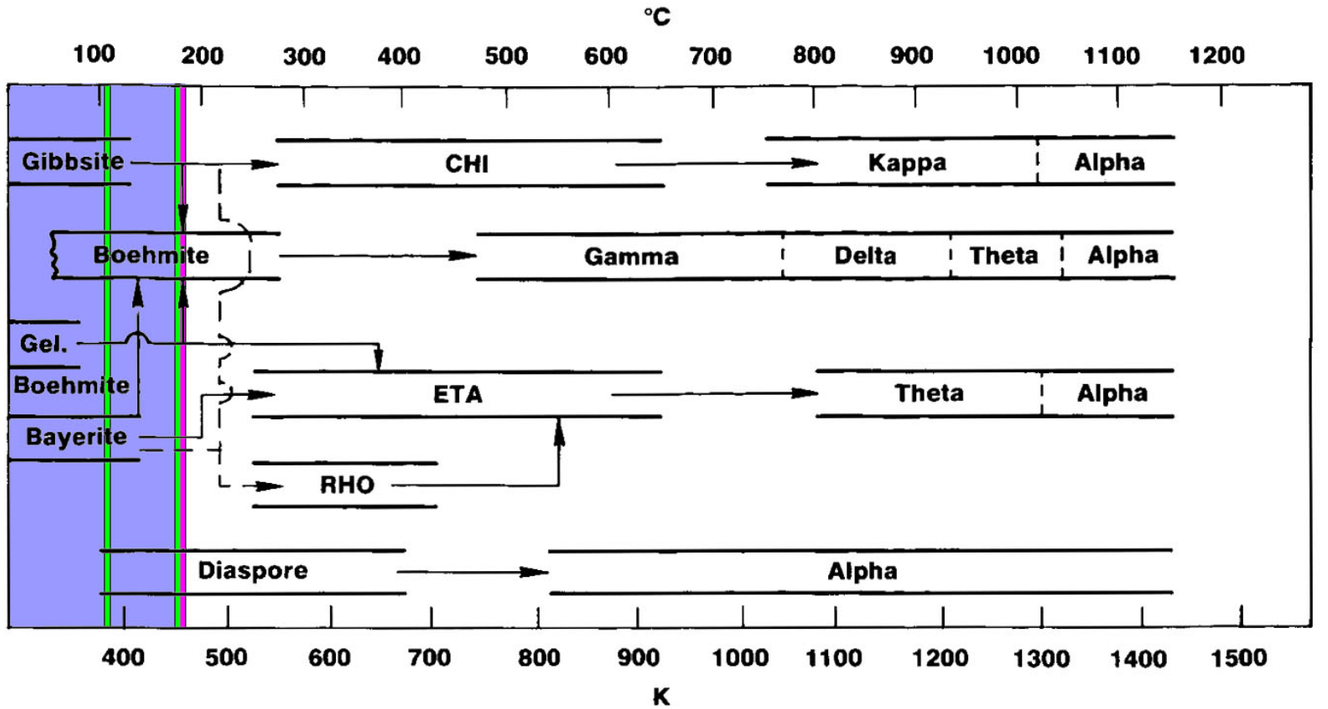
Crevice Corrosion in $FeCl_3$ solution (ASTM G48)

XPS of AA6061 from the Seedling study





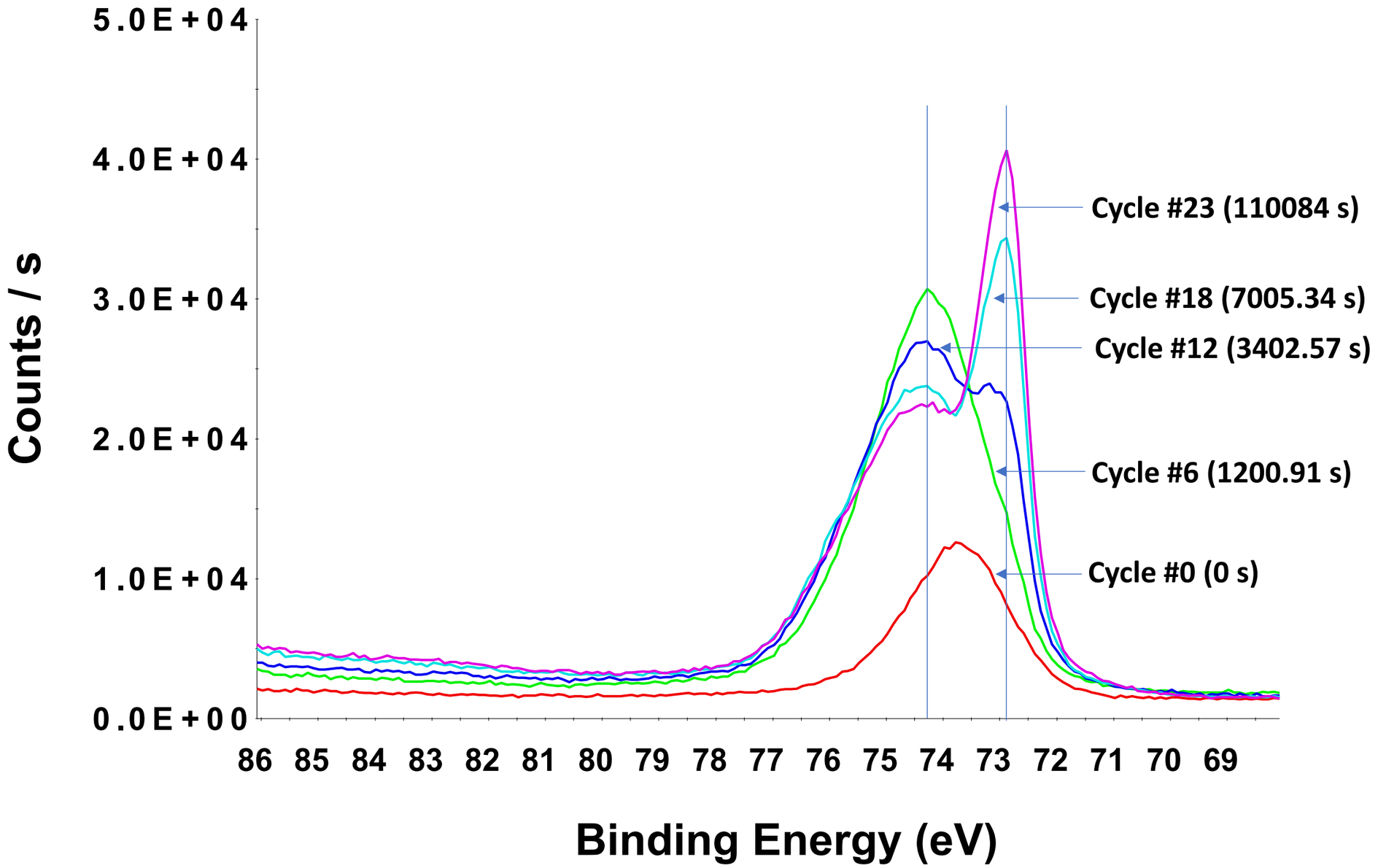
Sputter depth profiling etch depth of 10,000 seconds corresponds to 970nm in this case.



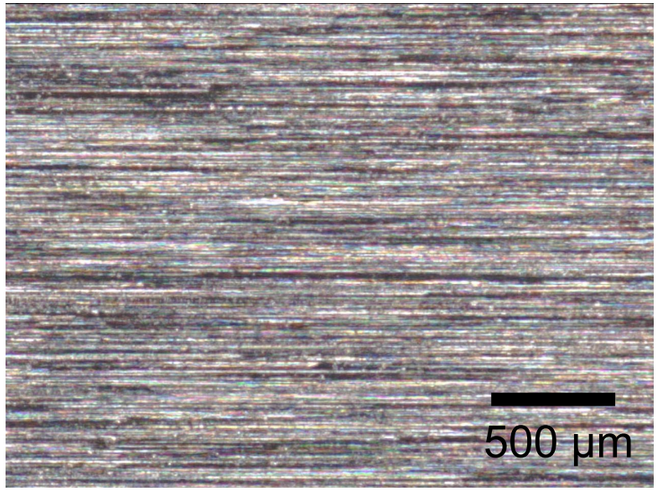
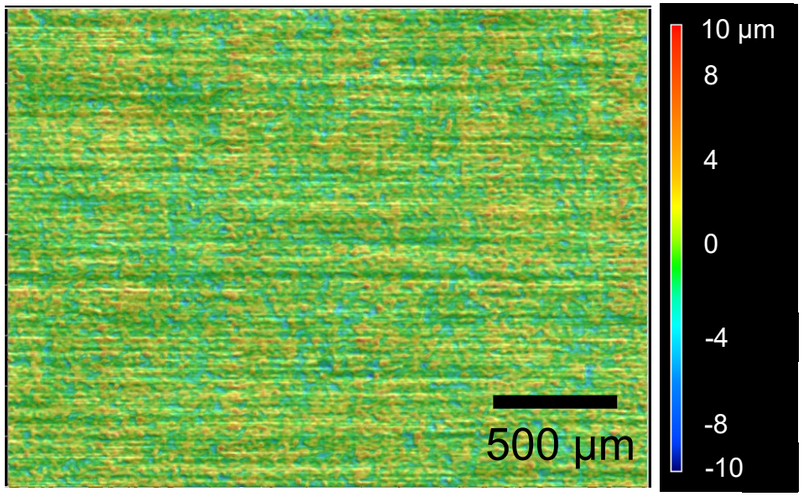
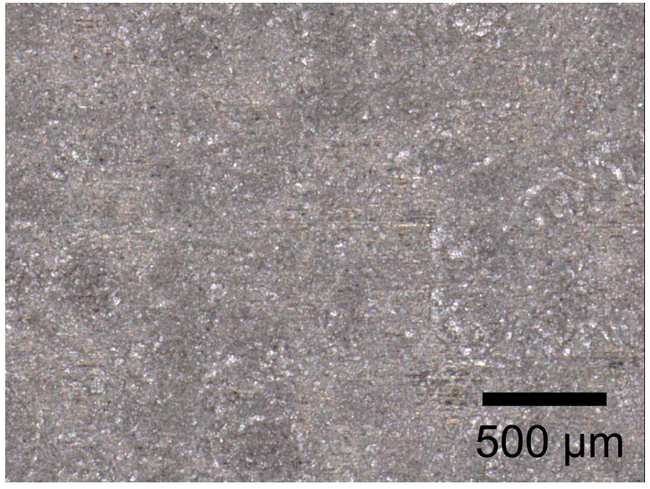
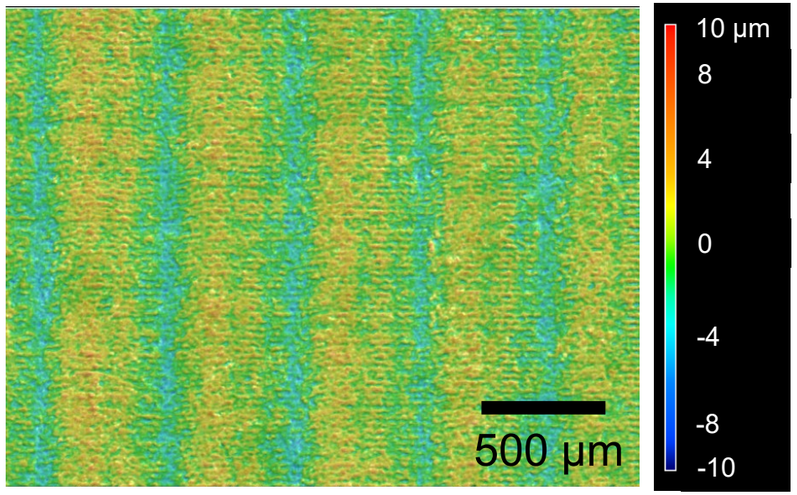
Evolution pathways for corrosion products on aluminum. Green lines denote test temperatures used in this study; magenta line denotes hydrothermal treatment temperature used for generation of boehmite in this study; blue region encompasses hydrothermal reactions relevant to these studies.

Reference: K. Wefers, C. Misra, "Oxides and Hydroxides of Aluminum", Alcoa Laboratories, Alcoa Technical Paper No. 19, Revised, 1987

XPS of AA6061 from the Seedling study



Surface Roughness Comparisons Before and After LSP

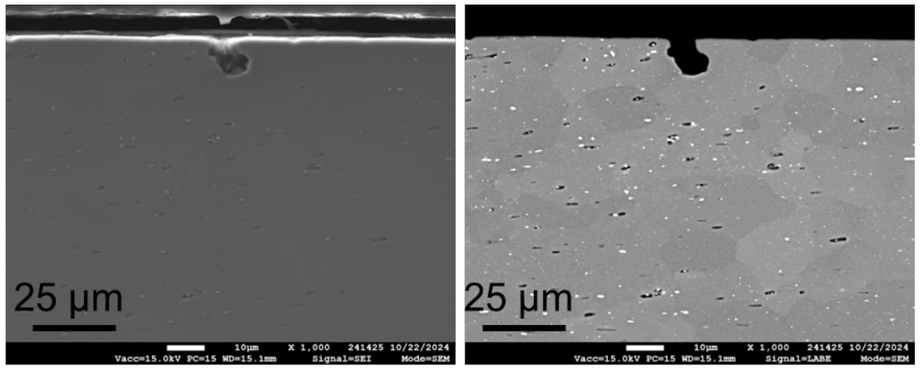
Surface Condition	Optical Micrograph	Height Profile	S_a µm	S_z µm	S_{pd} 1/mm²
Non-LSP AA6061			1.076	15.06	1388
LSP AA6061 (3.12W)			1.28	14.45	1479

Summary of SEM+EDS Observations in LSP vs Non-LSP AA6061 exposed to Lab 3.5 wt.% NaCl Solution

