PURDUE UNIVERSITY
School of Materials Engineering

Mechanical Behavior of 718 ODS Alloy Prepared by Directed Energy Deposition

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Abstract: The project objective was to evaluate the microstructure and mechanical behavior of additive-manufactured Alloy 718, produced by directed energy deposition (DED). After confirming optimal printing parameters for Alloy 718, chromia and yttria particles were added to the base alloy powder mixture and tested separately to determine if ceramic oxide dispersion strengthening was beneficial for DED processing of the alloy. Results indicated a general increase in hardness and tensile strength, favoring the chromia ODS. Increased properties are due to uniform dispersion of oxides throughout the nickel matrix.

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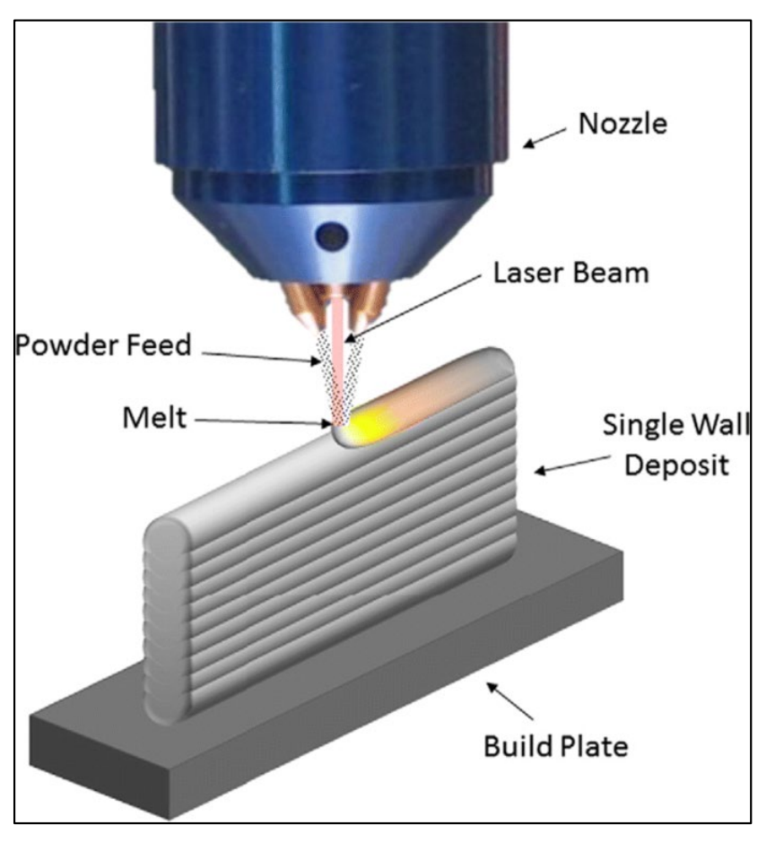
Background

Alloy 718 is a nickel-chromium alloy with high corrosion and oxidation resistance combined with high strength and easy weldability. It is typically used for extreme temperature applications such as gas turbine parts, aerospace applications, and rocket motors. Commonly manufactured using Laser Powder Bed Fusion (LPBF) additive manufacturing, this study utilized the less common Directed Energy Deposition (DED) additive process to produce samples for microstructural and mechanical observations.

Element	Ni	Cr	Fe	Nb	Mo	Ti	Al	C
wt%	Bal	19	18.5	5.1	3	0.9	0.5	0.04

A potential method to improve the mechanical strength of Alloy 718 is with oxide nanoparticles. The main objective of this study is to investigate the possible benefits of using either Yttria (Y_2O_3) or Chromia (Cr_2O_3) to fabricate 718 oxide dispersion-strengthened (ODS) Alloy. Additionally, a comparison will be made of the differences in microstructure and mechanical behavior of the two types of ODS Alloys [1].



[1]

Preparation & Methods

Sample Preparation

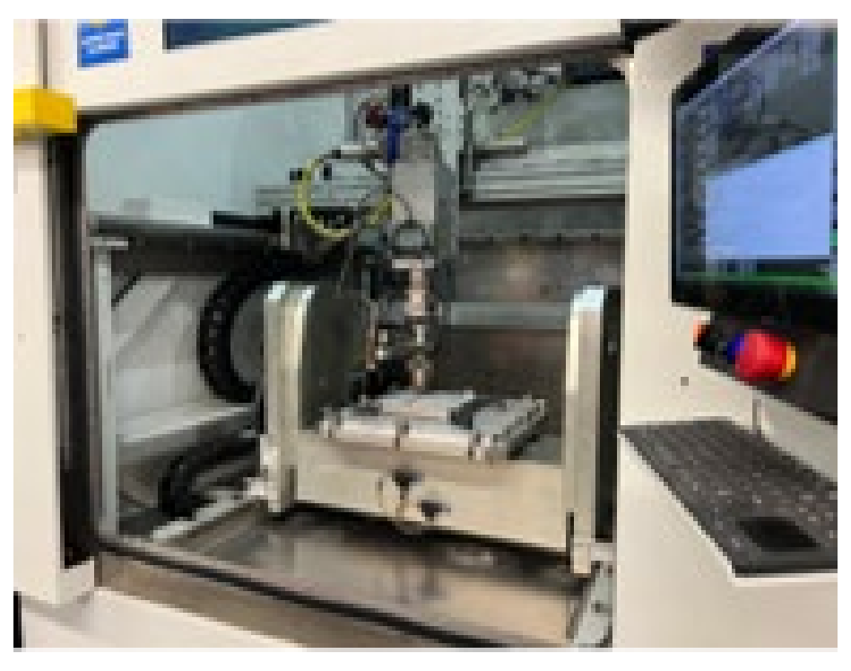
Ceramic particles were mixed into the alloy-718 powder through ResonantAcoustic® mixing in a LabRAM II apparatus.

