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Wear and corrosion properties of SLM-manufactured 17-4PH components: Comparison of the effects of solution heat treatment, aging, and combined treatments

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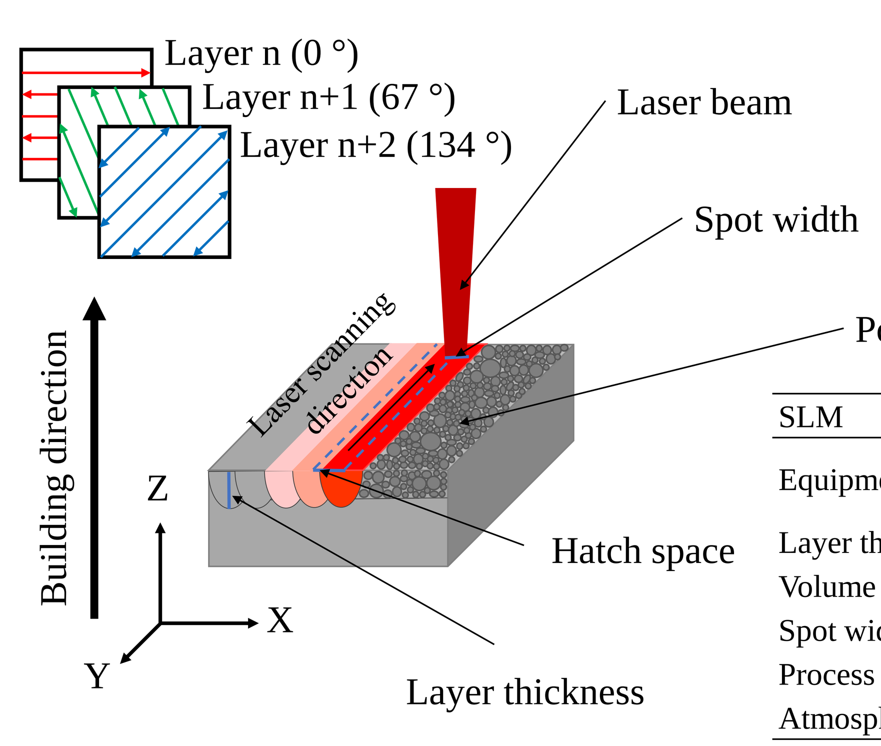
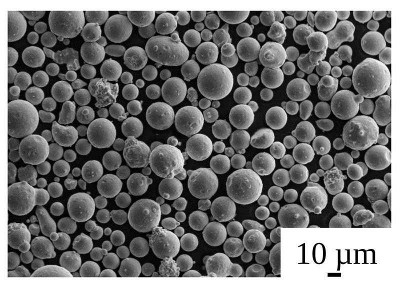
Abstract

Selective laser melting (SLM) has emerged as a versatile manufacturing method for complex metal components, offering high material utilization. 17-4PH stainless steel, which is known for its high strength and excellent corrosion resistance, is widely used in aerospace, biomedical, and mechanical manufacturing fields. However, the SLM process often results in microstructural features such as porosity and solute segregation, which significantly impact the wear and corrosion resistance of the produced components. Existing studies have primarily focused on the combined "solution heat treatment + aging" process, with limited research on individual solution or aging treatments. Furthermore, comparative studies on the effects of different heat treatment methods on wear and corrosion resistance remain insufficient. This study investigates the effects of three heat treatment methods—solution heat treatment (ST, 1 hour at 1040 °C), aging treatment (AG, 1 hour at 480 °C), and combined treatment (ST+AG, 1 hour at 1040 °C followed by 1 hour at 480 °C)—on the hardness, wear resistance, and corrosion resistance of SLM-manufactured 17-4PH stainless steel.

