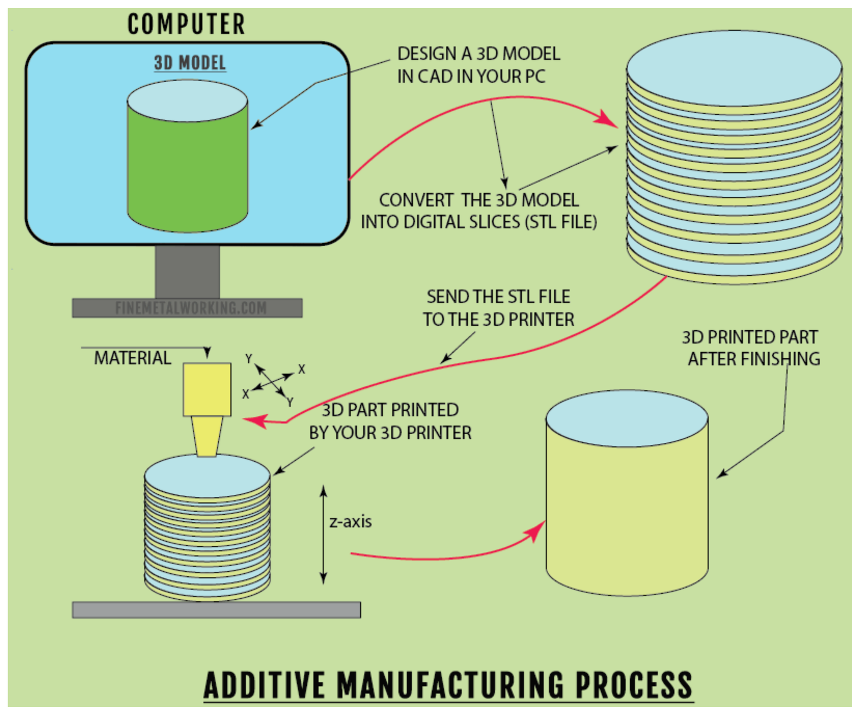
Corrosion Response of Laser Powder Bed Fusion (LPBF) Additive Manufactured Materials in Artificial Seawater (ASW)

Somdatta Basu, Aerospace Engineering – Penn State University
Advisor: Dr. Mala Sharma –Material Science Division, Penn State Applied Research Lab

Introduction

What is additive manufacturing (AM) and its benefits?

- Additive manufacturing (AM) is an industrial production process that creates 3D objects by depositing material layer by layer
- AM allows for components to have greater part complexity, reduced processing time, increased material utilization rates, potential superior performance



What is the motivation for this work?

- AM material properties have not been studied thoroughly and are not understood well
- Understanding the corrosion response of AM materials is imperative for Naval applications
- AM processes create orientation-dependent microstructure, which result in different corrosion responses
- Limited published information that is often conflicting [1-3].

Objectives

To evaluate the effects of build orientation and surface finish of LPBF samples on the corrosion response.

1) Characterize the effects of build direction and surface roughness on the corrosion response of various LPBF-manufactured materials via benchtop corrosion testing and microstructure analysis
2) Compare the corrosion performance of LPBF samples with traditional wrought materials used in Naval applications

Methodology

- EOS M280 Laser Powder Bed Fusion (LPBF) machine – high-power density laser melts pre-alloyed/mixed powders layer by layer
- "As built" samples – horizontal, vertical, and 45°
- Some samples are heat treated and stress relieved
- Benchtop corrosion testing - open circuit potential and cyclic polarization tests (ASTM G3 and G61) in aerated artificial seawater (ASTM D1141)
- Samples imaged with scanning electron microscope (SEM) to observe microstructure
- Surface preparation – grinding with 600 grit sandpaper
- Benchtop corrosion testing - open circuit potential and cyclic polarization tests (ASTM G3 and G61) in aerated artificial seawater (ASTM D1141)
- Samples imaged with scanning electron microscope (SEM) to observe microstructure changes