6 months Exposure

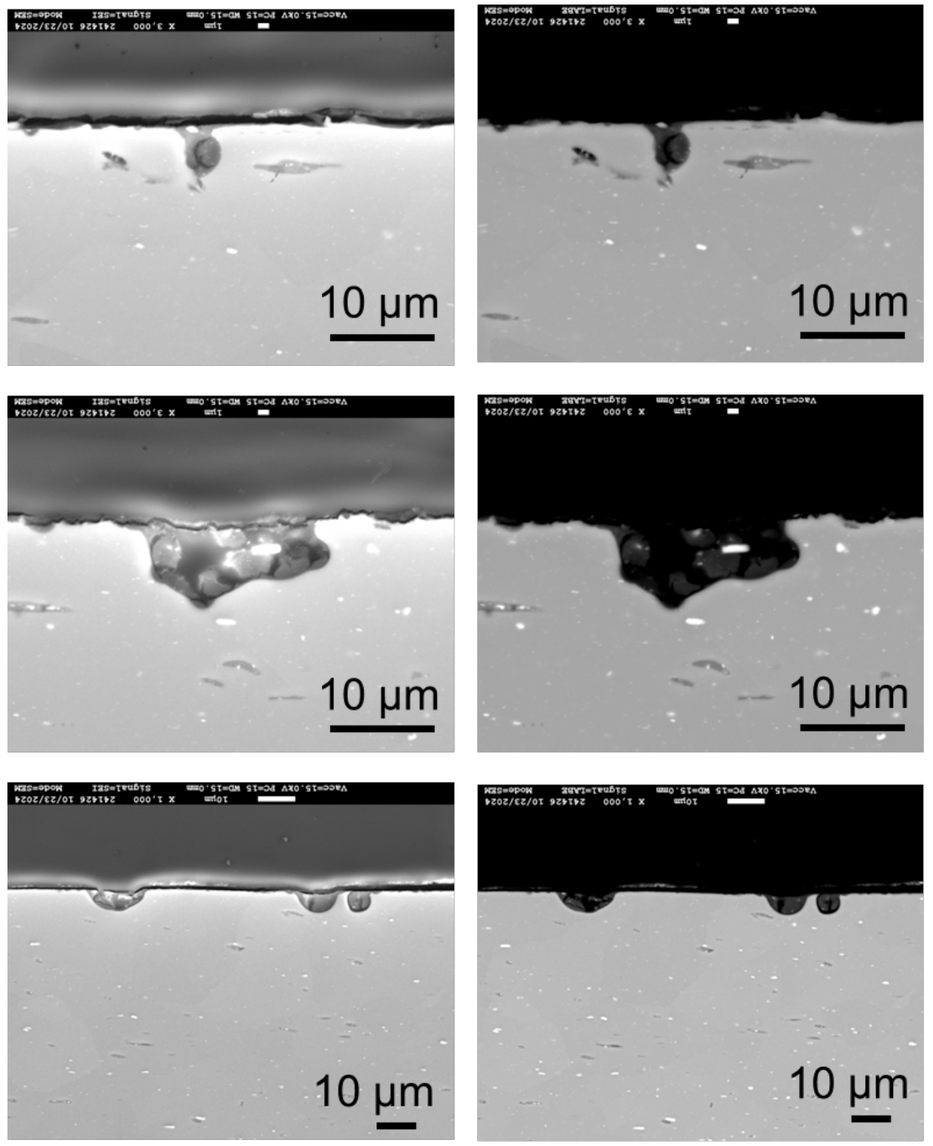
Non- LSP AA6061

6 months Exposure to Lab 3.5 wt.% NaCl solution



LSP 3.12W

6 months Exposure to Lab 3.5 wt.% NaCl solution



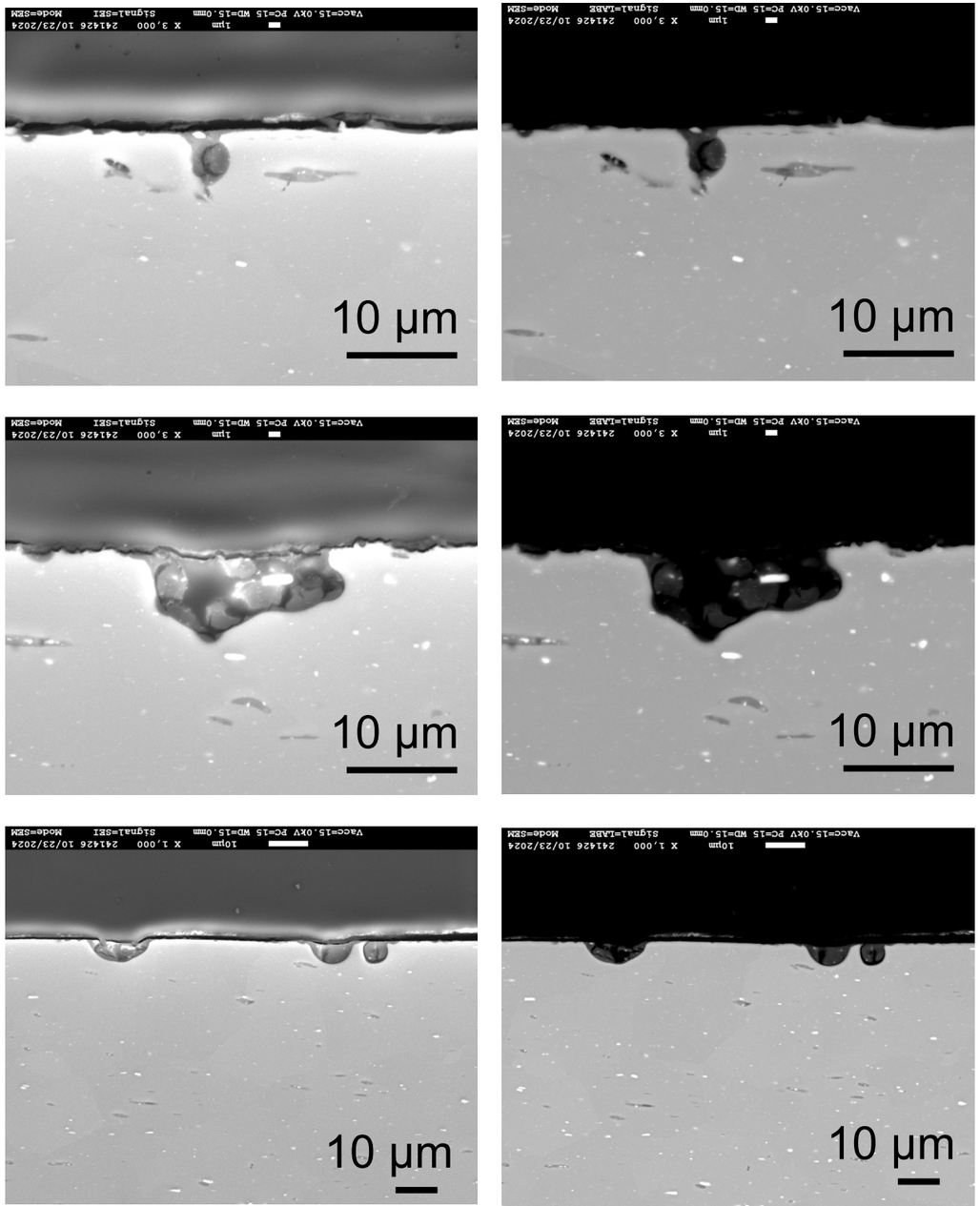
Summary of SEM+EDS Observations in LSP vs Non-LSP AA6061 exposed to Lab 3.5 wt.% NaCl Solution

LSP 3.12W

6 months Exposure to Lab 3.5 wt.% NaCl solution

- LSP 3.12W AA6061 sample was exposed to 6 months in 3.5 wt.% NaCl solution at PNNL.
- Sample shows the presence of very shallow (10 µm max) pits.
- Pit morphology appears bulbous or faceted with curvy corners

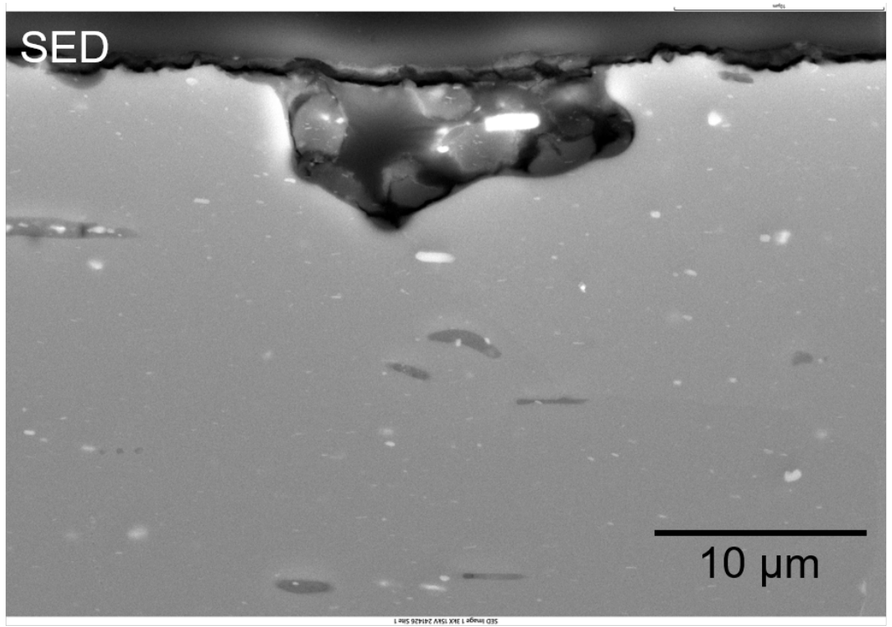
6 months Exposure

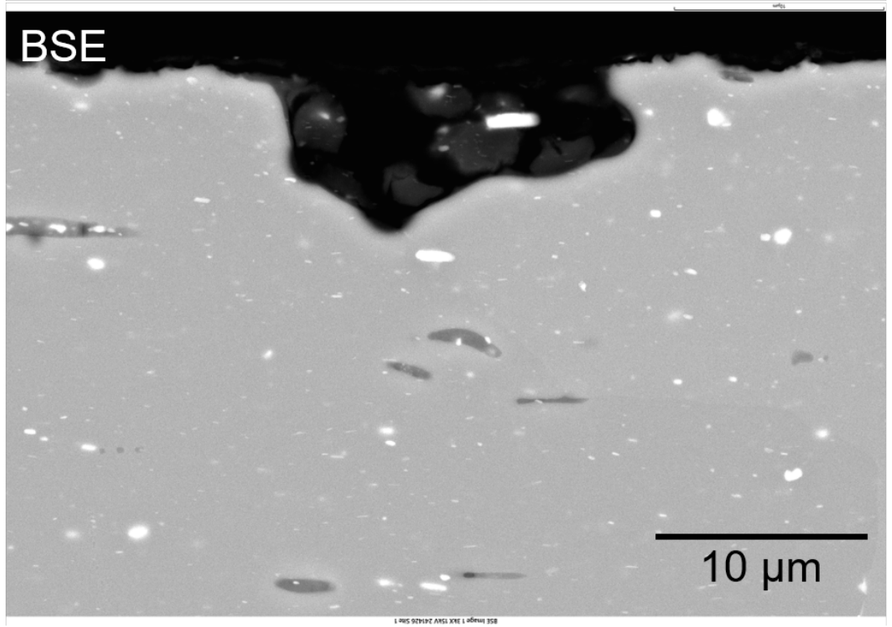


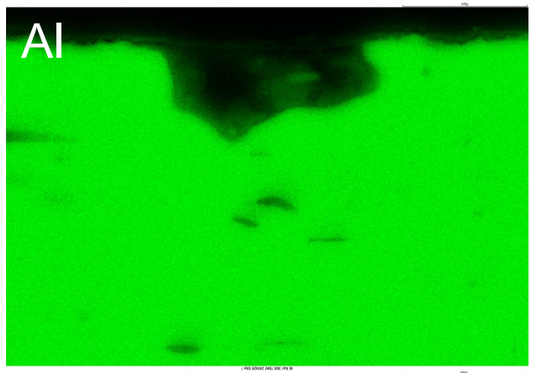
LSP 3.12W

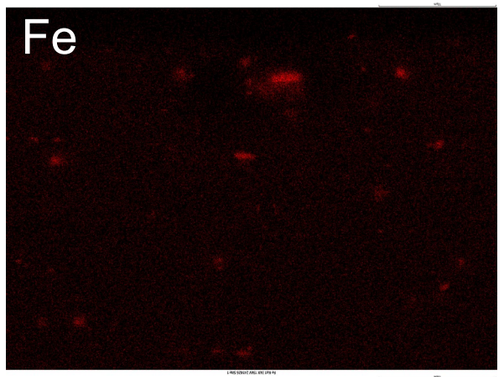
6 months Exposure to Lab 3.5 wt.% NaCl solution

