SAND2019-10726C

Influence of build orientation and surface finish on the corrosion of additively manufactured 316L

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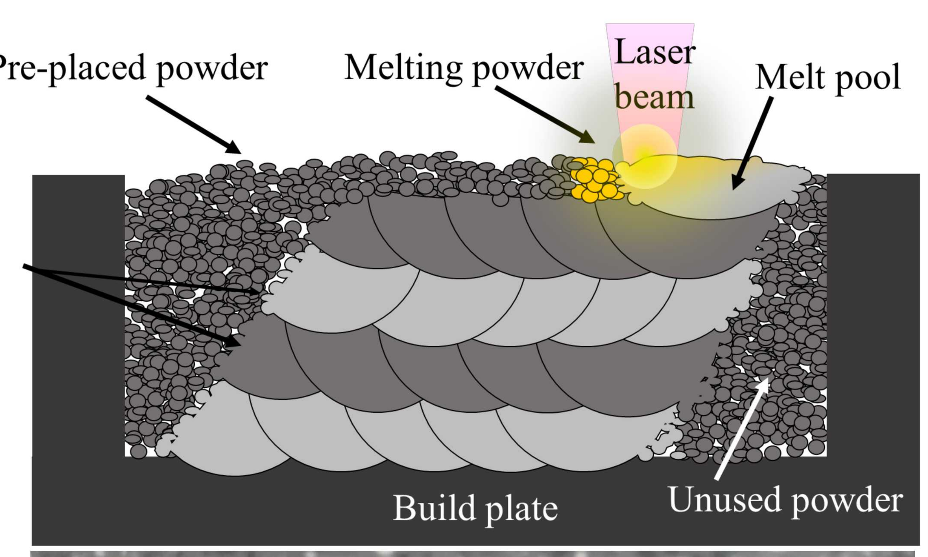
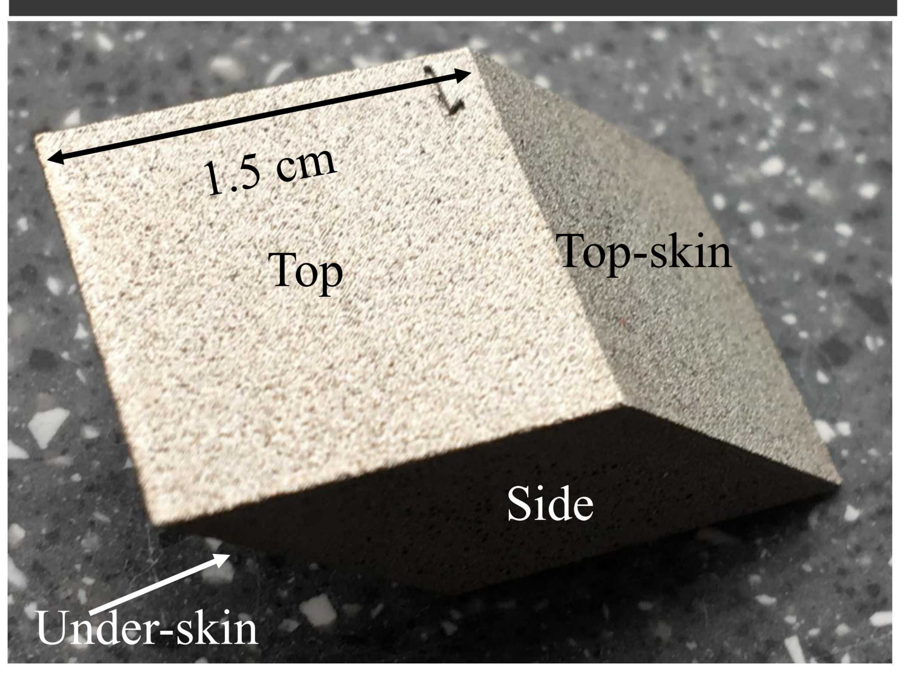
Introduction