Acknowledgements

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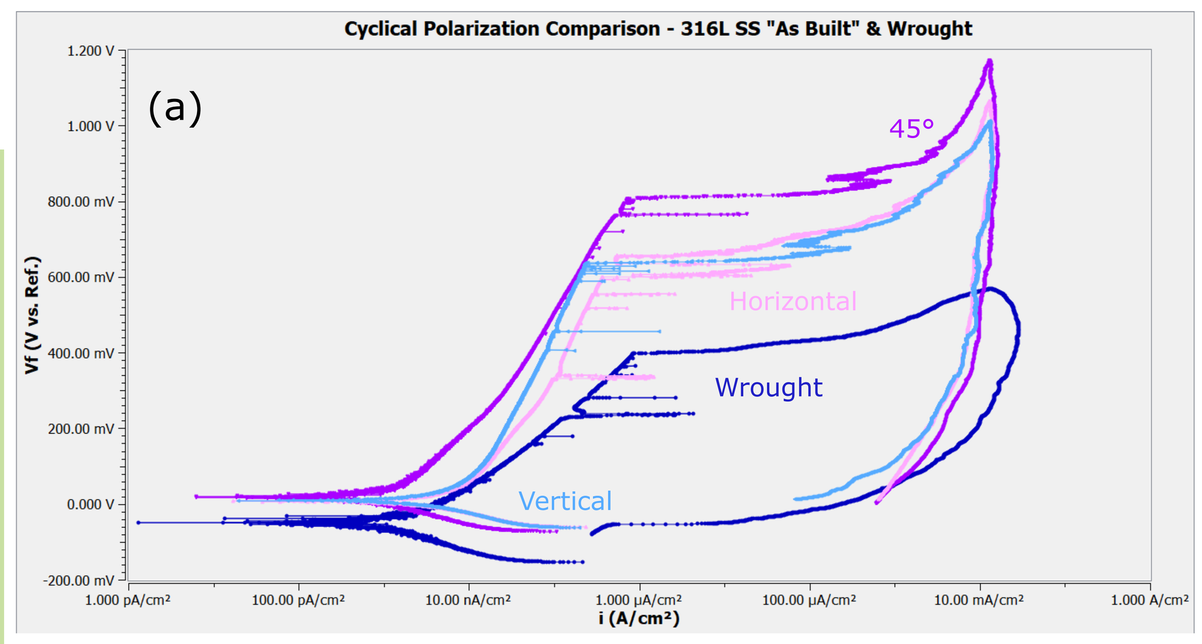