Production routine

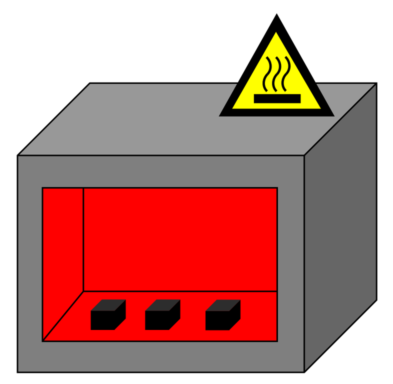
Selective laser melting

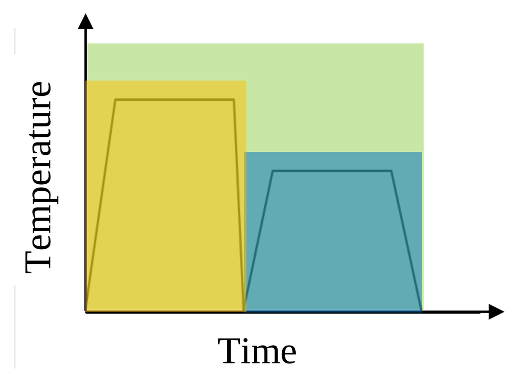




SLM	Parameter
Equipment	SLM 125 (Nikon Solutions AG, Lübeck, Germany)
Layer thickness (µm)	30
Volume energy (J/mm²)	78
Spot width (µm)	70
Process gas	Argon
Atmosphere O_2 purity (ppm)	<1000

Heat treatment



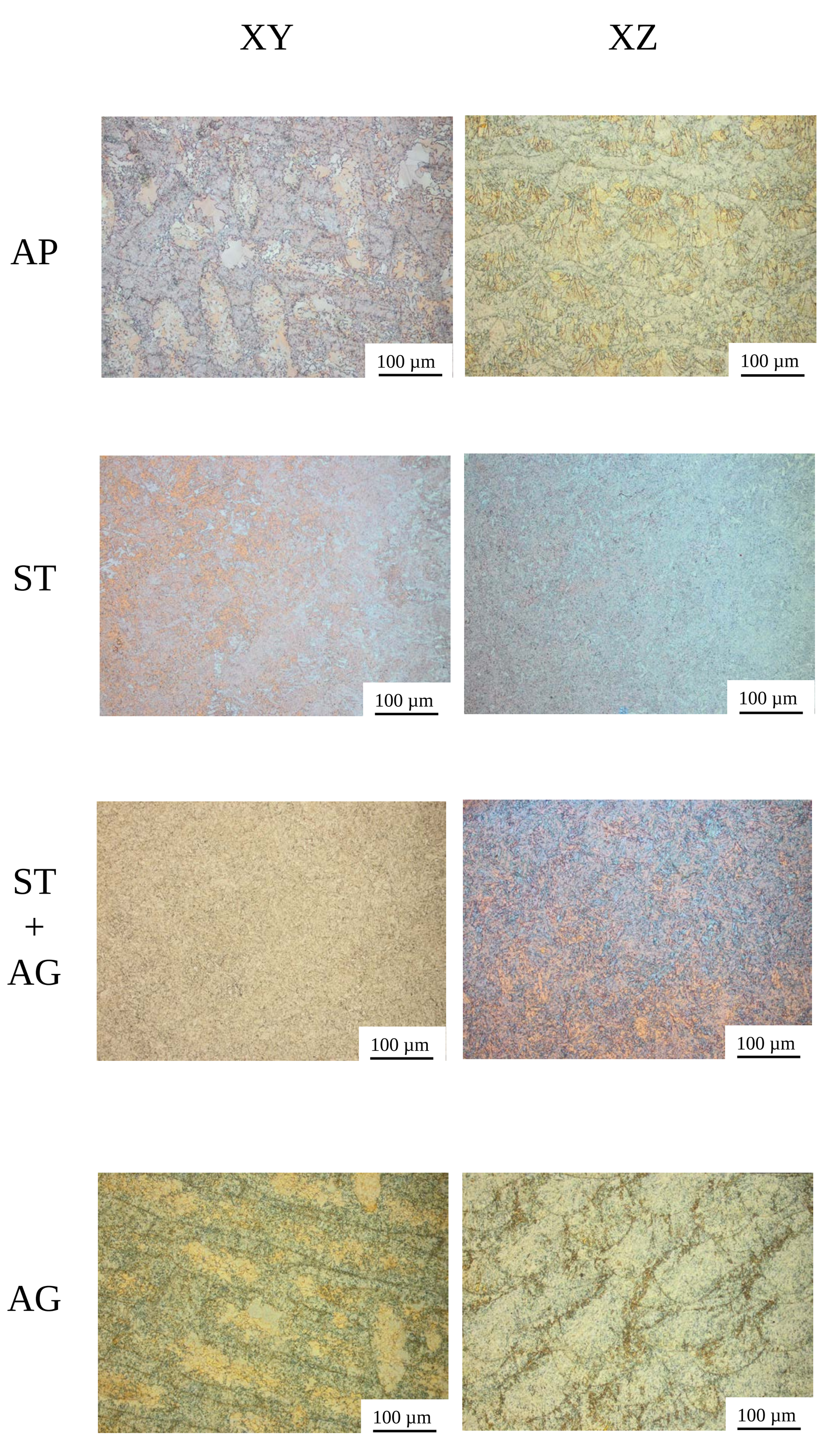


Heat treatment	Parameter
Equipment	Chamber Furnaces (Nabertherm GmbH, Lilienthal, Germany)
Solution heat treatment	1040 °C 1 h, then in oil quenching
Aging	480 °C 1 h, then in furnace cooling
Solution heat treatment + Aging	1040 °C 1 h, then in oil quenching + 480 °C 1 h, then in furnace cooling