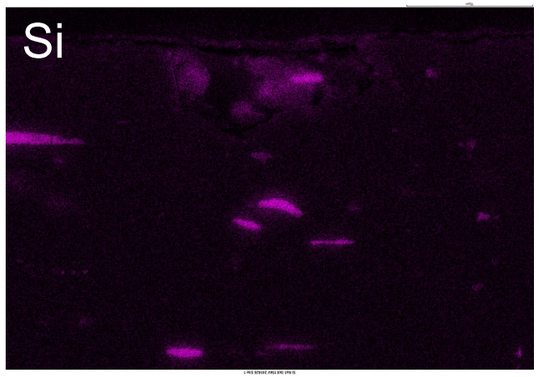
6 months Exposure

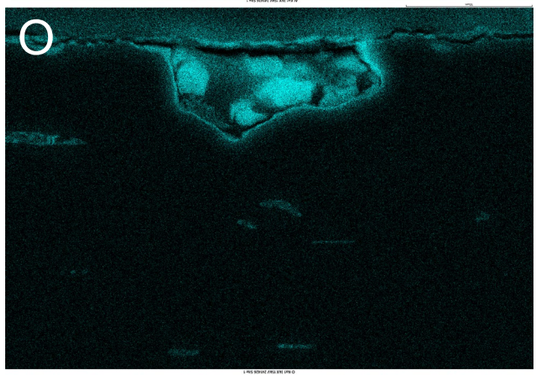


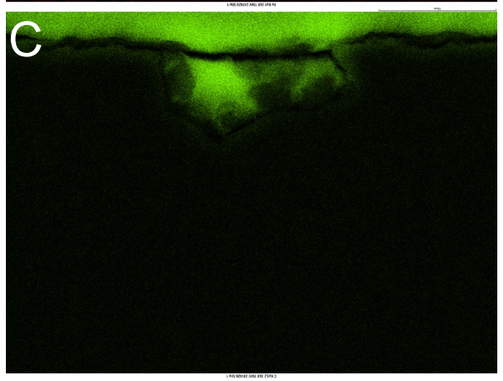


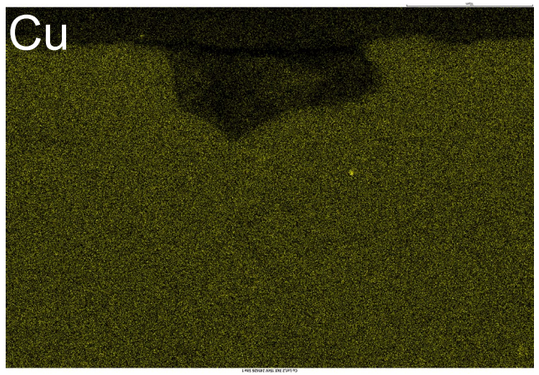


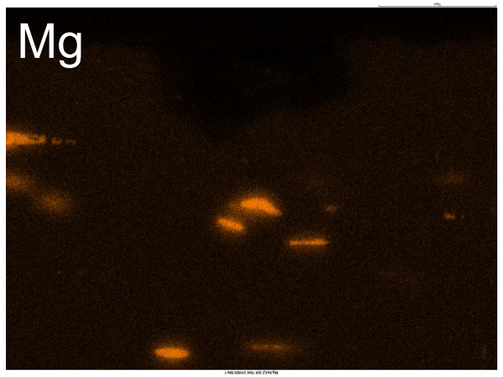








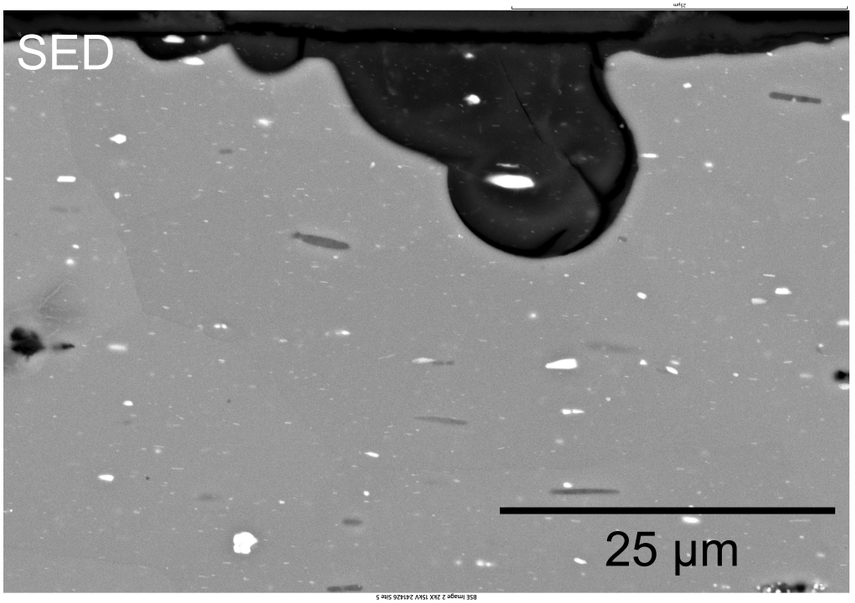


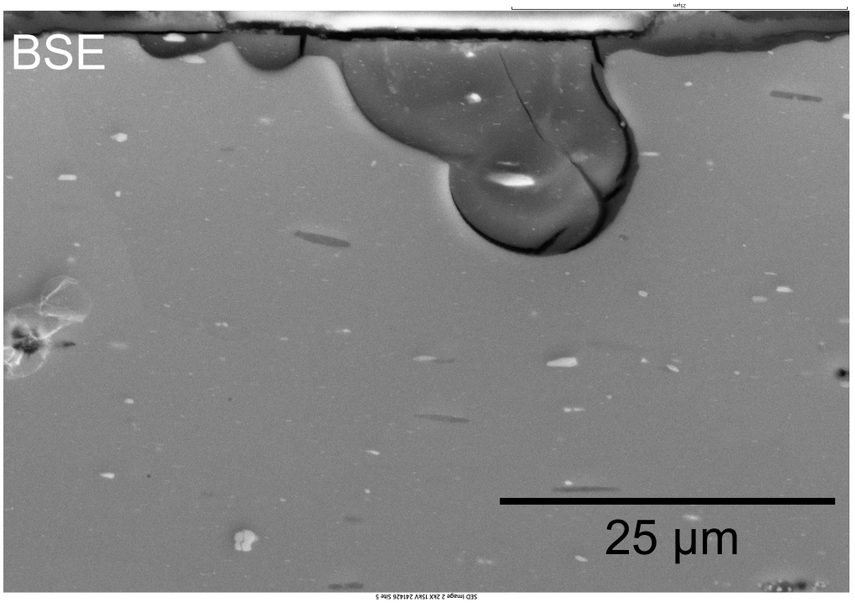


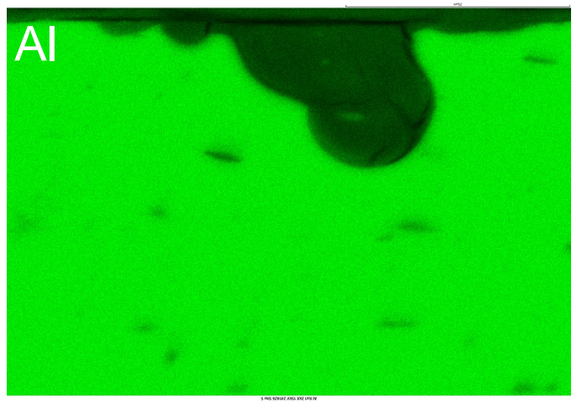
LSP 3.12W

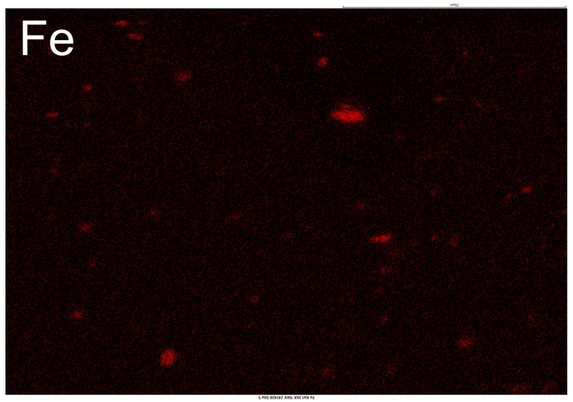
6 months Exposure to Lab 3.5 wt.% NaCl solution

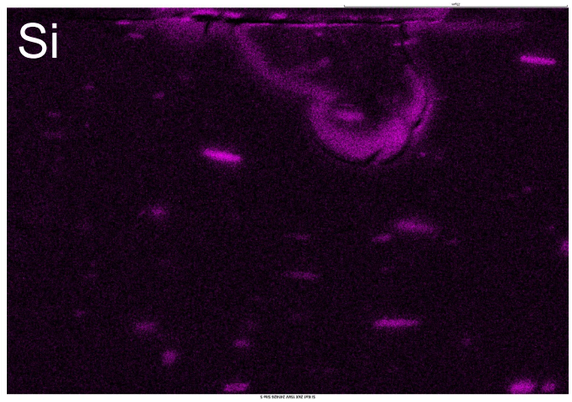
6 months Exposure

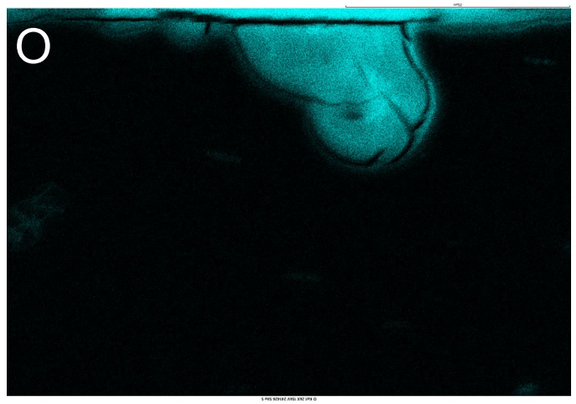


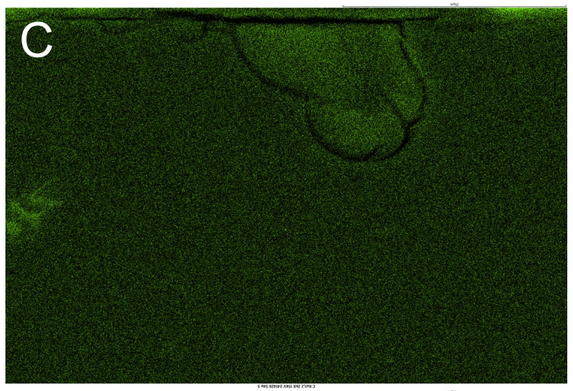


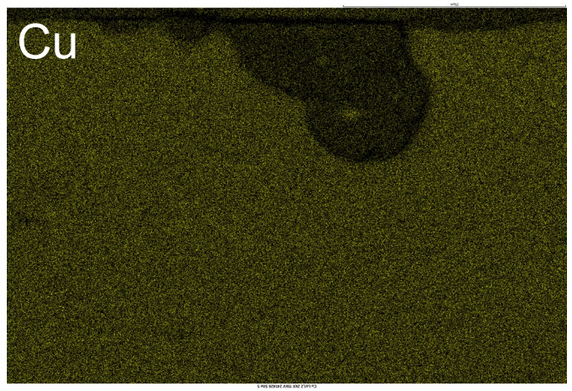


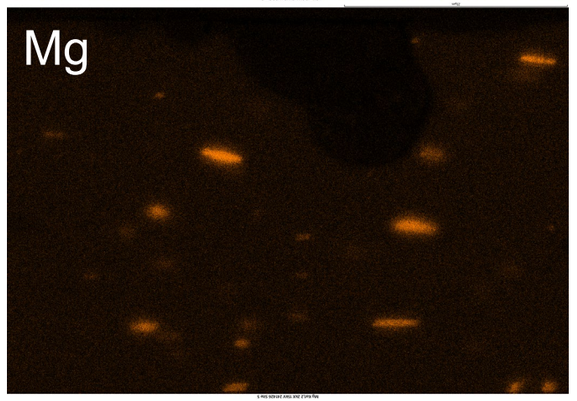










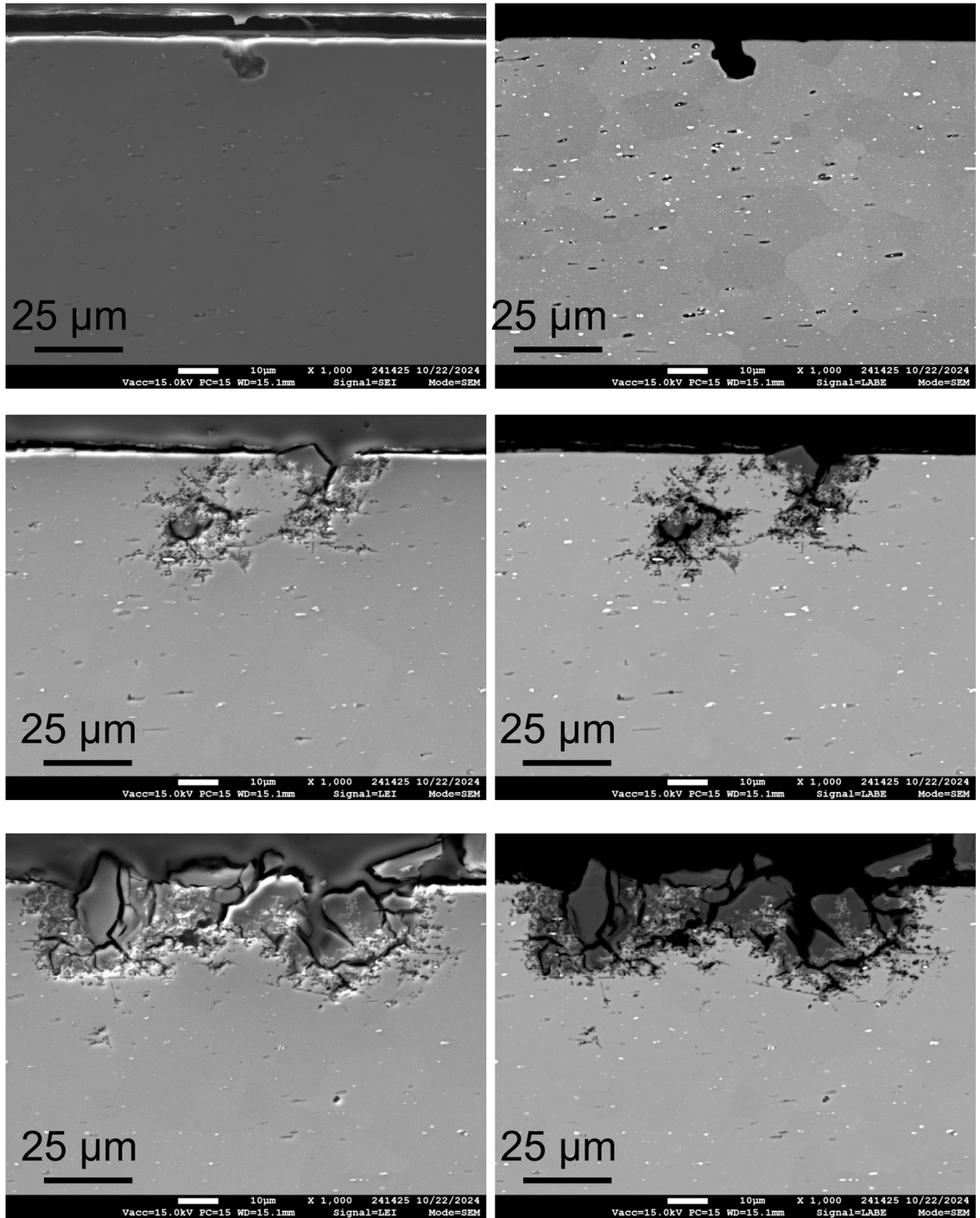


Non- LSP AA6061

6 months Exposure to Lab 3.5 wt.% NaCl solution

6 months Exposure

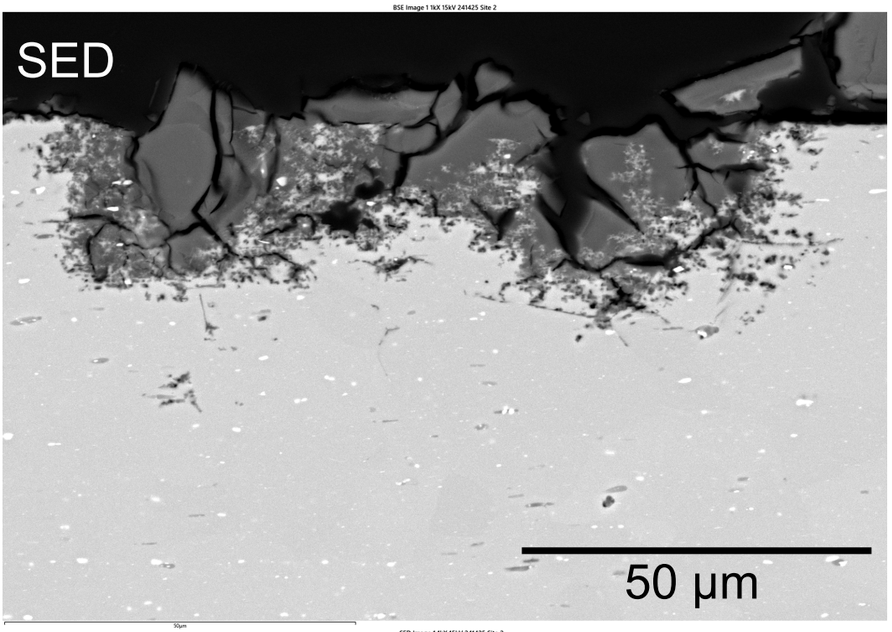
- Non-LSP AA6061 sample was exposed to 6 months in 3.5 wt.% NaCl solution at PNNL.
- Sample shows the presence of pits that are deeper (30µm max) than the pits in the LSP 3.12W AA6061.
- Pit morphology appears to show significant intergranular corrosion combined with grain dissolution.