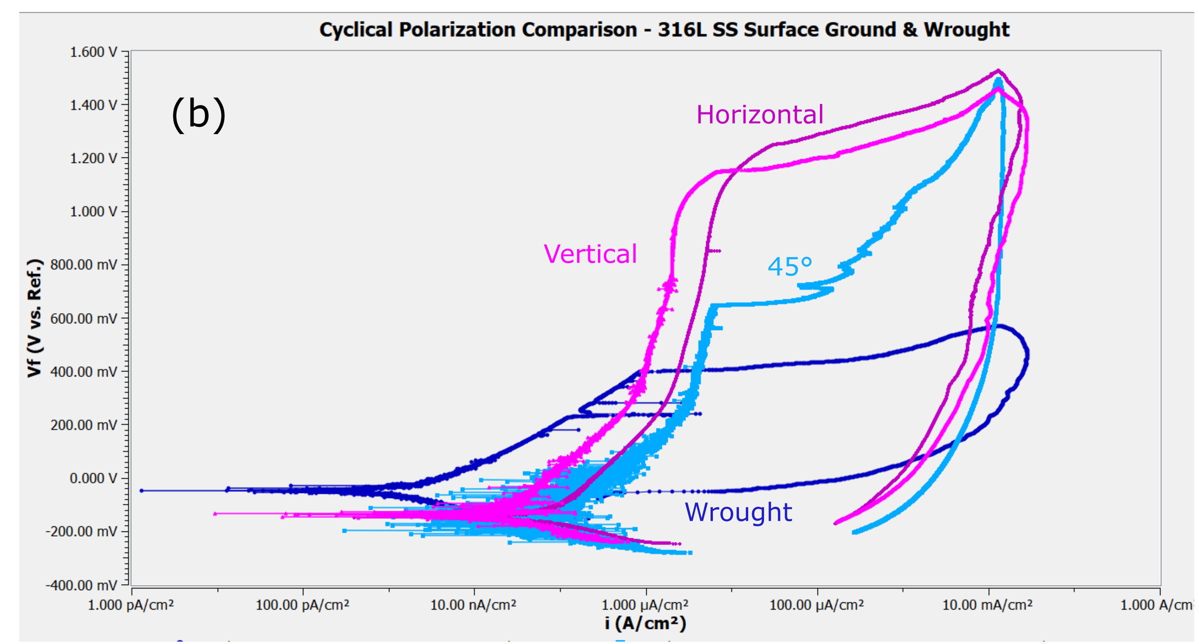
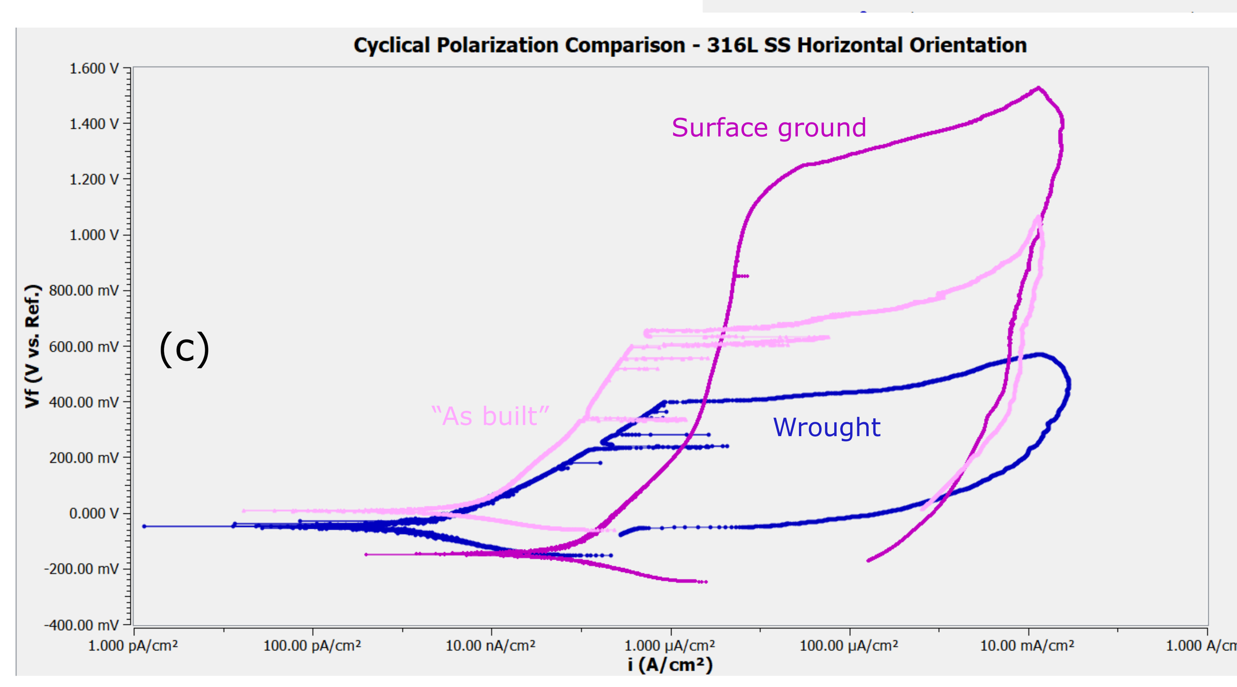
Results / Analysis