Experimental results

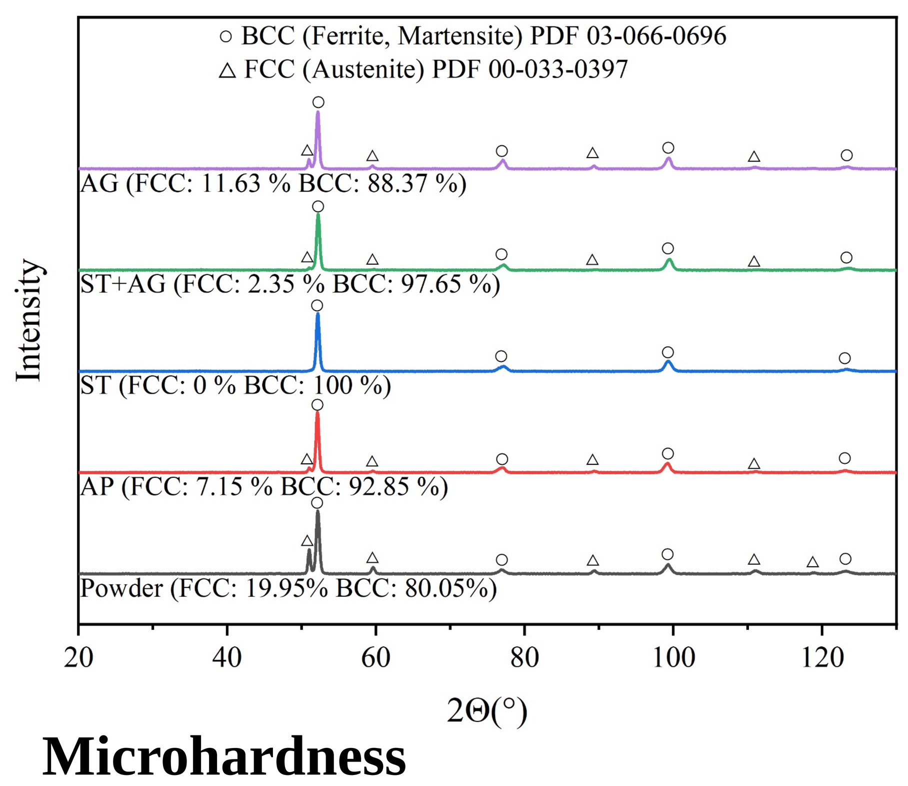
Microstructure

BERAHA II etchant

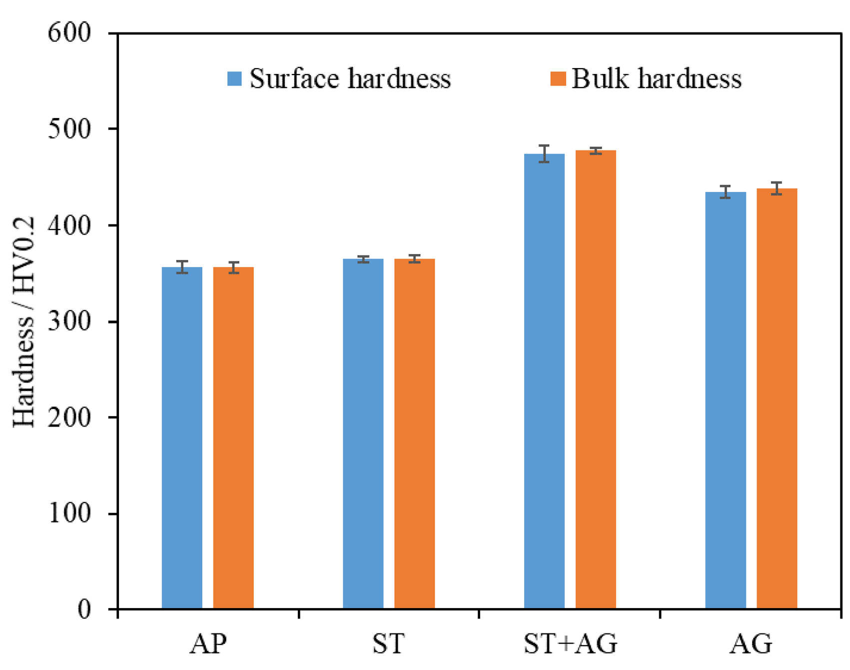


XRD

Quantitative analysis - Rietveld

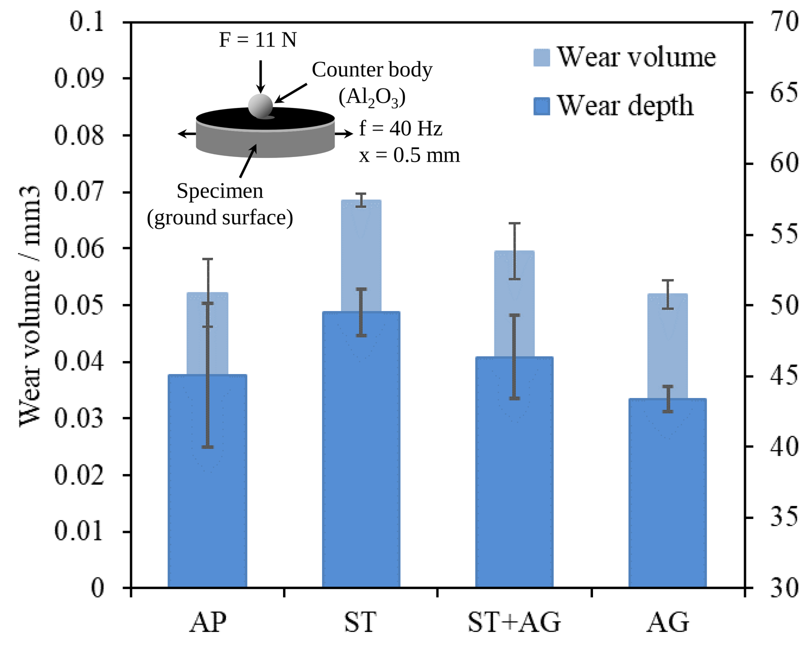


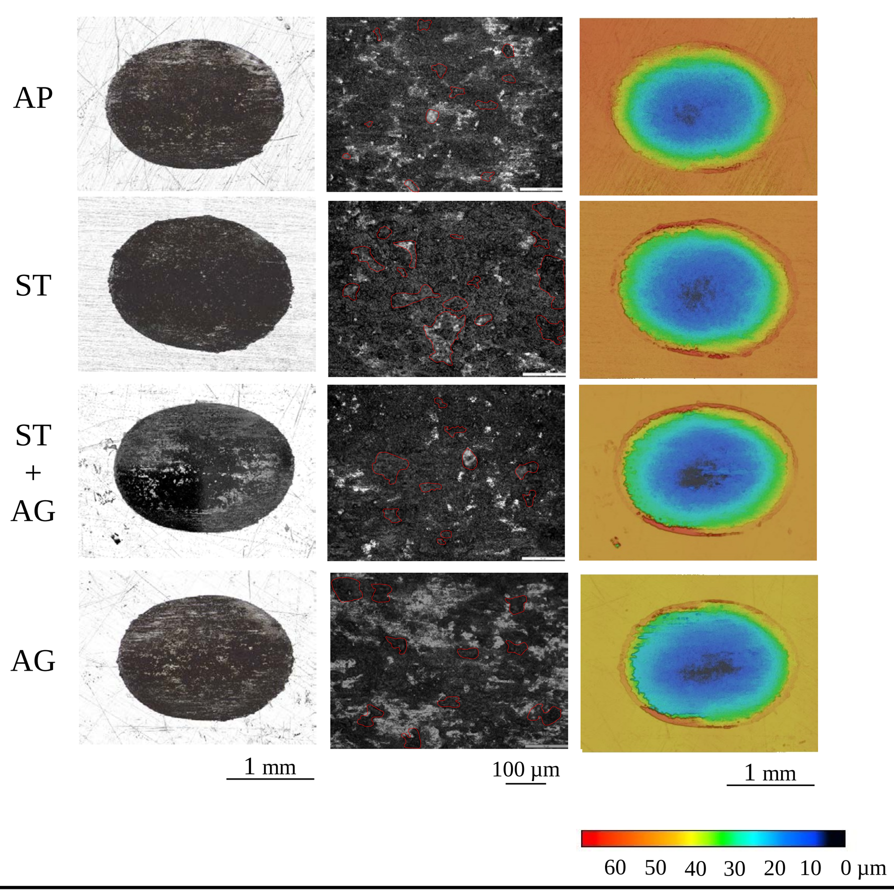
Microhardness



Wear

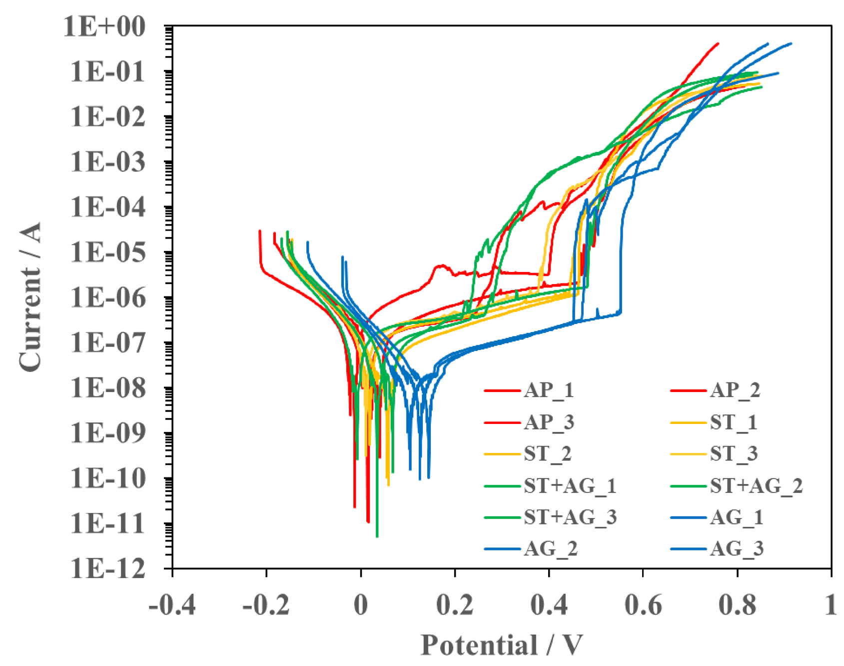
Reciprocating ball-on-plane test



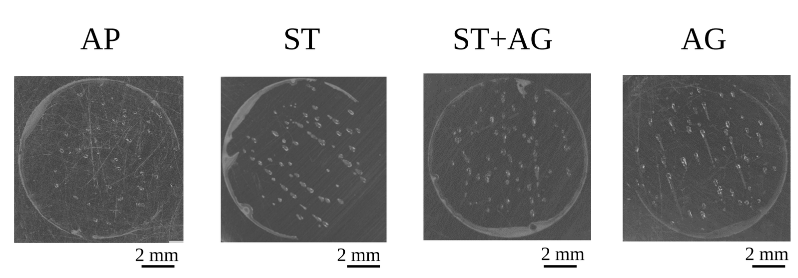


Corrosion

Polarization curve (3.5% NaCl)



	E_{corr} (mV)	Average (mV)	Standard deviation (mV)	I_{corr} (A/cm²)	Average (A/cm²)	Standard deviation (A/cm²)
AP_1	26.18	4.19	24.81	2.31E-07	2.92E-07	1.68E-07
AP_2	9.1			1.63E-07		
AP_3	-22.71			4.81E-07		
ST_1	12.31	20.39	19.13	2.30E-07	1.73E-07	8.31E-08
ST_2	42.24			7.74E-08		
ST_3	6.63			2.10E-07		
ST+AG_1	29.84	4.35	68.16	1.24E-07	4.02E-07	5.22E-07
ST+AG_2	56.10			7.73E-08		
ST+AG_3	-72.88			1.00E-06		
AG_1	106.90	109.43	14.78	4.56E-08	3.99E-08	5.87E-09
AG_2	125.31			4.04E-08		
AG_3	96.08			3.39E-08		



Summary

AG improves hardness, wear and corrosion resistance. ST enhances corrosion resistance but reduces wear resistance, with negligible effect on hardness. ST+AG increases hardness but decreases wear and corrosion resistance. This study highlights AG's potential to optimize 17-4PH stainless steel performance in SLM manufacturing.

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