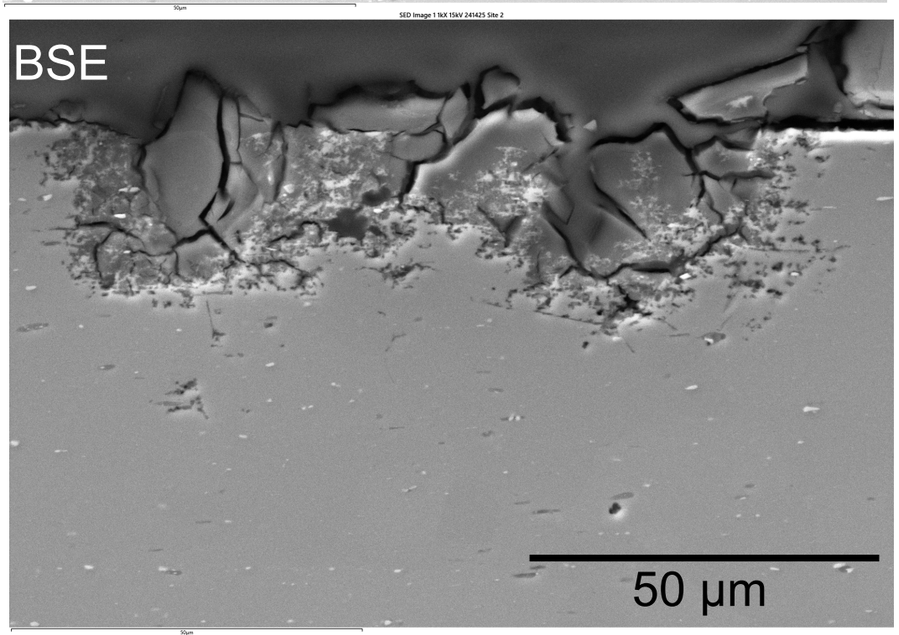


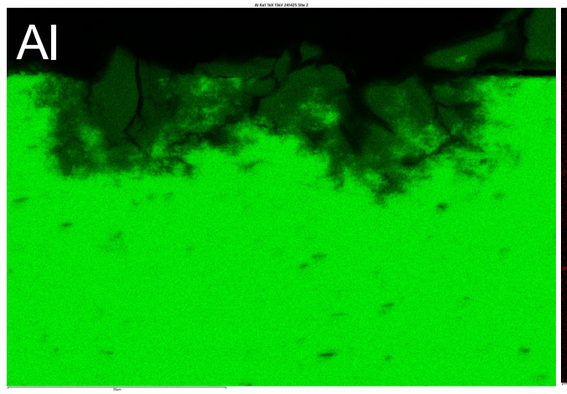
6 months Exposure

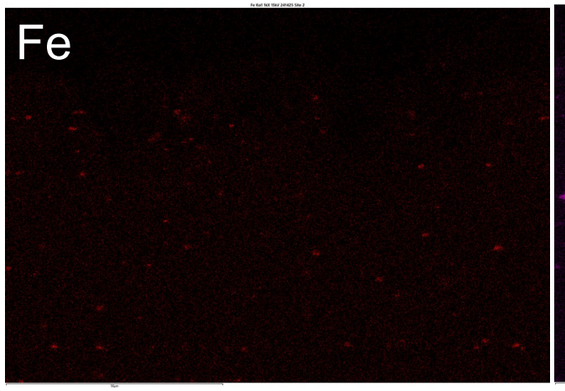
Non- LSP AA6061

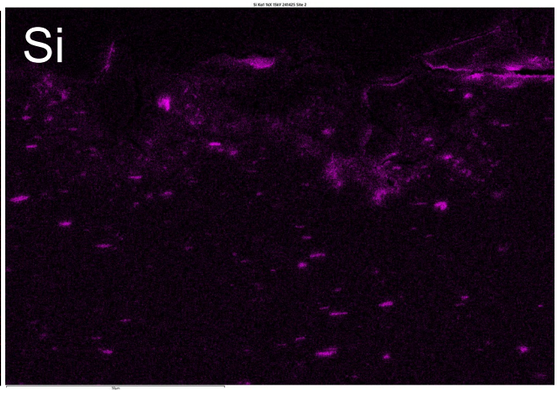
6 months Exposure to Lab 3.5 wt.% NaCl solution

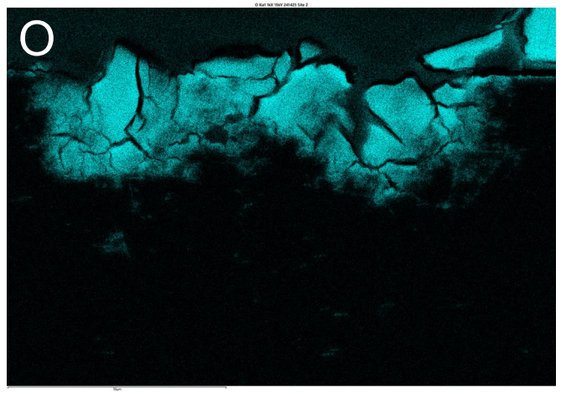


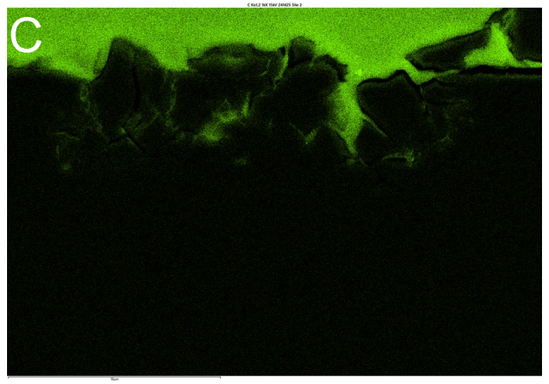


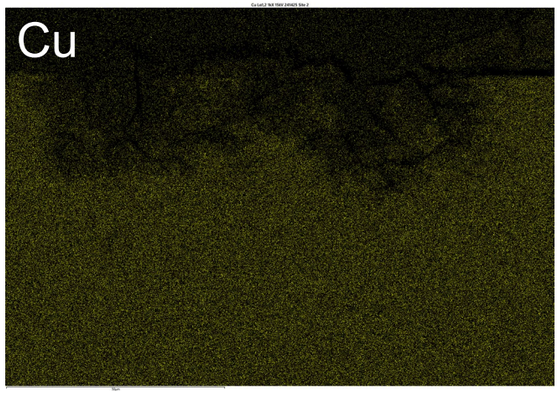


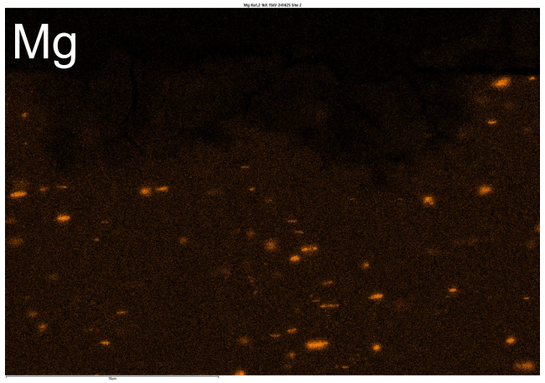








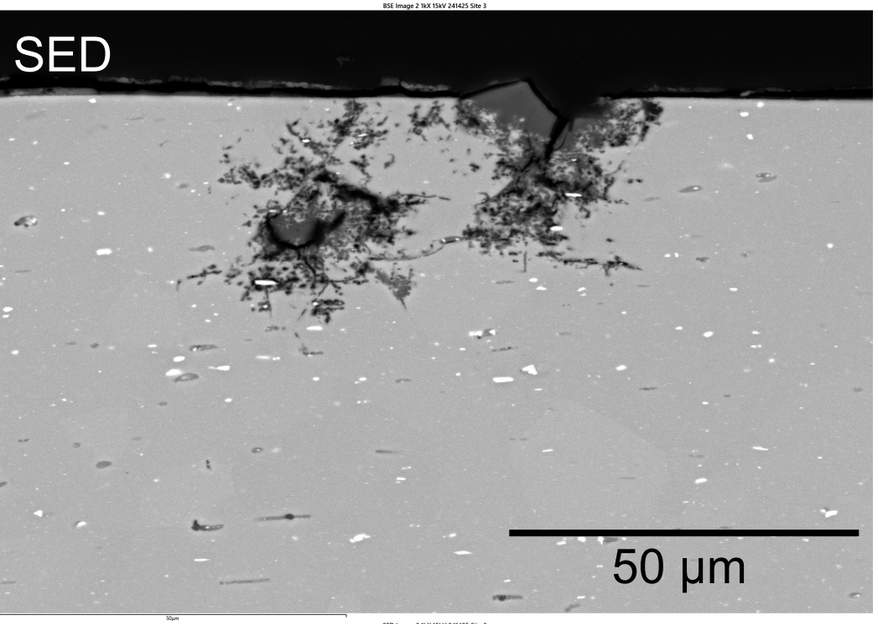


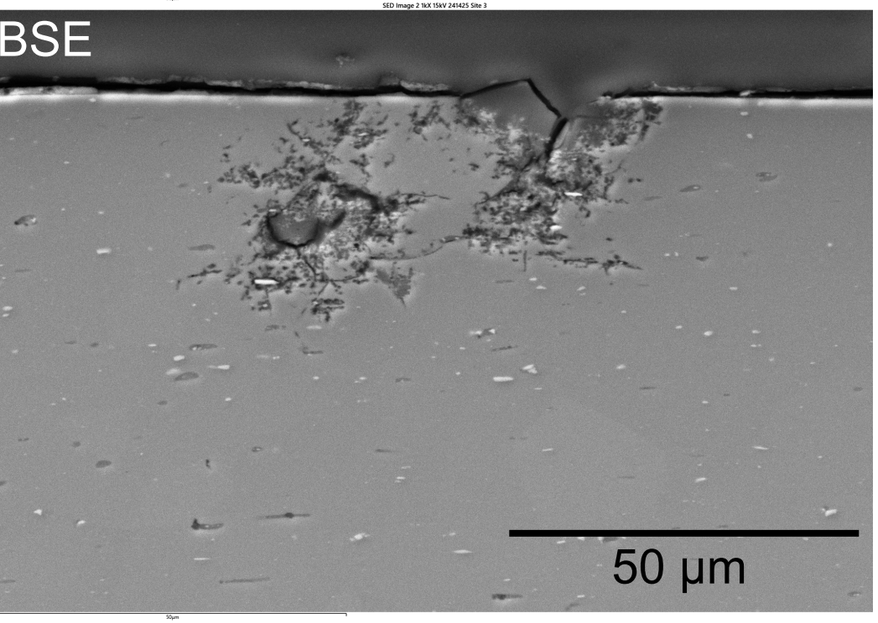


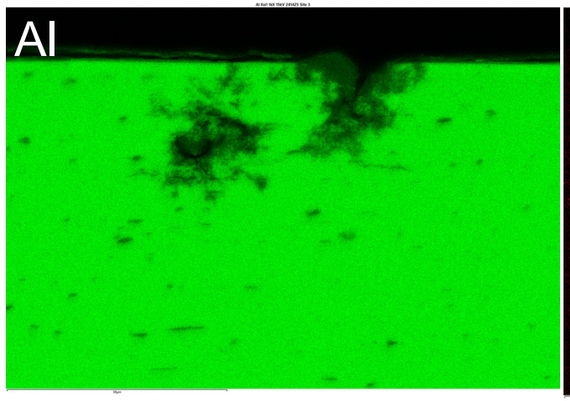
6 months Exposure

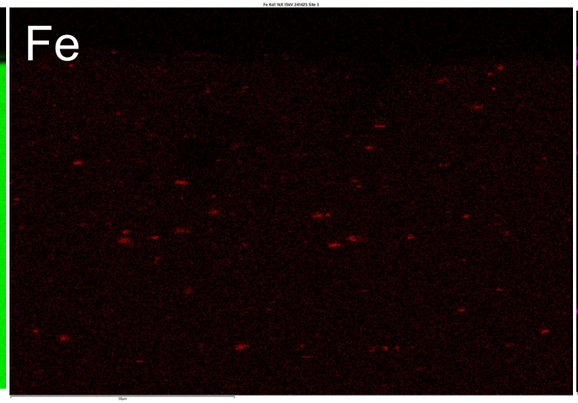
Non- LSP AA6061

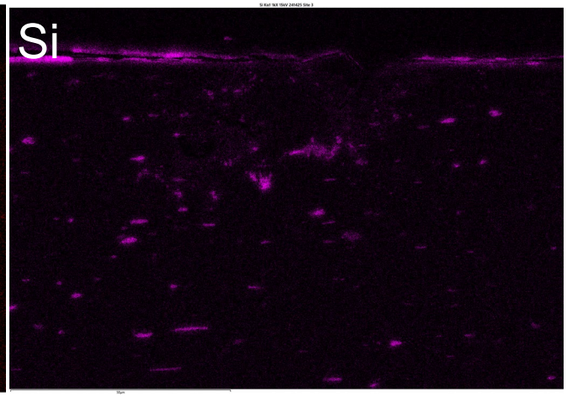
6 months Exposure to Lab 3.5 wt.% NaCl solution