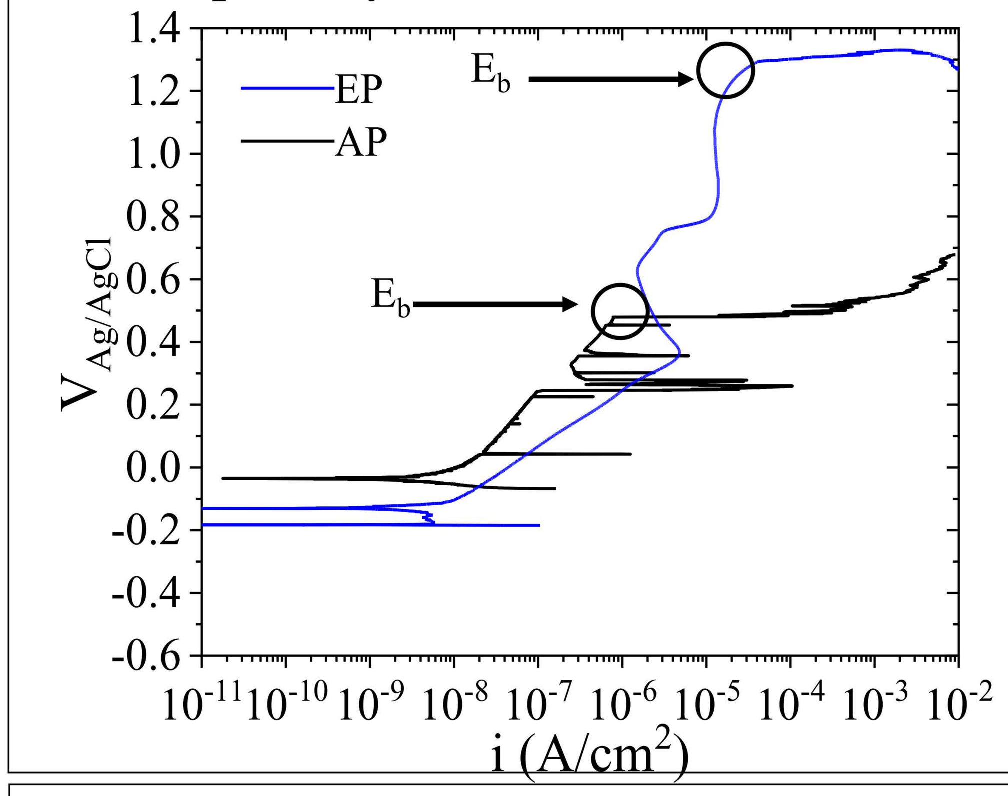
Metal additive manufacturing(AM) is unique in its ability to produce complex metallic parts. The build process and rapid cooling time frames create microstructures, and tortuous surface finishes which lead to large variability in surface's susceptibility to local corrosion. This study investigates how surface treatments and build orientation impact surface roughness and local corrosion initiation of 316L stainless steel parts using a powder bed fusion technique.

