



ELECTROLYTIC ETCH UNIFORMITY OF 304L STAINLESS STEEL

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Background

Electrolytic etching of 304L stainless steel involves using an electrolyte solution and electrical current to selectively remove material from the surface. This reveals grain boundaries, phases, and other microstructural features for metallographic examination. A primary issue with current 304L stainless steel etching techniques is the inability to achieve a uniform etch across the entire surface of larger (>2 inch) samples.

Motivation

Variations in etch uniformity can result in a failure to reveal true microstructural features. This study focuses on cathode-anode geometry, sample placement within the electrolytic cell, electrolyte selection, voltage applied, and etch duration to optimize the etch response of 304L.

Approach

- Test a variety of stainless-steel cathodes.
- Test anode placement by connecting the stainless-steel anode to various regions on the sample.

Cathode	#1	#2	#3
Description	Stationary rod perpendicular w sample surface	Large rectangular sheet parallel with sample surface	Stainless Steel beaker
Material	Stainless Steel	Stainless Steel	Stainless Steel

Anode	#1	#2	#3
Description	Side	Diagonal Corner	Bottom Middle
Material	Stainless Steel	Stainless Steel	Stainless Steel

- Refine etch conditions using multiple electrolytes.

Electrolyte	ASTM 219	Oxalic
Description	Grain Boundary Etch for austenitic stainless steels 60mL HNO3 & 40mL DI H2O	Etch for austenitic stainless steels 10% Oxalic 90% DI H2O
Ideal Test Range	1-5 V : 1-5 Seconds	5-10V : 15-90 Seconds *

Method

Sample Prep

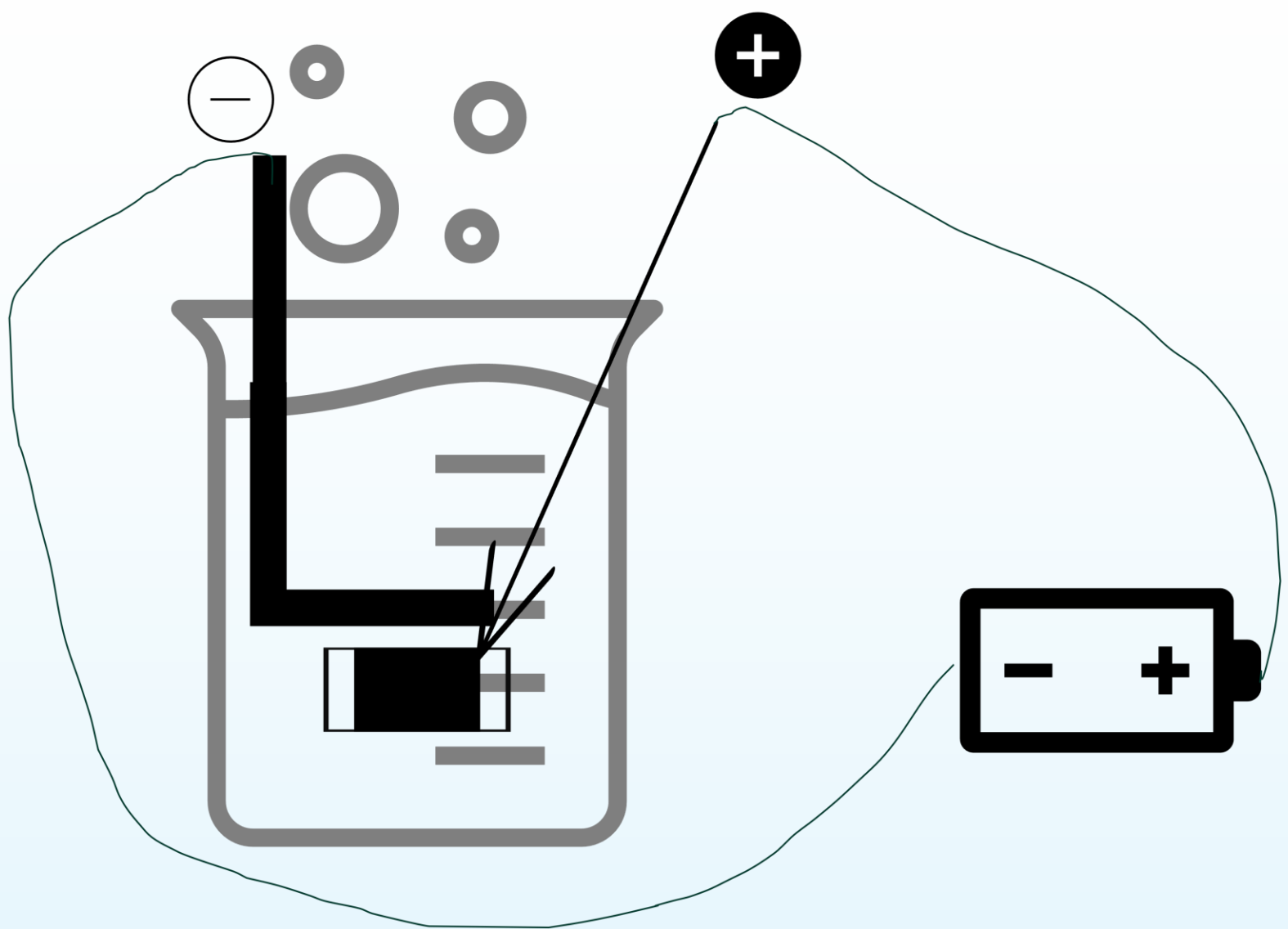
- Grinding - SiC 120, SiC 220, SiC 400, SiC 600.
- Polishing (10 min per step) – 9µm, 6µm, 3µm, 1µm.
- Final Polish (VibroMet) – 24hrs 0.3µm Al₂O₃ (Aluminum Oxide), 4hrs 0.04µm SiO₂ (Colloidal Silica).
- *Tests are conducted on 25mm x 40mm samples of 304L mounted in 2" epoxy mounts.