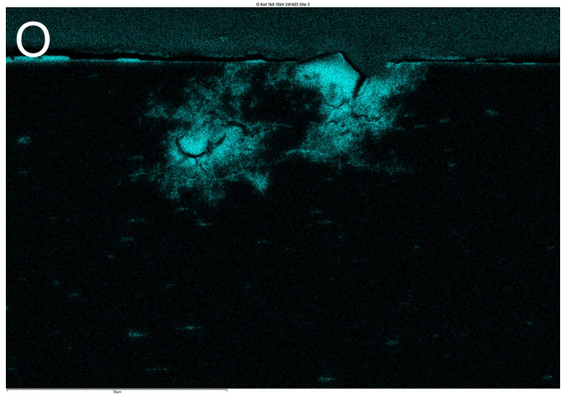


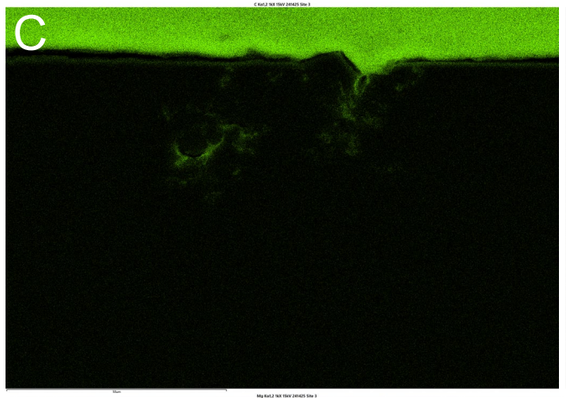


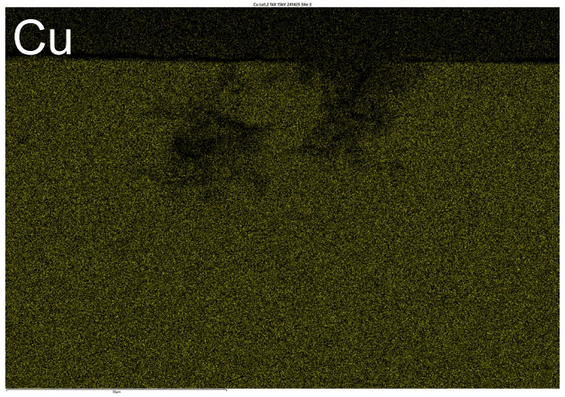


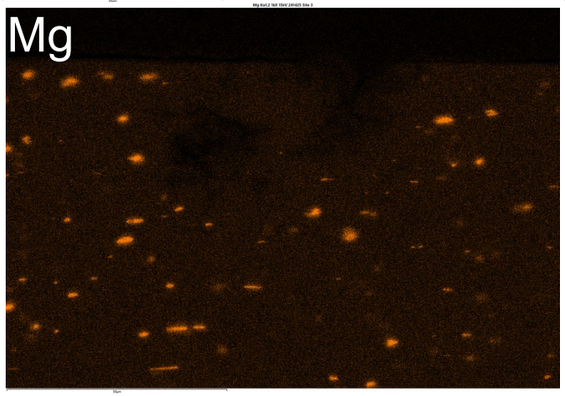




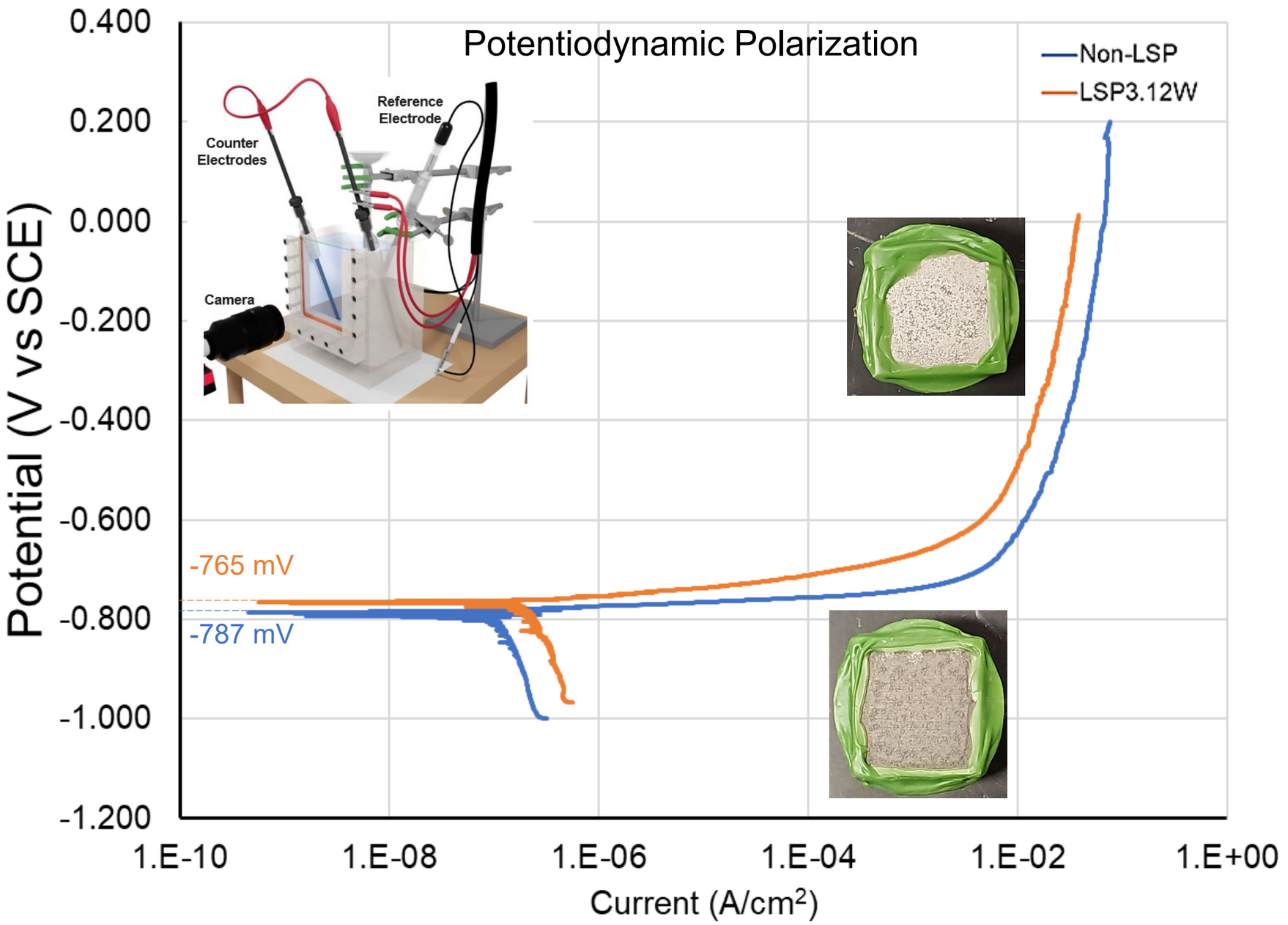


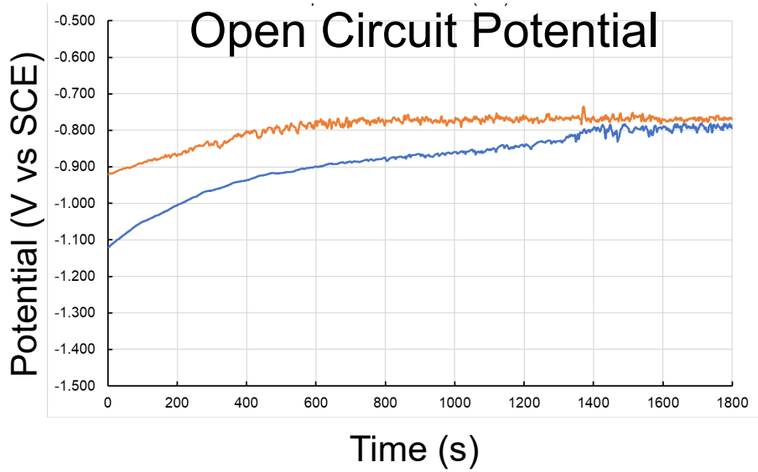






Multimodal Corrosion (Polarization+ Imaging) of LSP vs Non-LSP AA6061

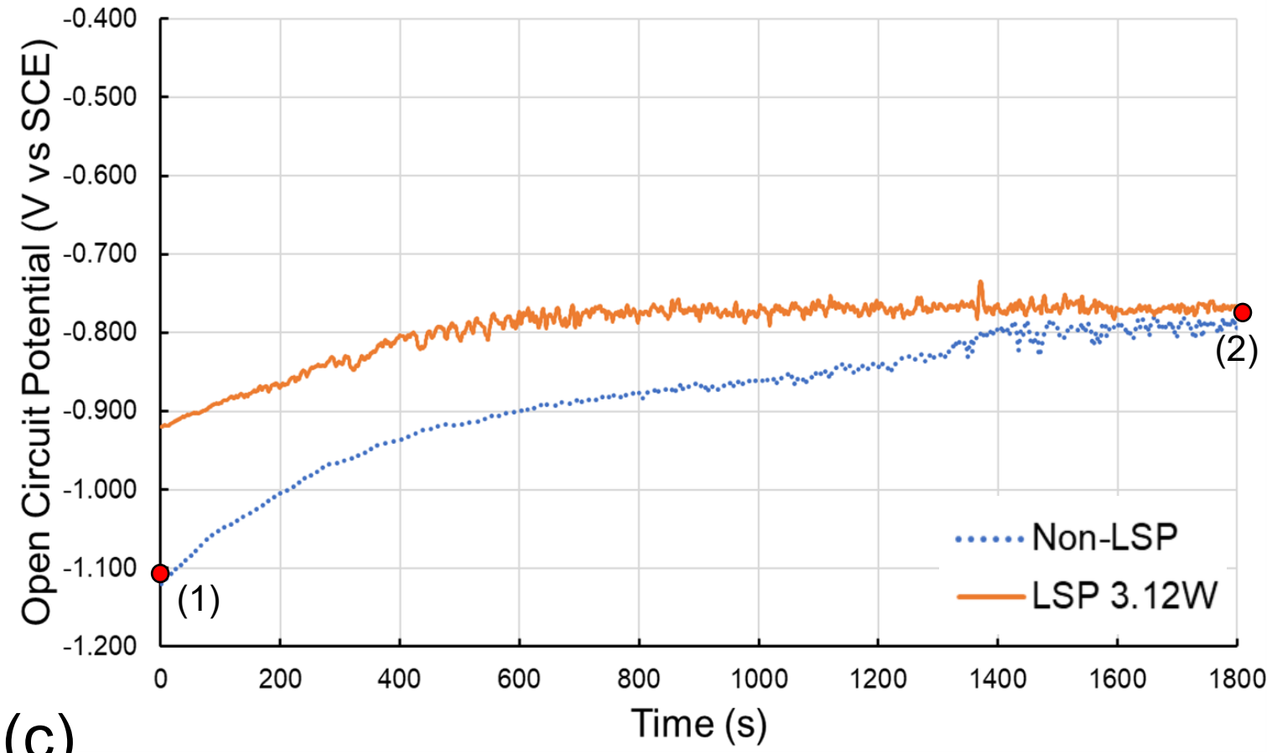




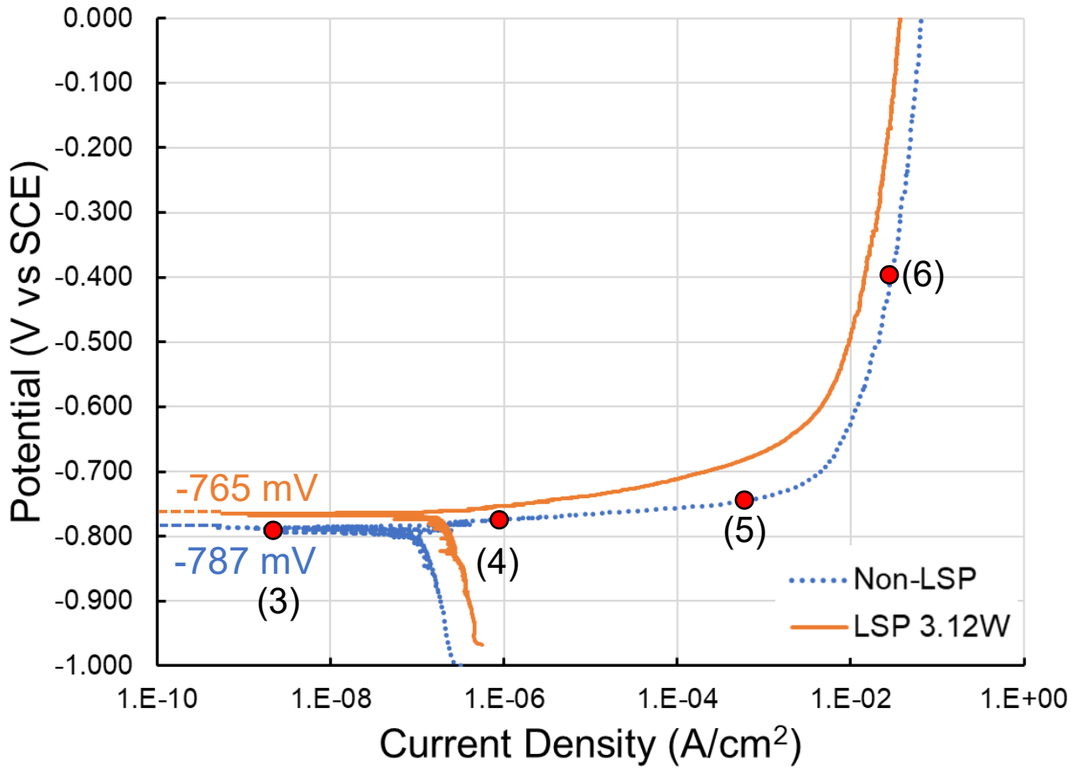
Surface peeling behavior at very high potential values.

Multimodal Corrosion (Polarization+ Imaging) of Non-LSP AA6061

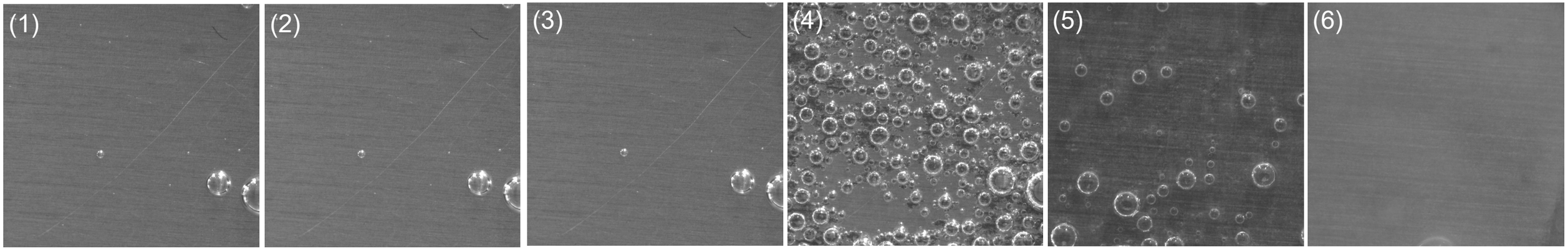
(a)



(b)



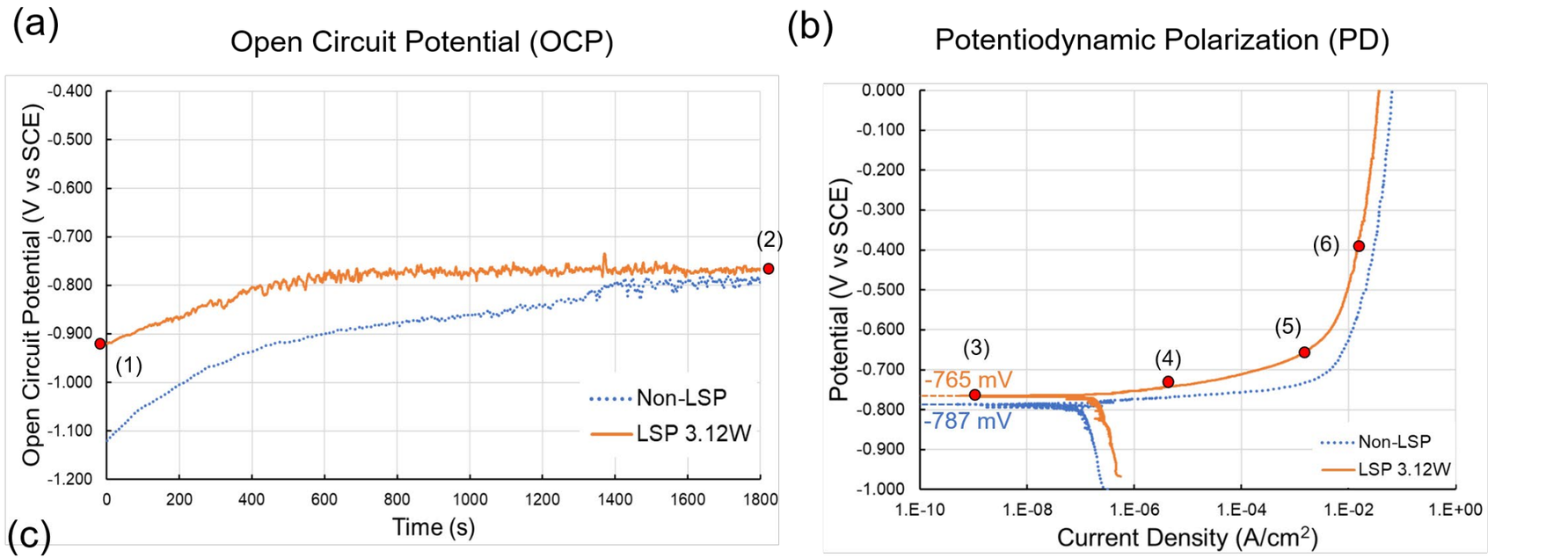
(c)