Experimental

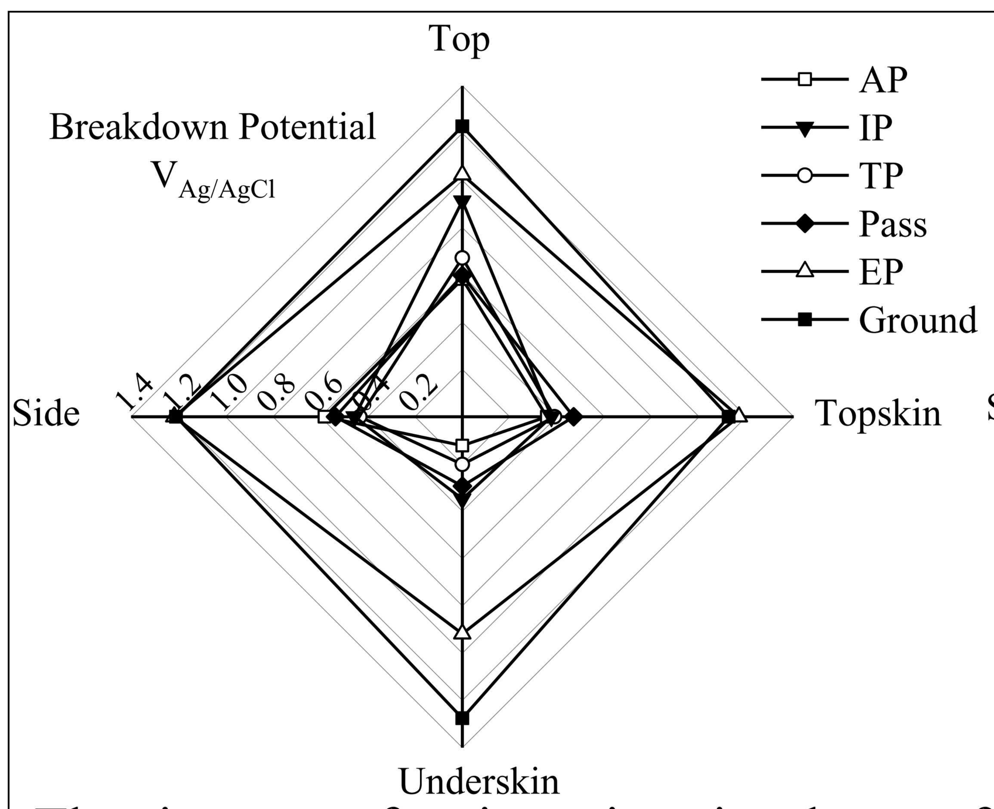
- Surface treatments included grinding with SiC paper (Ground), tumble polishing (TP), electropolishing (EP), chemical passivation (Passive), and an in-process laser polish (IP).
- Microstructure and surface roughness (S_a and S_z) for each surface treatment and build orientation were analyzed using scanning electron microscopy and white light interferometry.
- The corrosion behavior was measured by anodic potentiodynamic measurements of the surface in a quiescent 0.6 M NaCl solution to determine a breakdown potential (E_b), an indication of pit susceptibility.