- All orientations of the "as built" and wrought samples show metastable pitting
- LPBF "as built" samples clearly have a higher pitting potential (less active) than the wrought material (more active)
- AM corrosion rates are comparable to wrought or improved.

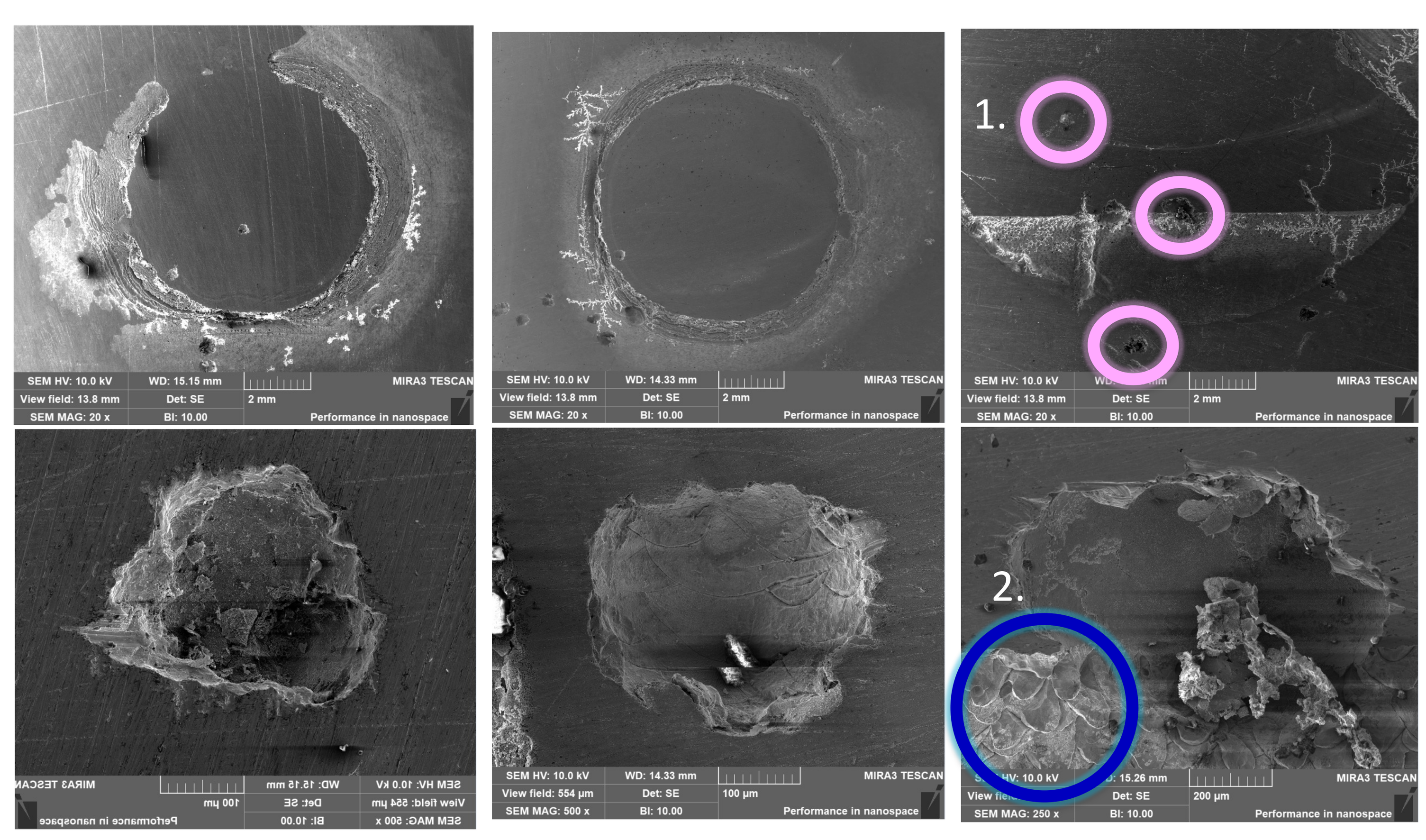
- All orientations of the surface ground LPBF samples show less metastable pitting, larger passive regions and higher pitting potential (less active) than the wrought.
- Corrosion rates of LPBF samples are higher (more active) than wrought in the surface ground condition.





- Surface ground LPBF samples show limited metastable pitting & higher pitting potentials
- Corrosion rates in the horizontal build direction are higher for LPBF than wrought.

Figure 1 – Cyclic polarization curve comparisons for representative (a) as-built and wrought, (b) ground & wrought, (c) horizontal as-built, ground and wrought



(a) (b) (c)

1. The 45° sample depicts more pits than the other two directions
2. Degradation of material visible in remelt zones

Figure 2 – scanning electron microscope (SEM) images of surface ground 316L SS samples, depicting pitting due to corrosion – (a) horizontal, (b) vertical, and (c) 45°

Sample	Orientation	Corrosion Rate (mmpy)	Sample	Orientation	Corrosion Rate (mmpy)
316LSS	Horizontal	17.34	IN718	Horizontal	19.94
316L SS	Vertical	12.20	IN718	Vertical	26.85
316L SS	45°	1.74	IN718	45°	78.56

Sample	Orientation	Corrosion Rate (mmpy)	Sample	Orientation	Corrosion Rate (mmpy)	Sample	Orientation	Corrosion Rate (mmpy)
Ti64	Horizontal	82.84	ALF357	Horizontal	58.16	AF9628	Horizontal	436.20
Ti64	Vertical	361.40	ALF357	Vertical	34.08	AF9628	Vertical	674.40
Ti64	45°	125.10	ALF357	45°	840.00	AF9628	45°	575.00

Table 1 – Corrosion rates calculated for all "as built" samples

Future Objectives

Evaluate the corrosion response of additional LPBF and other AM processed alloys (Steel, Al, Ti) with various surface roughness to generate data and begin building a data base of corrosion properties for AM alloys.

References

[1] Shihao Zhang et.al., "The effects of heat treatment and surface state on the corrosion resistance of laser powder bed fusion 304L stainless steel in 3.5 wt% NaCl solution, J of Mat Res and Tech, Vol 29, 2024, pp 5620-5632.
[2] Zhenglei Yu, et.al., "Enhancing the surface finish and corrosion resistance of laser powder bed fusion NiTi surfaces through chemical polishing" J of Mat Res and Tech Vol 29, 2024, pp 5507-5516.
[3] Li Wang, et.al. "The effect of multiscale second-phase particles on the corrosion behavior of laser powder bed fusion high strength stainless steel", Mat Char, Vol 205, 2023, 113244.