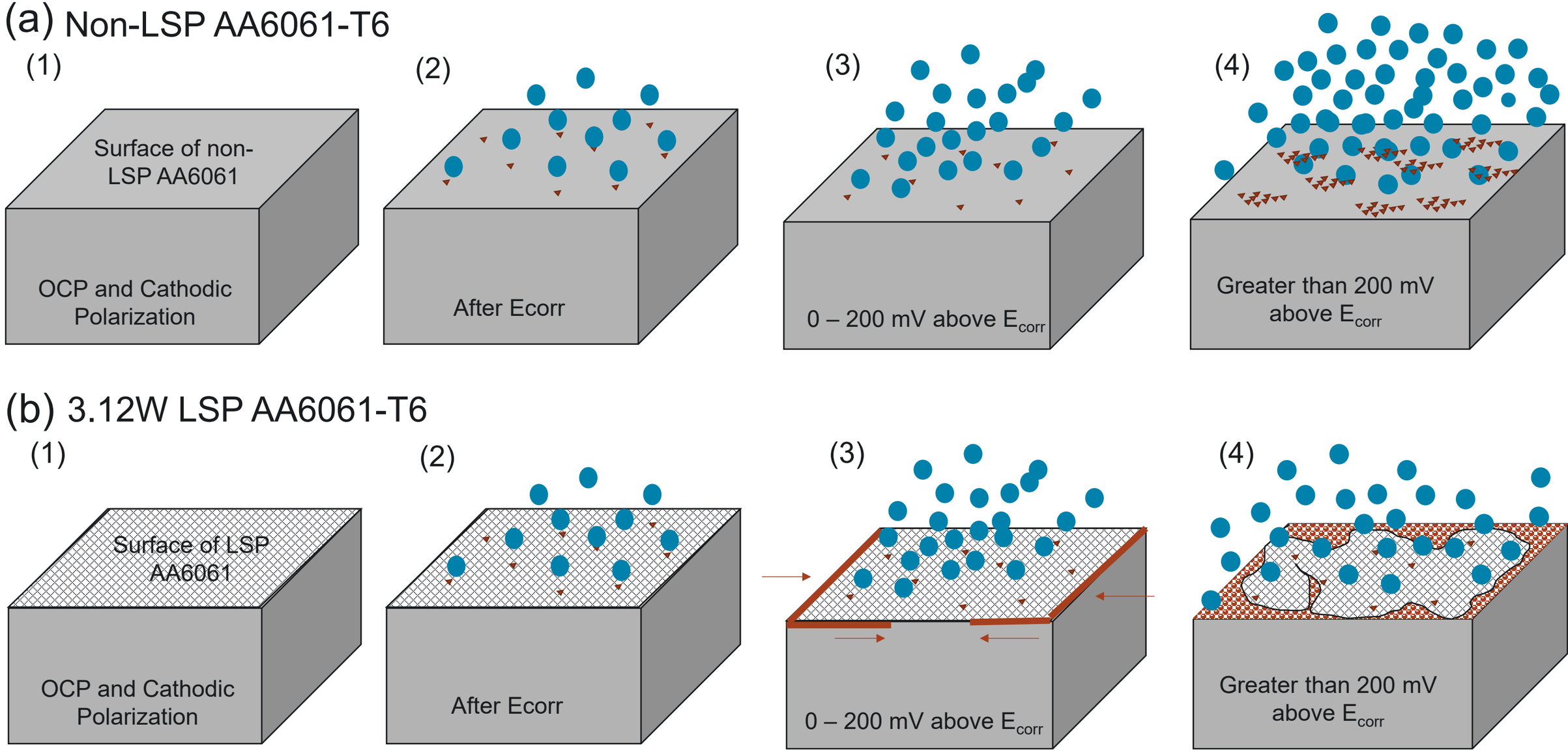
Non-LSP AA6061

5 mm

Multimodal Corrosion (Polarization+ Imaging) of LSP AA6061



Comparing Corrosion Mechanisms between Non-LSP and LSP AA6061

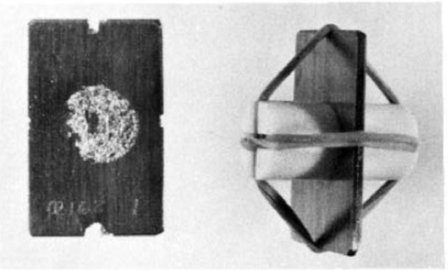


Crevice Corrosion Testing

Samples received from Iowa State University

AA6061-T6 Plate material	**Wear Testing**	**Crevice Corrosion**
Number of Samples needed	**LSP at 3.12W**- 3 replicates	**LSP at 3.12W**- 3 replicates
Size of each sample	3” x 3”	2” x 2”
	3 samples of 3”x3”. Only one surface to be LSP’d	3 samples of 2”x2”. Both surfaces to be LSP’d

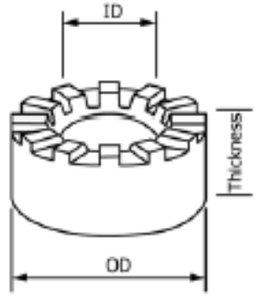
THE LSP Wear and crevice samples were compared with Non-LSP Counterparts



(a) Specimen After Test with Attack at Four Crevices Under Rubber Bands and Under One Block
(b) Assembled Crevice Test Specimen
FIG. 3 Ferric Chloride Crevice Test Specimen

Crevice Corrosion Method B- ASTM G48-11

- **Test Temperature:** For Methods A and B, the recommended test temperatures are 22 °C ± 2 °C or 50 °C ± 2 °C, or both.
- **Crevice Formers:** Method B: Cylindrical TFE-fluorocarbon Blocks, two for each test specimen. Each block shall be 12.7 mm (0.5 in.) in diameter and 12.7 mm high, with perpendicular grooves 1.6 mm (0.063 in.) wide and 1.6 mm deep cut in the top of each cylinder for retention of the O-ring or rubber bands. Blocks can be machined from bar or rod stock.
- **$FeCl_3$ solution preparation:** For Methods A and B, dissolve 100 g of reagent grade ferric chloride, $FeCl_3 \cdot 6H2O$, in 900 mL of Type IV reagent water (Specification D1193) (about 6 % FeCl3 by mass). Filter through glass wool or filter paper to remove insoluble particles if present.
- **Sample Dimensions:** A test specimen 25 mm by 50 mm (1 in. by 2 in.) is recommended as a standard size, although various shapes and sizes can be tested by this method. All specimens in a test series should have the same dimensions when comparisons are to be made.
- **Test Duration:** A reasonable test period is 72 h, although variations may be used at the discretion of the investigator and depend on the materials being evaluated.



Crevice Washer Dimensions							
Type	ID		OD		Thickness		Number of Slots
	mm	in	mm	in	mm	in	
A	6.73	0.265	15.9	0.625	2.54	0.100	12
B	6.73	0.265	15.9	0.625	6.34	0.250	12
C	9.92	0.391	15.9	0.625	6.34	0.250	12

FIG. 2 TFE-fluorocarbon Crevice Washers

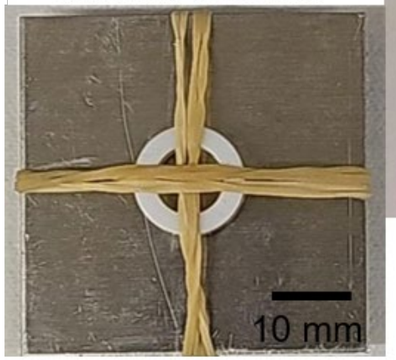
https://www.alspi.com/insulators.htm

Crevice Corrosion Testing Framework using Optical Profilometry

Crevice Corrosion in $FeCl_3$ solution (ASTM G48)



Toothed Washer



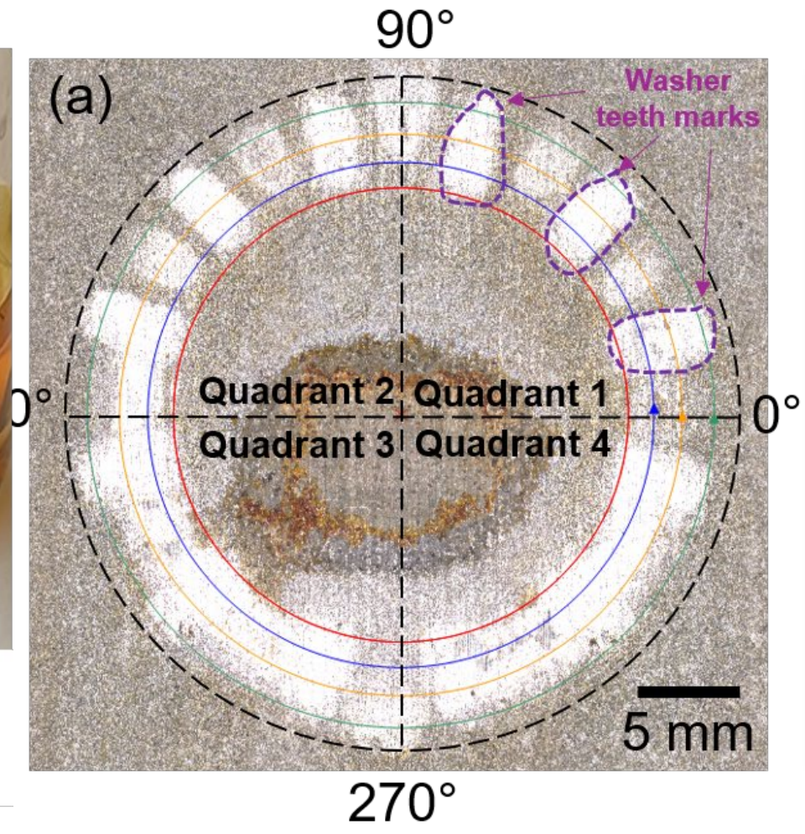
Assembled Sample

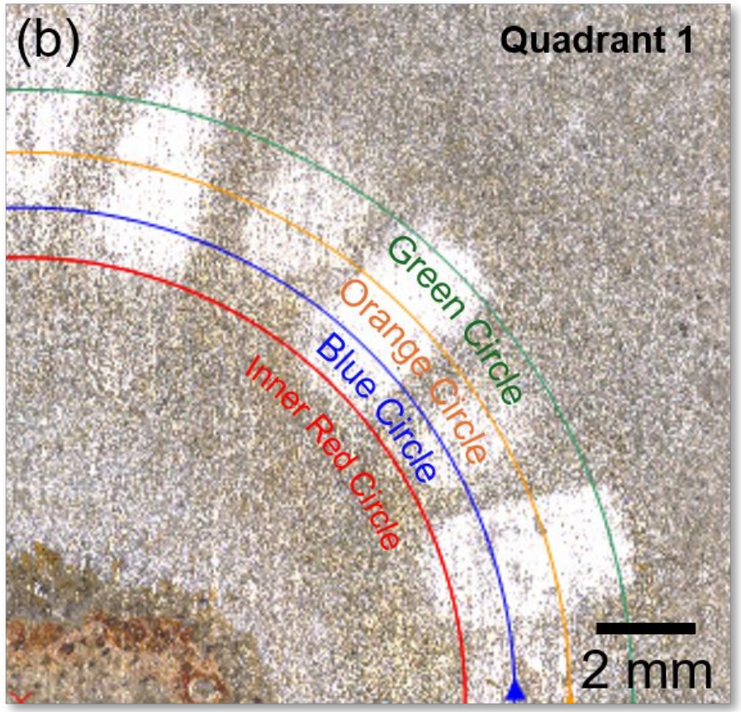


Assembled samples immersed into a beaker containing $FeCl_3$ solution

Post Crevice Corrosion Surface Analysis

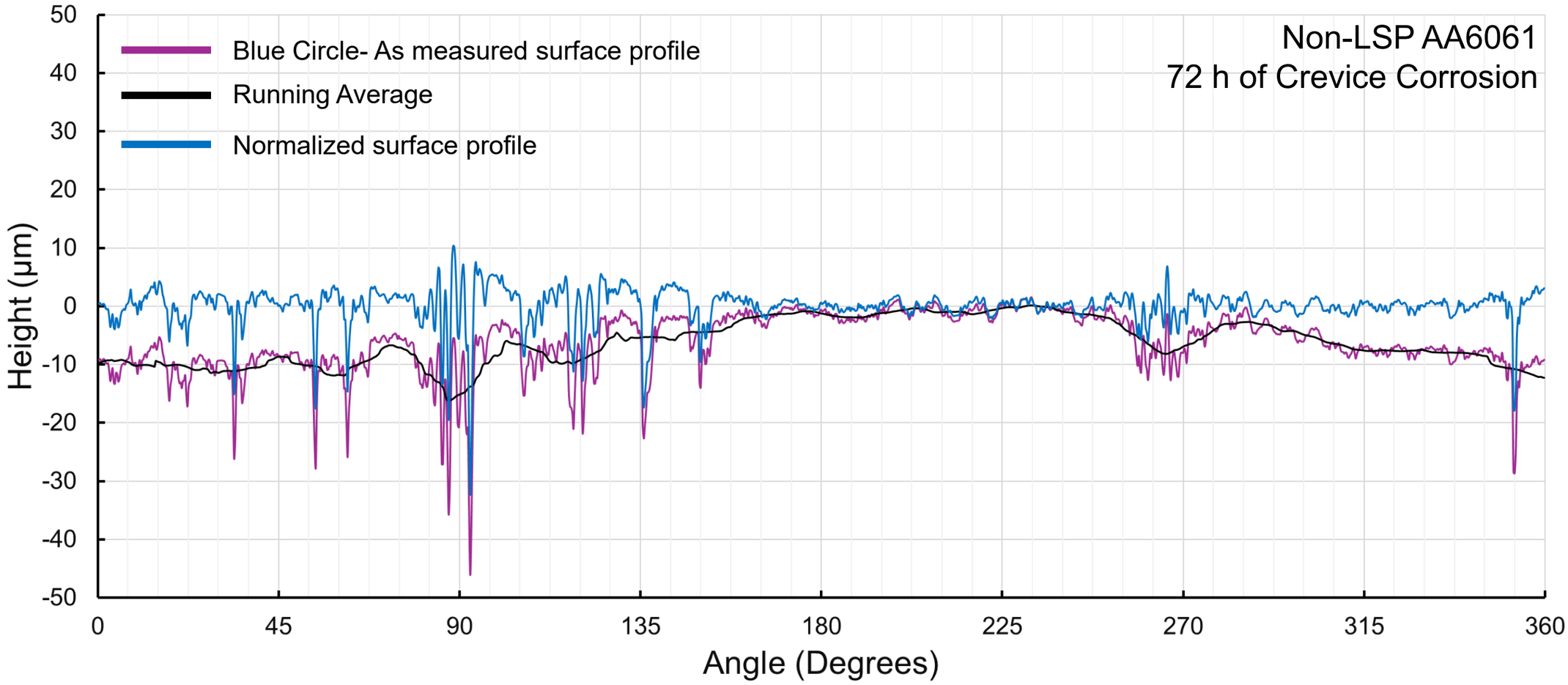
Profilometry along concentric circles





Crevice Corrosion Testing Framework using Optical Profilometry

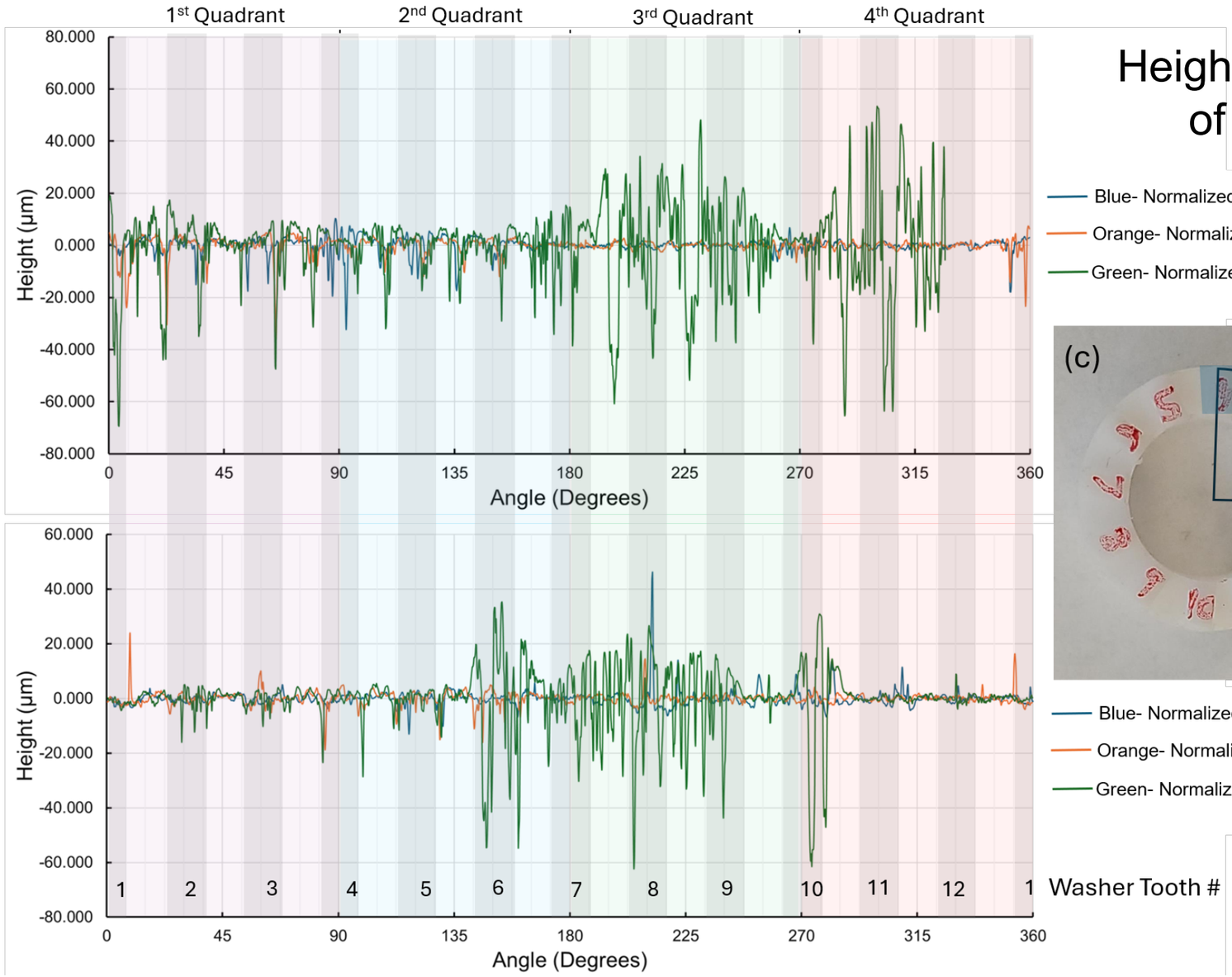
Example of a roughness profile along a concentric circle converted to Height vs Angle