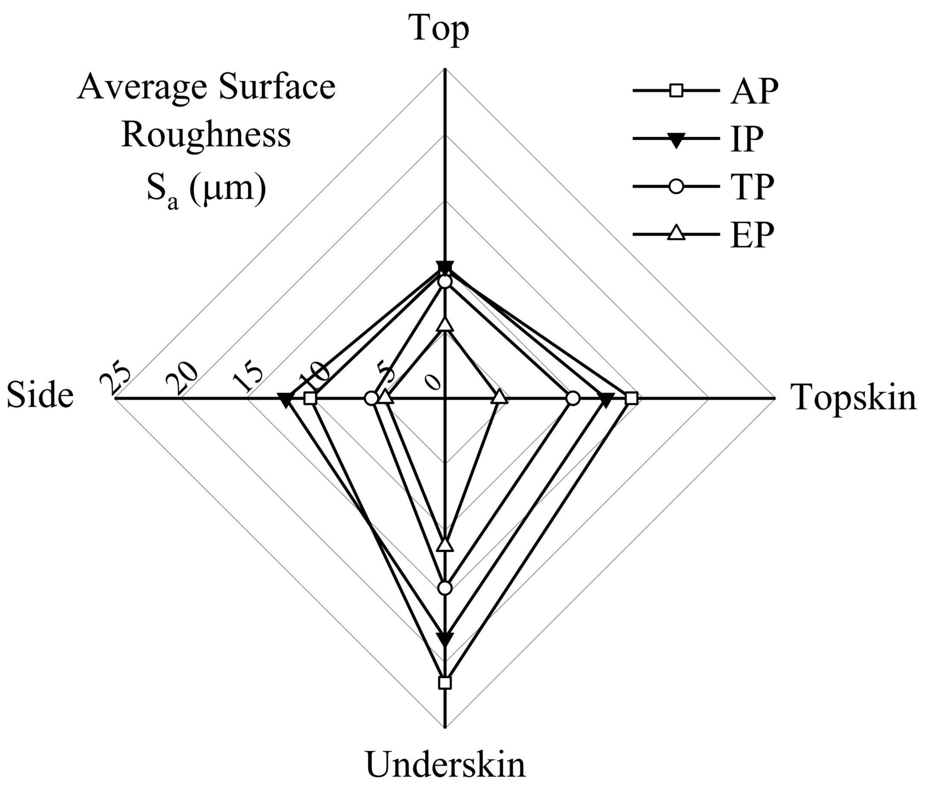




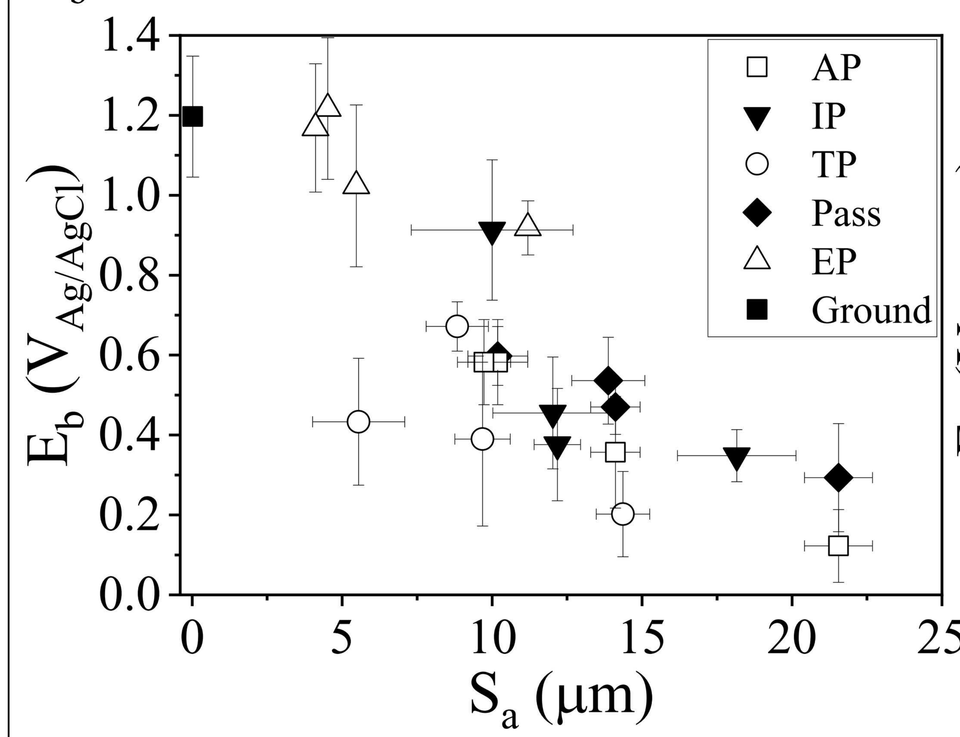


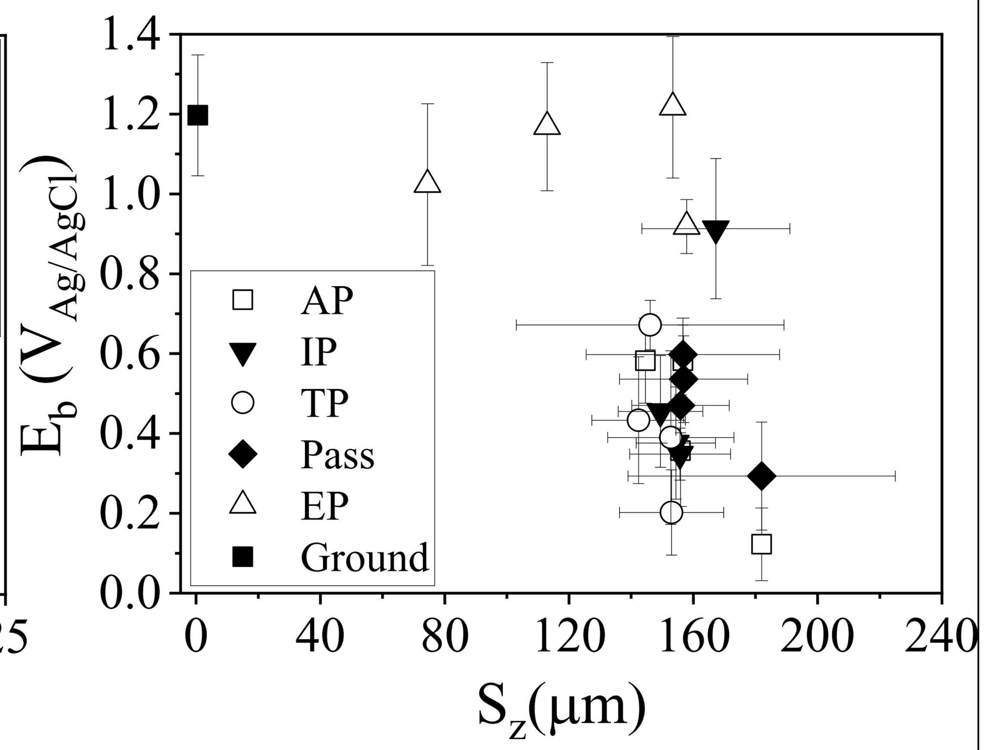
Representative potentiodynamic measurements comparing the side orientation of AP and EP. Eight (8) similar experiments were performed on all surface treatments and sample orientations.