Experiment #1 – Anode/Cathode Geometry

- All possible variations of cathode #1-3 and anode #1-3 were tested.
- All variations were tested under the same conditions
 - Etchant: ASTM 219 (60/40).
 - Voltage: 5V.
 - Duration: 5-7 seconds.
 - Cathode Distance to sample surface: 5-10mm.

Experiment #2 – Electrolyte/Voltage/Duration

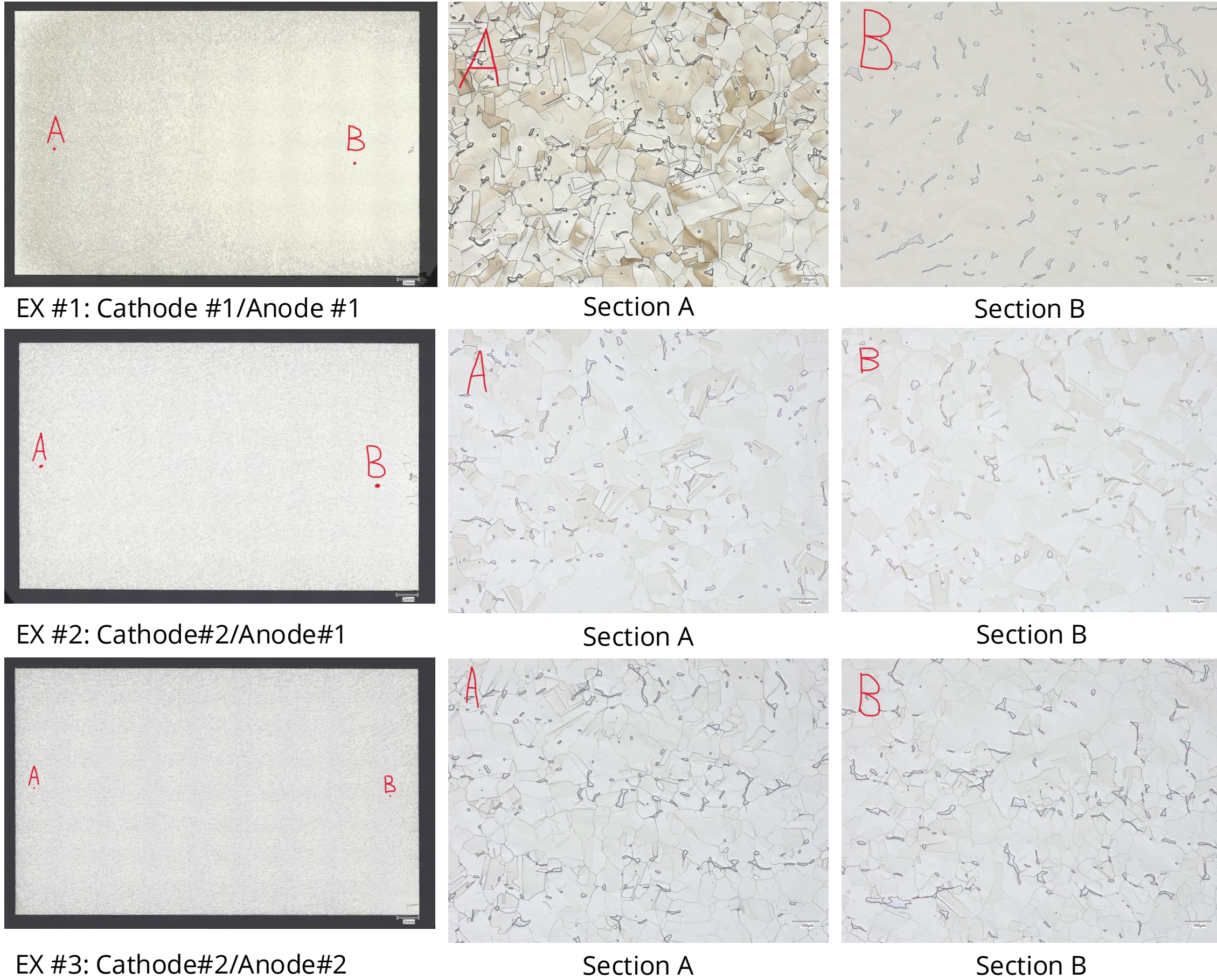
- Experiment utilized various test conditions to optimize the etch response of 304L.
- Cathode/Anode: #2/#2.
- Etchants: ASTM 219 & Oxalic Etch.
- Test parameters
 - ASTM 219: 1-5V, 2-10 seconds.
 - Oxalic: 6-10V, 30-90 seconds.