Crevice Corrosion Testing Framework using Optical Profilometry

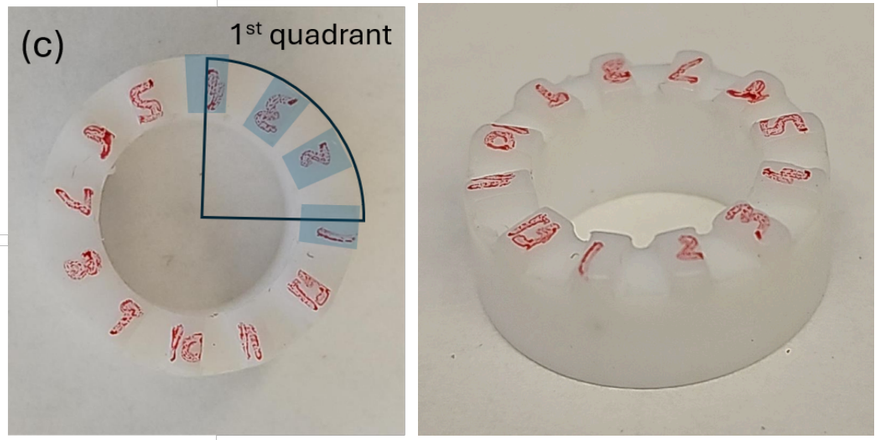
(a)
Non-LSP
72 h

(b)
LSP
72 h



Height profile of the topography of each concentric circle

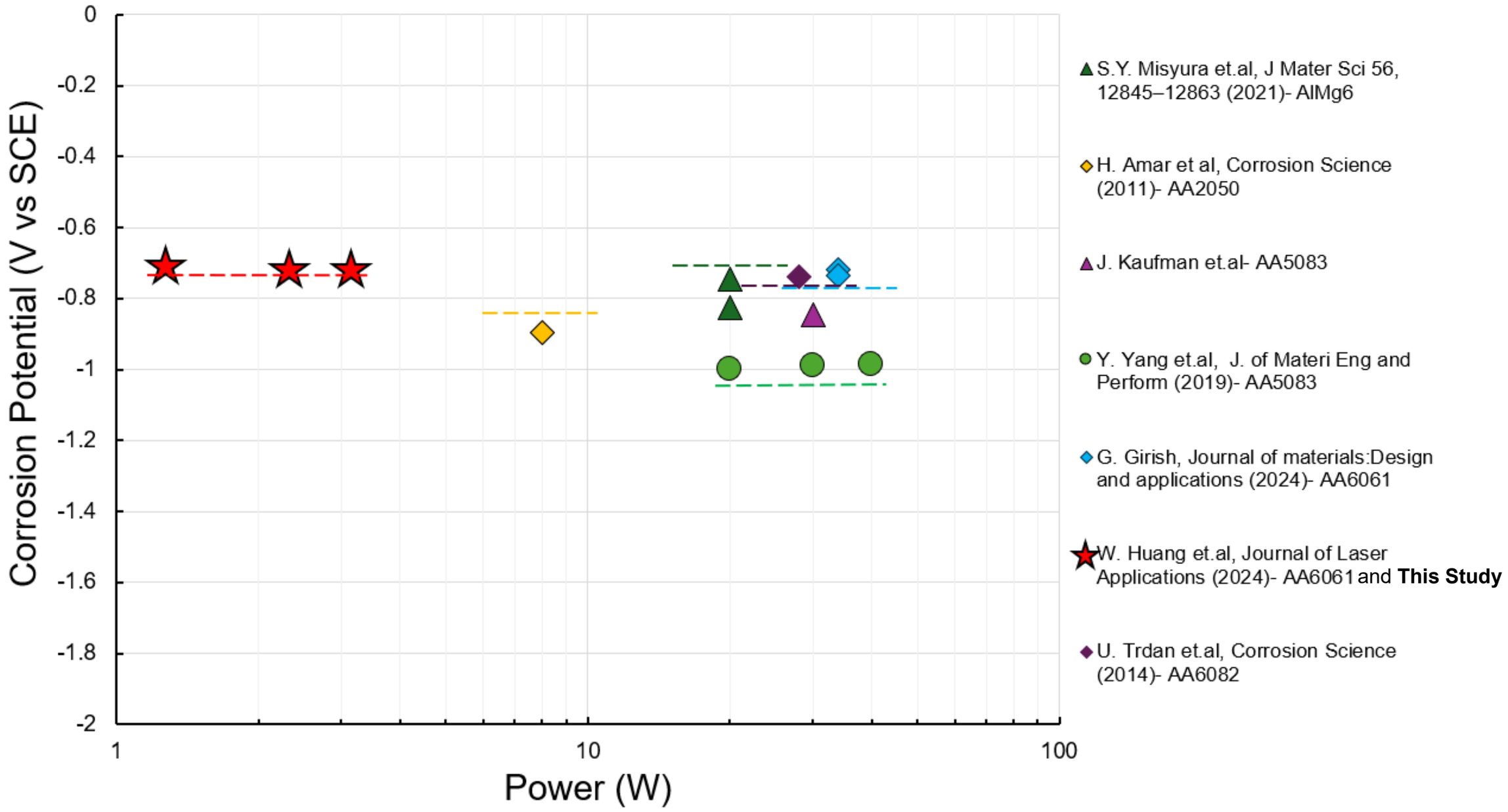
Blue- Normalized surface profile
Orange- Normalized surface profile
Green- Normalized surface profile



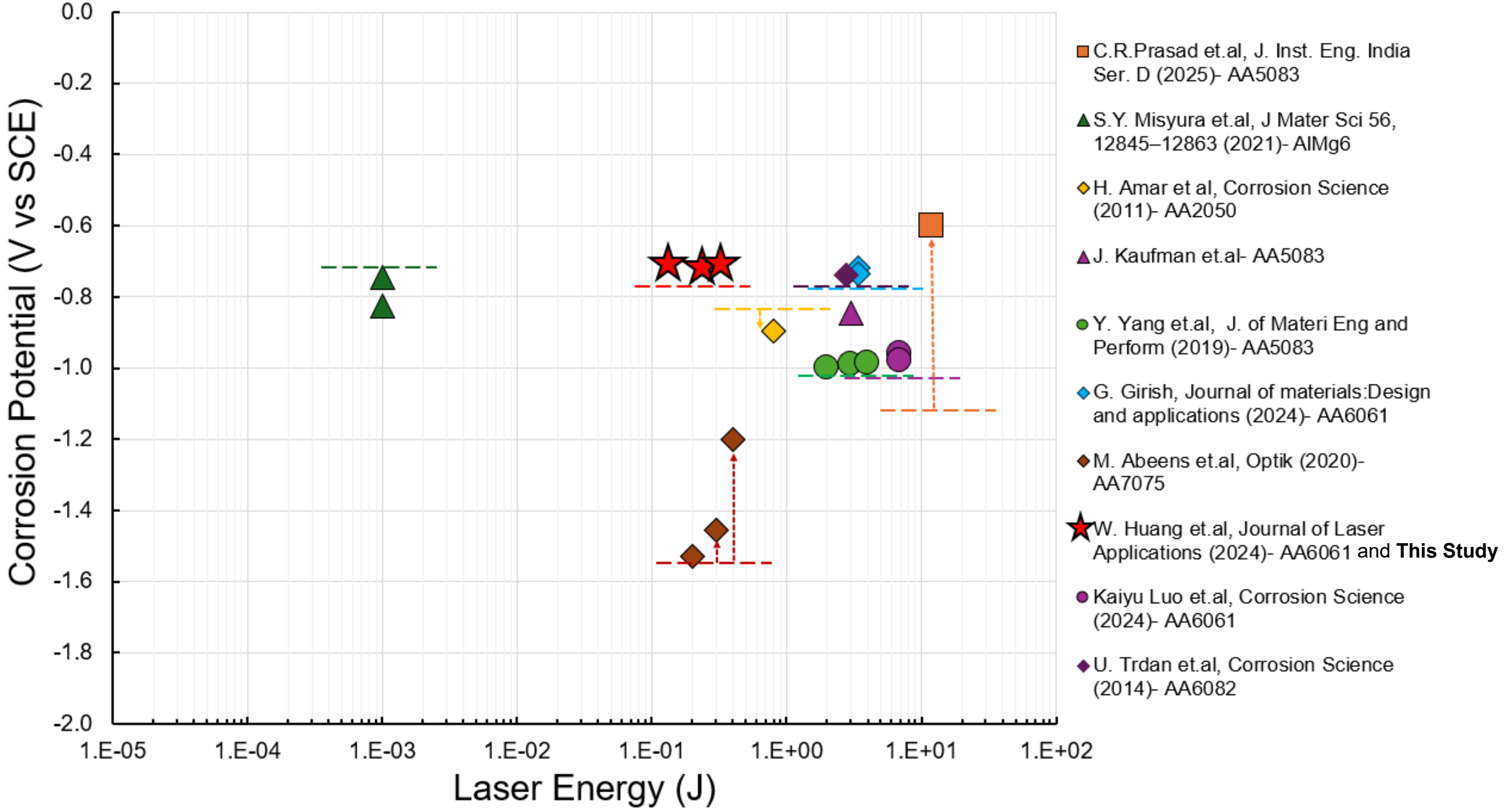
Blue- Normalized surface profile
Orange- Normalized surface profile
Green- Normalized surface profile

Washer Tooth #

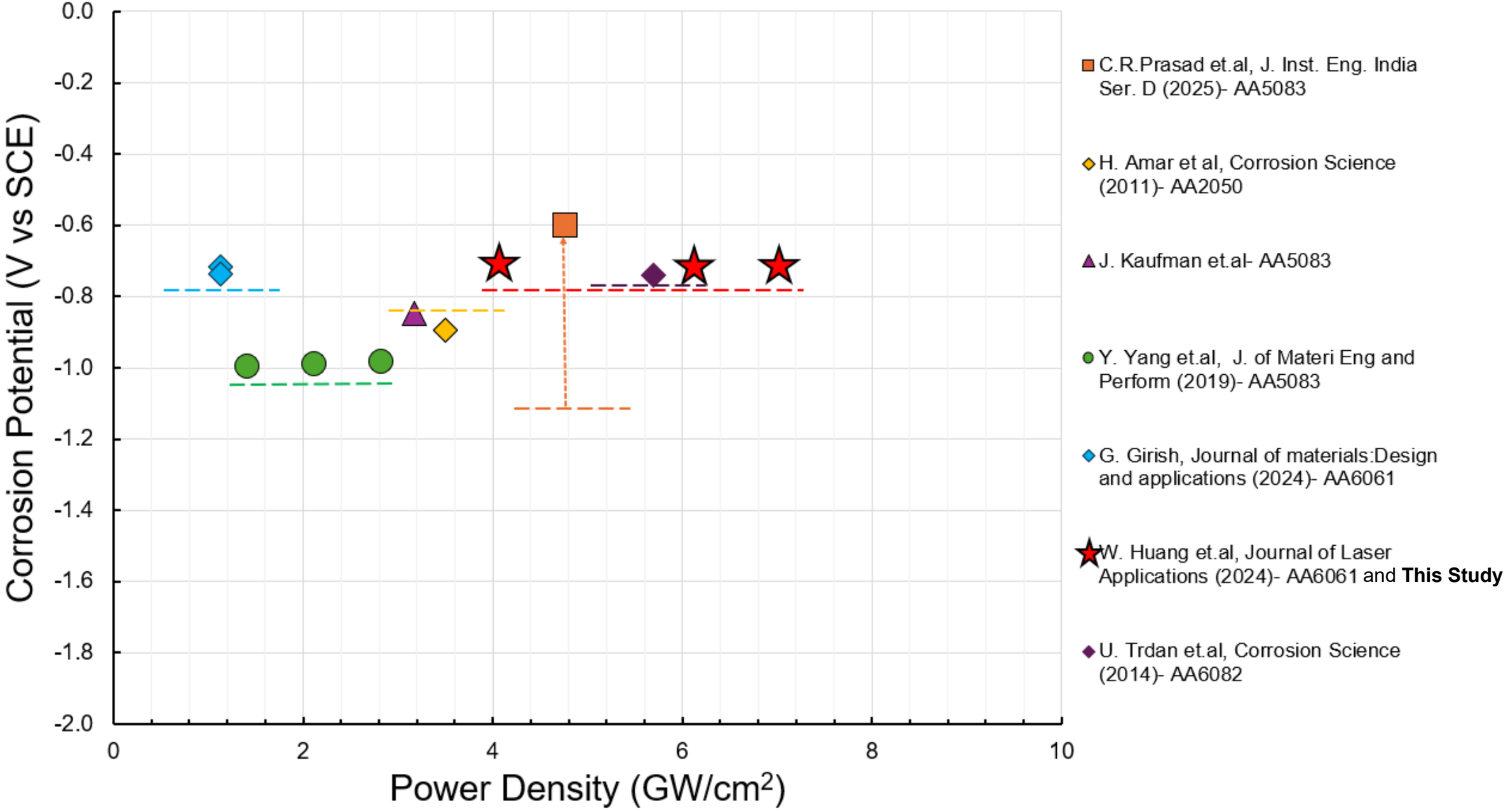
Power (W) vs Corrosion Potential (V vs SCE)