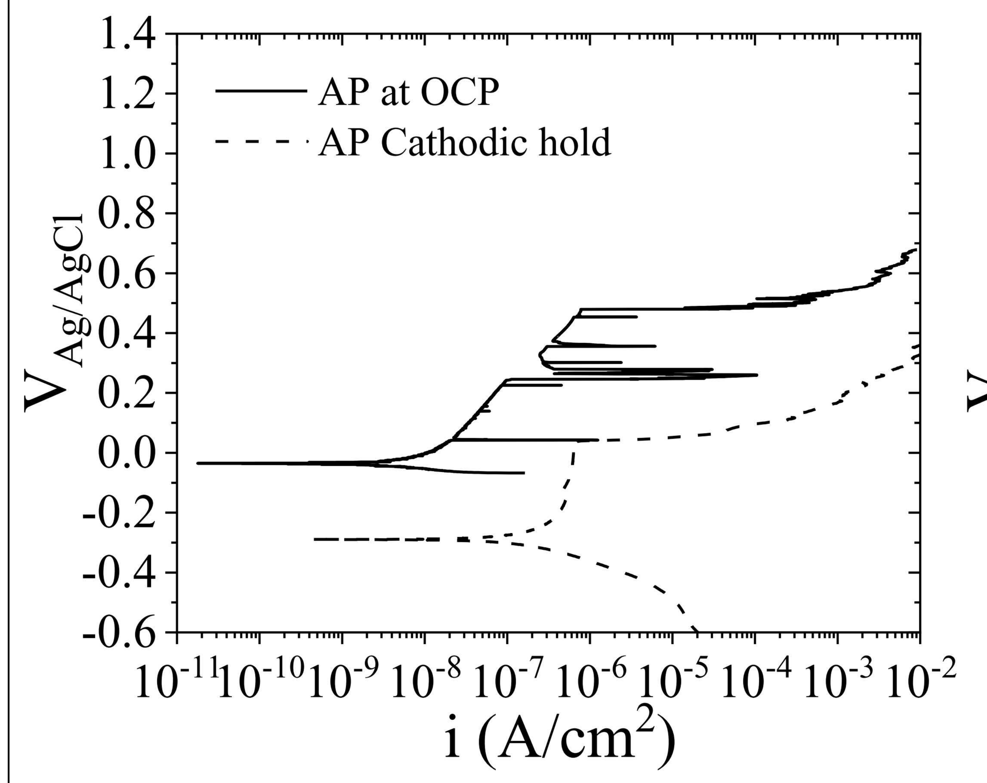


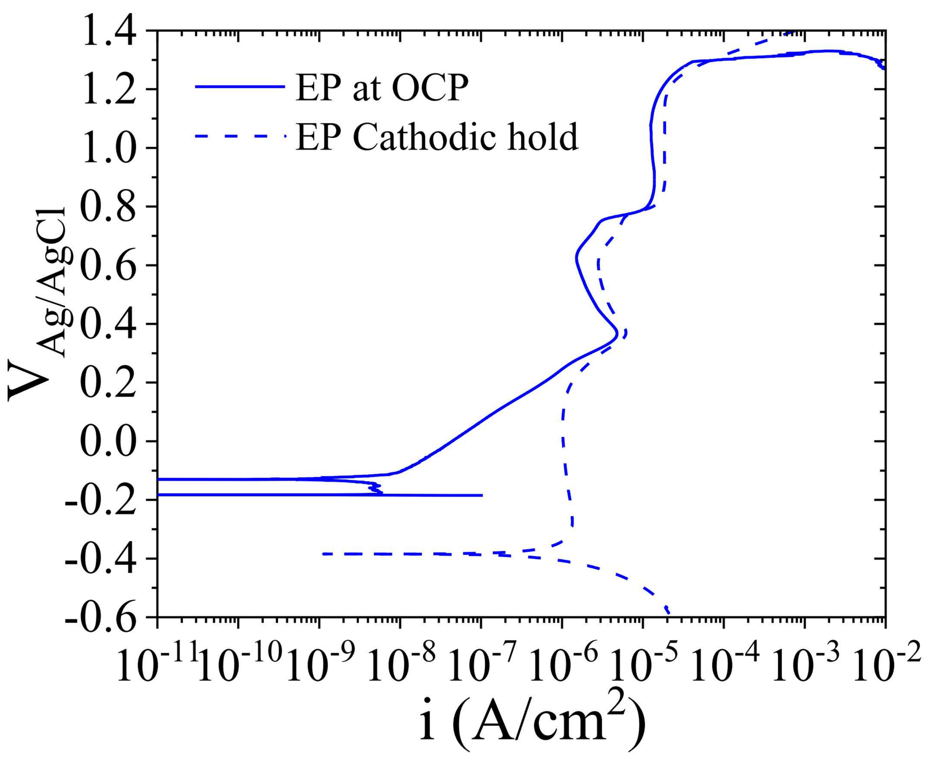
The impact of orientation is shown for S_a (left) and E_b (right). The Top orientation generally had the smallest S_a, which typically correlated to the largest E_b for all surface treatments.





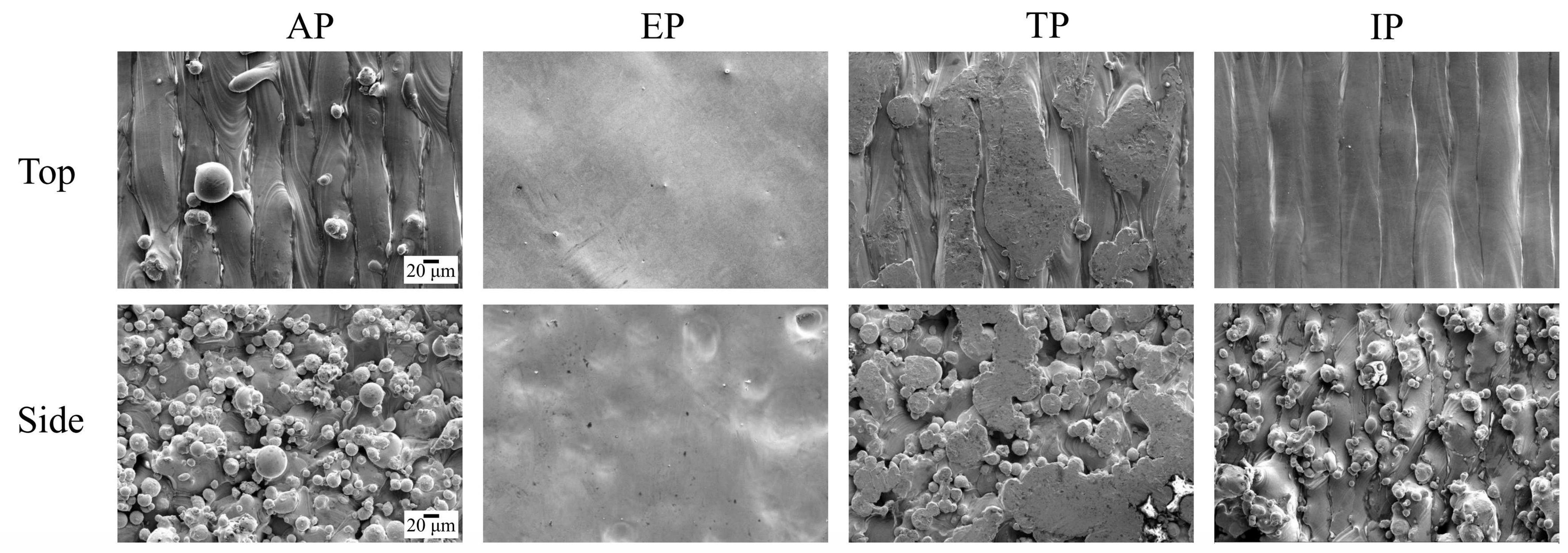
A larger S_z typically corresponded with a lower E_b, however the scatter in the S_z measurement leads to low confidence in this trend. There is a stronger correlation comparing S_a to E_b, and excluding some outliers gives a generally linear trend which plateaus at the ground condition.