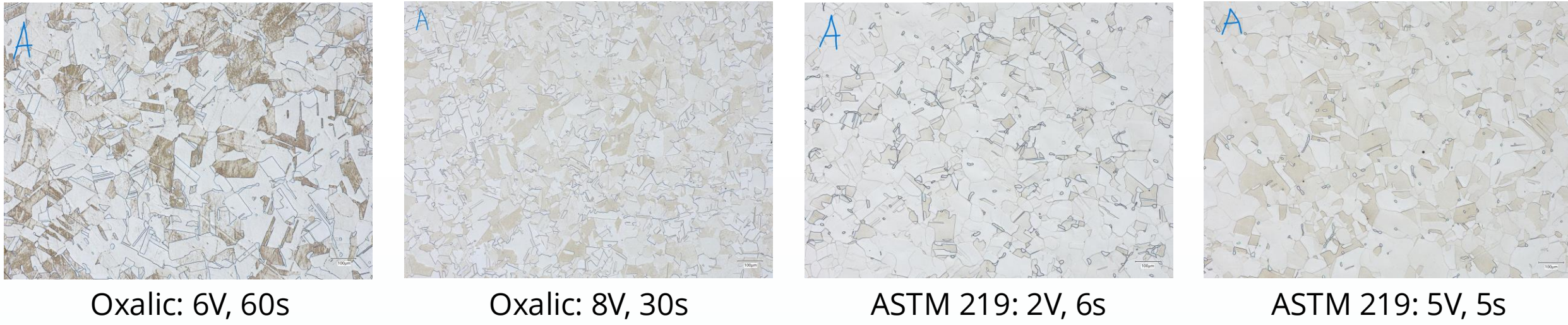
* Anode #2 & Cathode #2

Results

Experiment #1



Experiment #2



Conclusions & Future Research

- Cathode#2/Anode#2 & Cathode#2/Anode#1 provided the most uniform etch under the control test conditions.
- Ideal Oxalic etch range: 6-8V, 30-60s.
- Ideal ASTM 219 etch range: 2-5V, 5-6s.
- Further research will be done to optimize electro-etching techniques and procedures for 304L stainless steel and other materials.

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