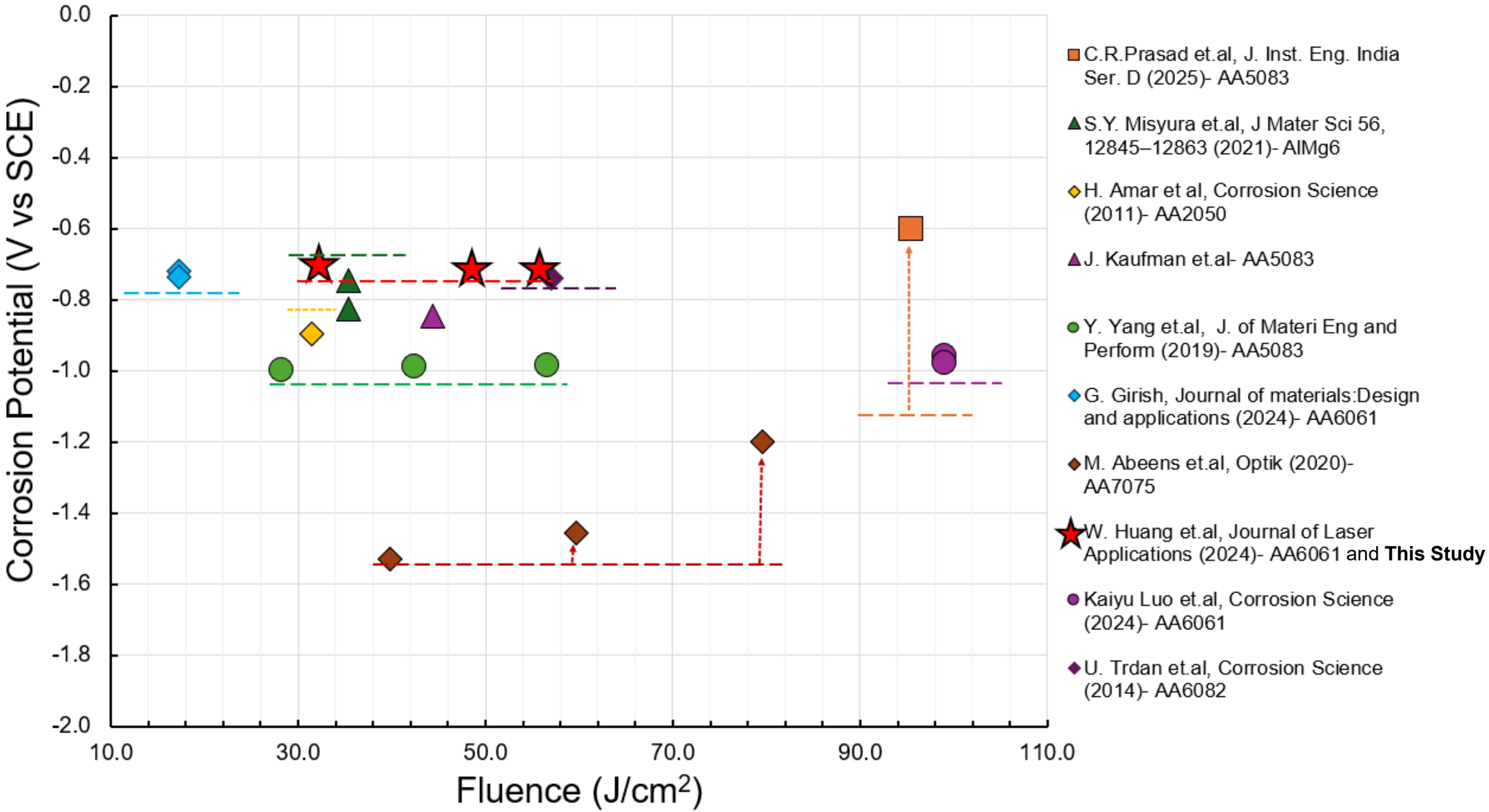
Laser Energy (J) vs Corrosion Potential (V vs SCE)



Power Density (GW/cm^2) vs Corrosion Potential (V vs SCE)

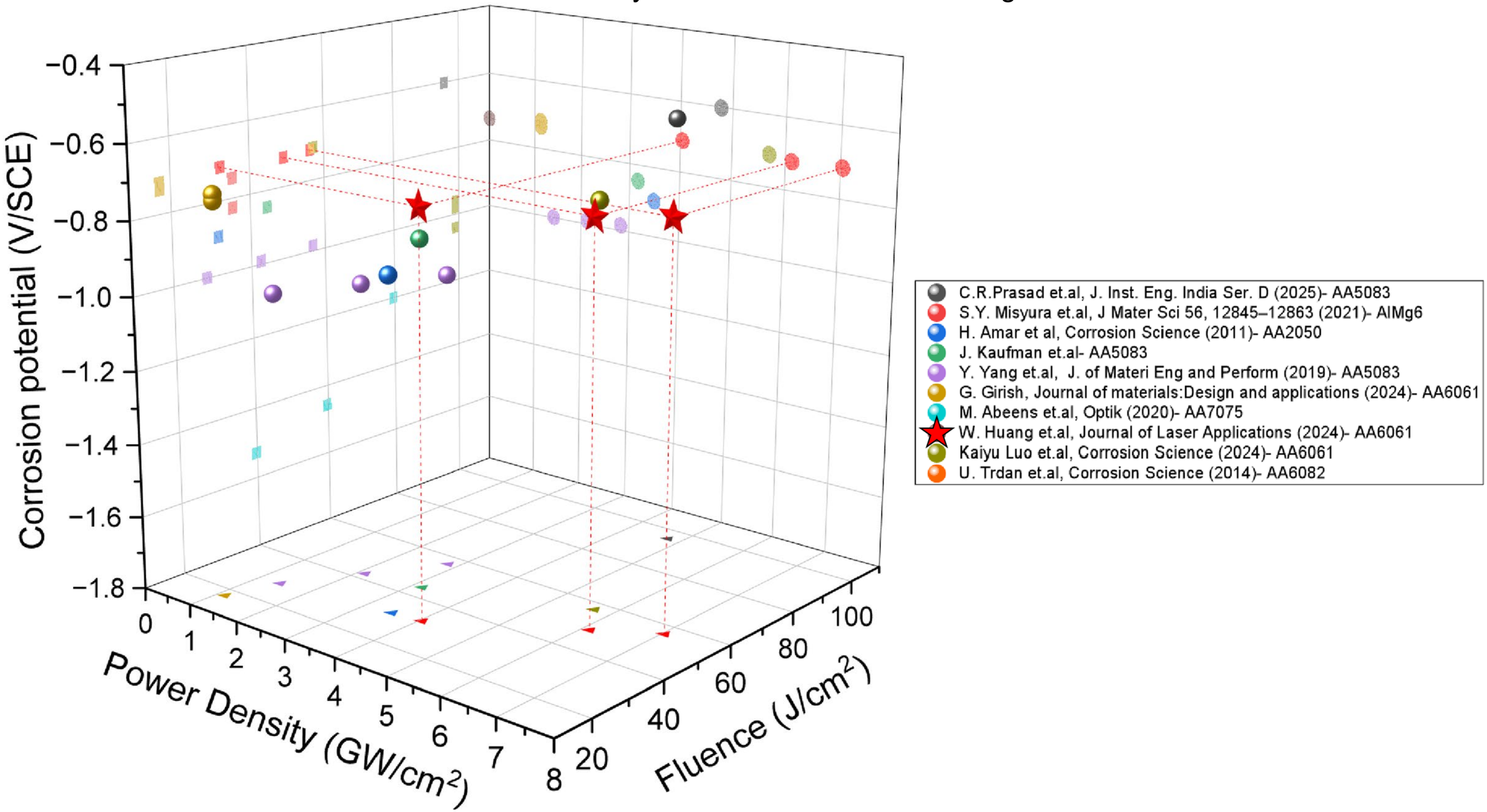


Fluence (J/cm^2) vs Corrosion Potential (V vs SCE)

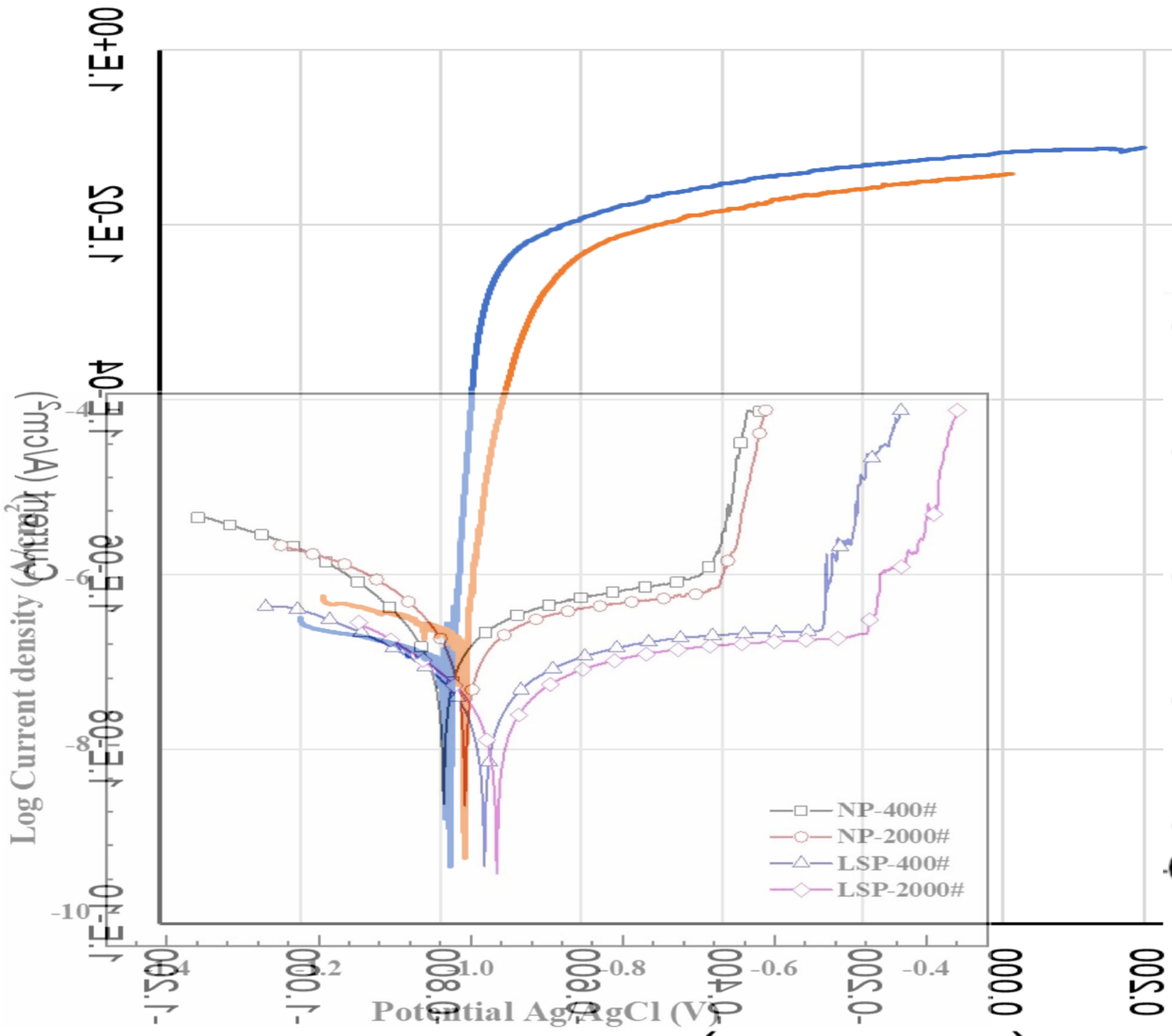


Extra Slides

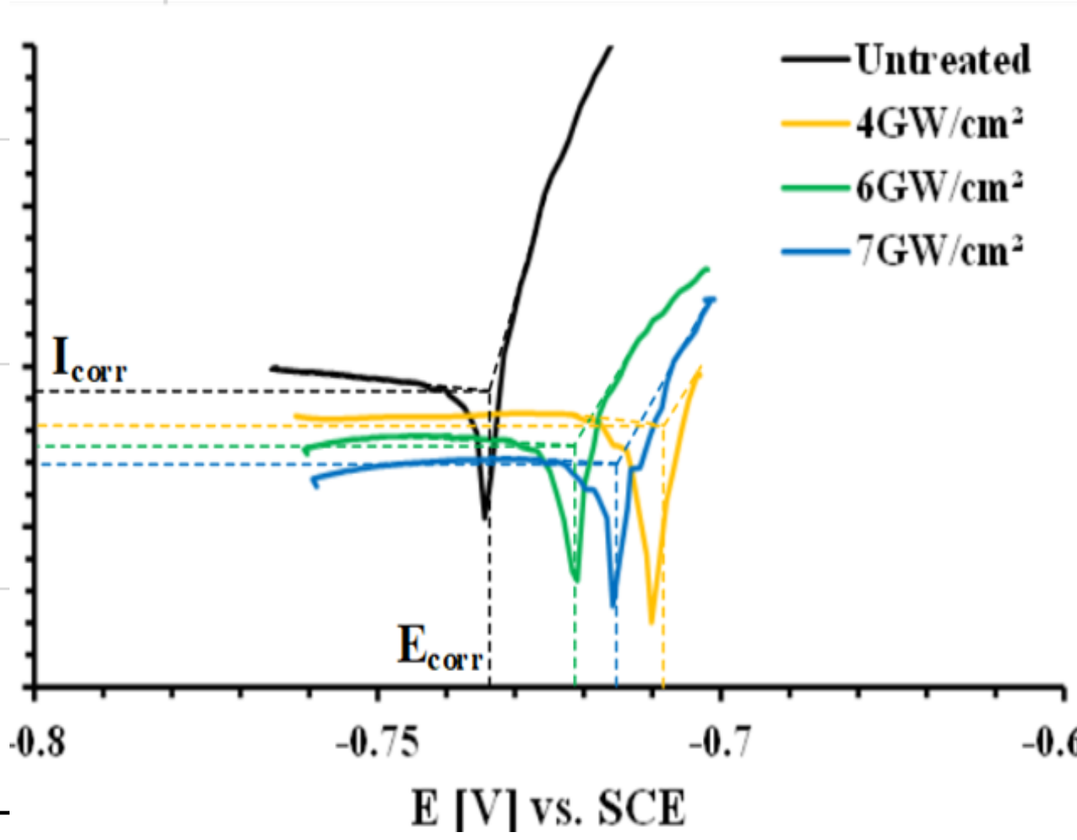
LSP Power Density vs LSP Fluence vs Resulting Ecorr



Multimodal Corrosion (Echem + Imaging) of LSP vs Non-LSP AA6061



Surface peel of behavior at very high potential values.



Separate paper on this

Elcometer- Coating Durability Testing

Wear Testing Specs:

- Minimum Sample Size- 3” x 3”
- Elcometer- LSP and non-LSP. 3 replicates each. 3 replicate samples can be run at the same time in seawater only. 6 in total.
- Tom uses Universal tool clamp + P120 grit Sand paper with 500g weight on top of it.
- Number of cycles (FREQUENCY??)- TBD after performing Weight change vs number of cycles measurement using trial runs. Tom runs 1000 cycles for his sold gel coatings. Send 3-4 extra dummy samples of non-LSP. 2”x2” samples are ok. He may have to fabricate a holder for 2”x2”.
- Ideally, best to keep parameters same as his coating parameters for one to one comparison of our LSP surfaces with their antifouling coatings. We can do this. Maybe compare these in a future paper.
- Initial study- ~10 hours for both materials.
- Main studies- ~15 hours in total.

- Let us focus on AA6061 ONLY- 05/29/2025

	Non-LSP	LSP
AA6061	3 samples	3 samples
Mild Steel	3 samples	3 samples

I will also share ~ 4 dummy samples with Tom for trial testing to determine weight change as a function of cycles. 3”x3” and 2”x2”. Weight will be measured every 100 cycles.