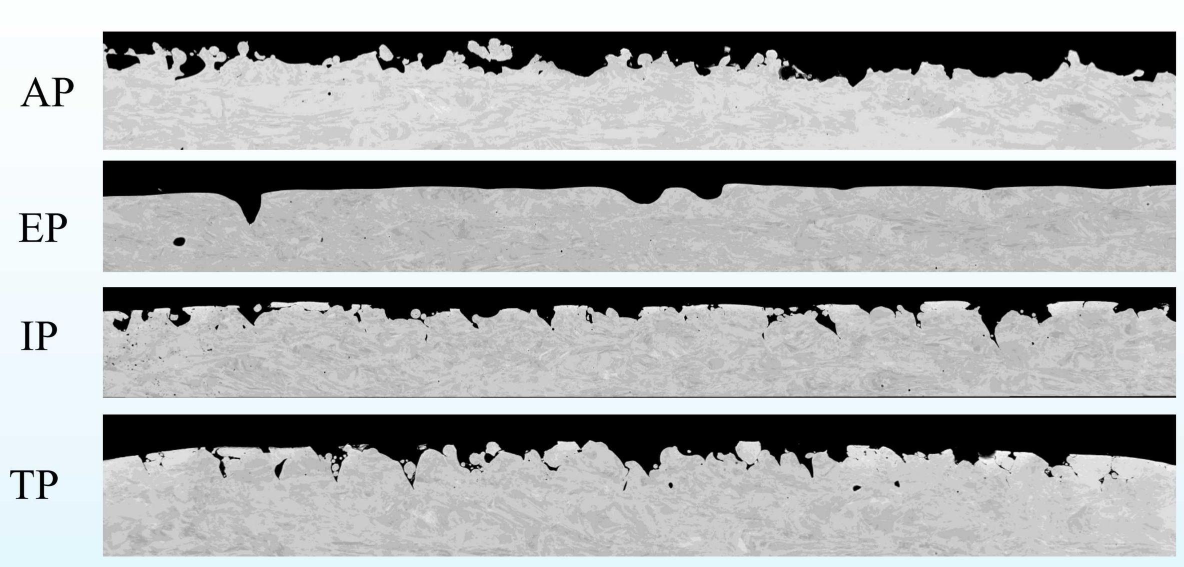
To deconvolute S_a effects on E_b from surface oxides formed during AM processing, a potentiostatic cathodic hold of -1.8$V_{Ag/AgCl}$ was applied to the side orientation of an EP and AP sample prior to a potentiodynamic measurement. Minimal change in E_b magnitude further suggests E_b is largely dictated by S_a.

Results



SEM cross-sections (right) and plan view (above) give an indication of the tortuous surface features caused by AM processes and surface treatments. The Side surface shows noticeably higher roughness than Top resultant of build geometry.

Cross-section of Side Surface



Conclusions

- Cross-section images show tortuous features, not considered in optical profilometry.
- The rougher and more tortuous surface finishes exhibited orientation dependent E_b values from 0.15-0.90 $V_{Ag/AgCl}$.
- Smaller S_a led to larger E_b, reaching maximums for the electropolished and ground surface treatments ranging on average from 0.95-1.22 $V_{Ag/AgCl}$ and 1.13-1.28 $V_{Ag/AgCl}$, respectively.
- Removing the oxides formed during AM processing prior to determining E_b emphasized S_a as the dominant factor in pit initiation.

Acknowledgements

The authors thank Sarah Dickens for SEM.

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.
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