Additive manufacturing: FormAlloy X5 DED printer

Control alloy parameters:
See DOE below

ODS alloy
Laser scanning speed: 700 mm/min
Laser power: 600 W

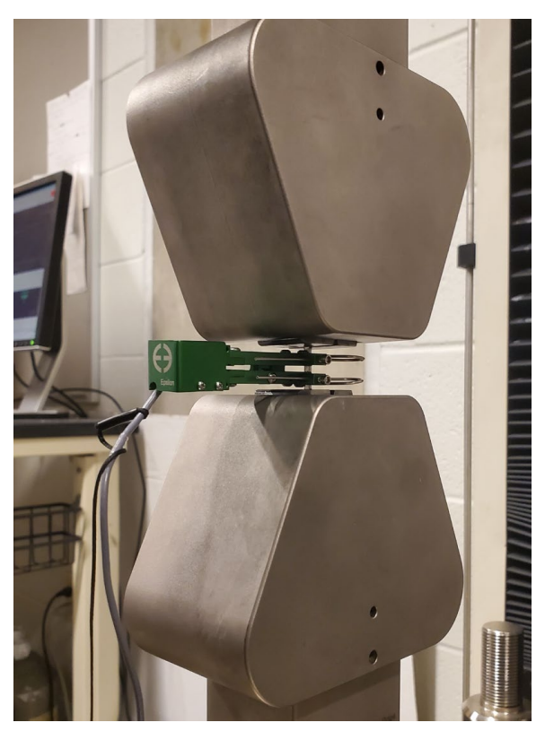
Tensile coupons were prepared for mechanical testing.



		Laser Scan Speed (mm/min)		
		600	700	800
Laser Power (W)	550	(A) Ψ=39.3	(B) Ψ=33.7	(C) Ψ=29.5
	600	(D) Ψ=42.9	(E) Ψ=36.7	(F) Ψ=32.1
	650	(G) Ψ=46.4	(H) Ψ=39.8	(I) Ψ=34.8

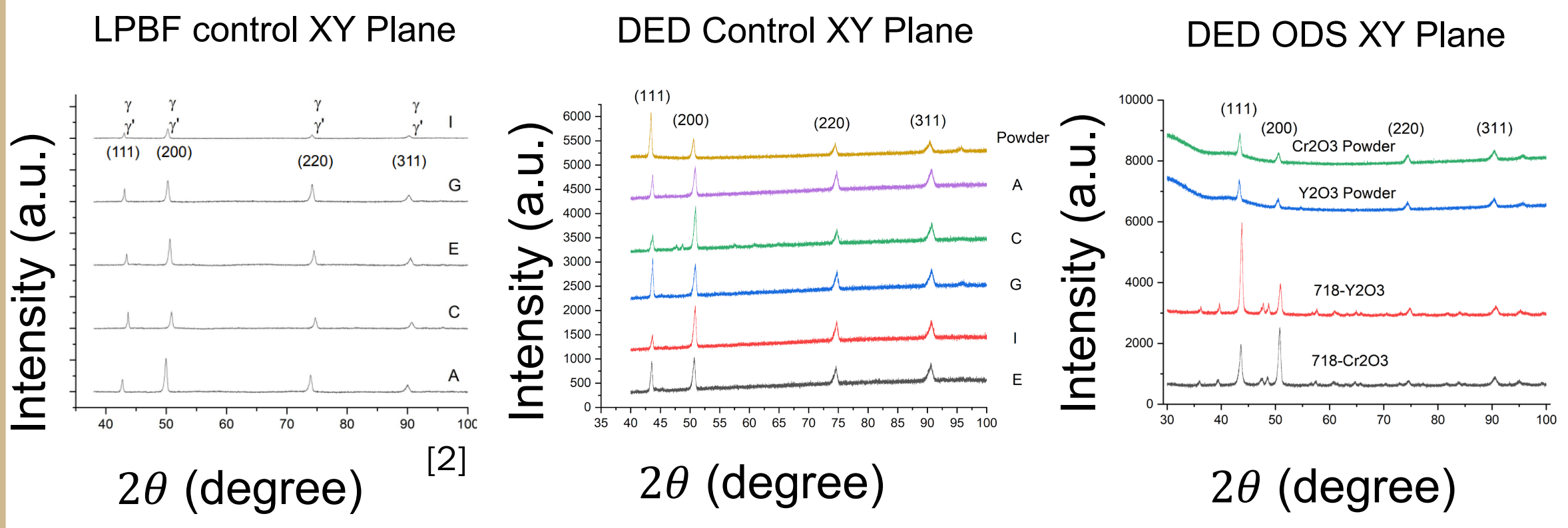
Methods:

- X-Ray Diffraction (XRD) using a Bruker D8 Focus diffractometer
- Scanning Electron Microscopy (SEM): Quanta 650 Scanning Electron Microscope
- Energy-dispersive X-ray spectroscopy (EDS) by using the Quanta 650
- Tensile testing: MTS Insight Electromechanical Testing System
- Microhardness by a Leco Vickers Indenter



Microstructural Examinations

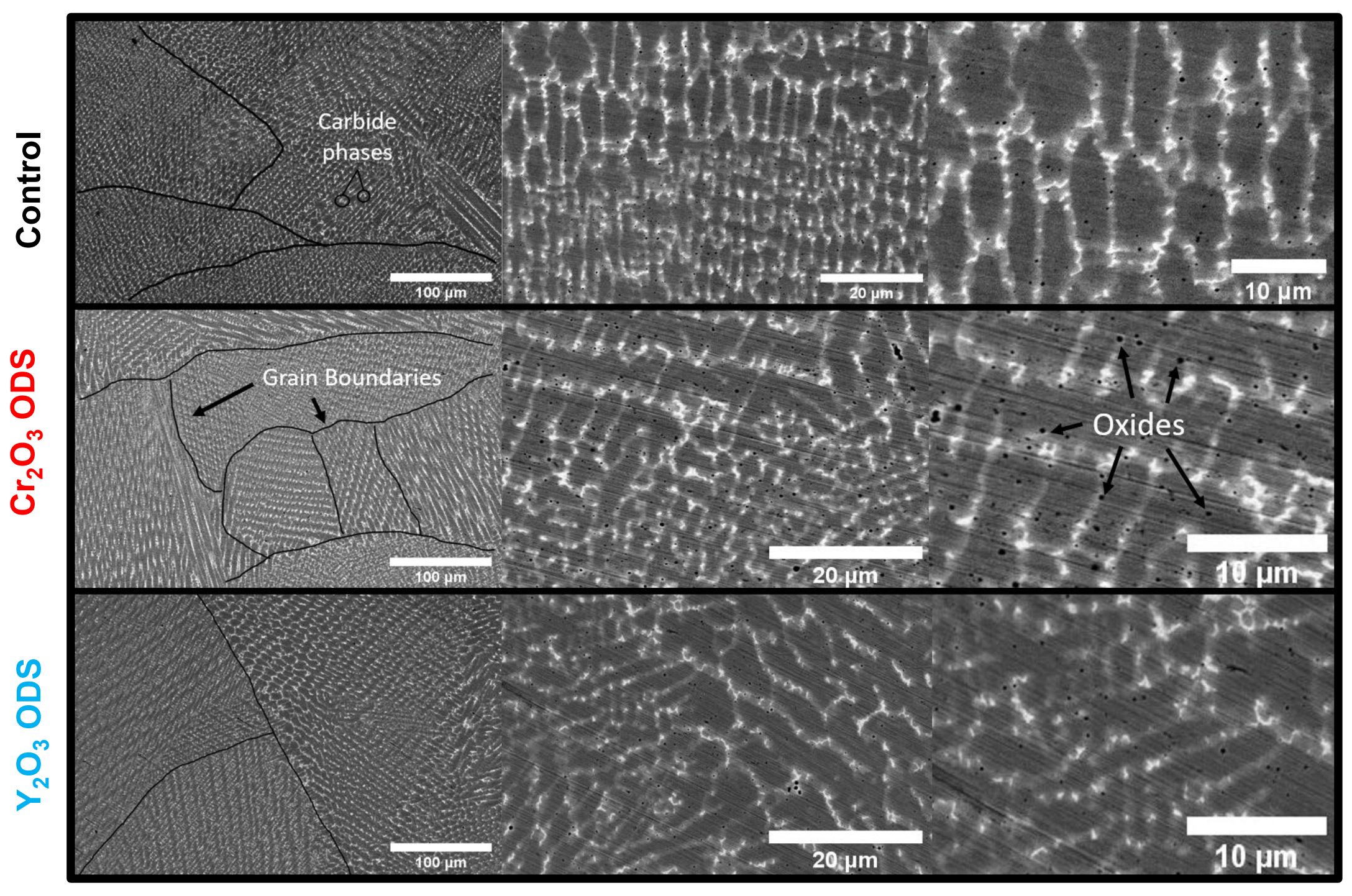
XRD Results



[2]

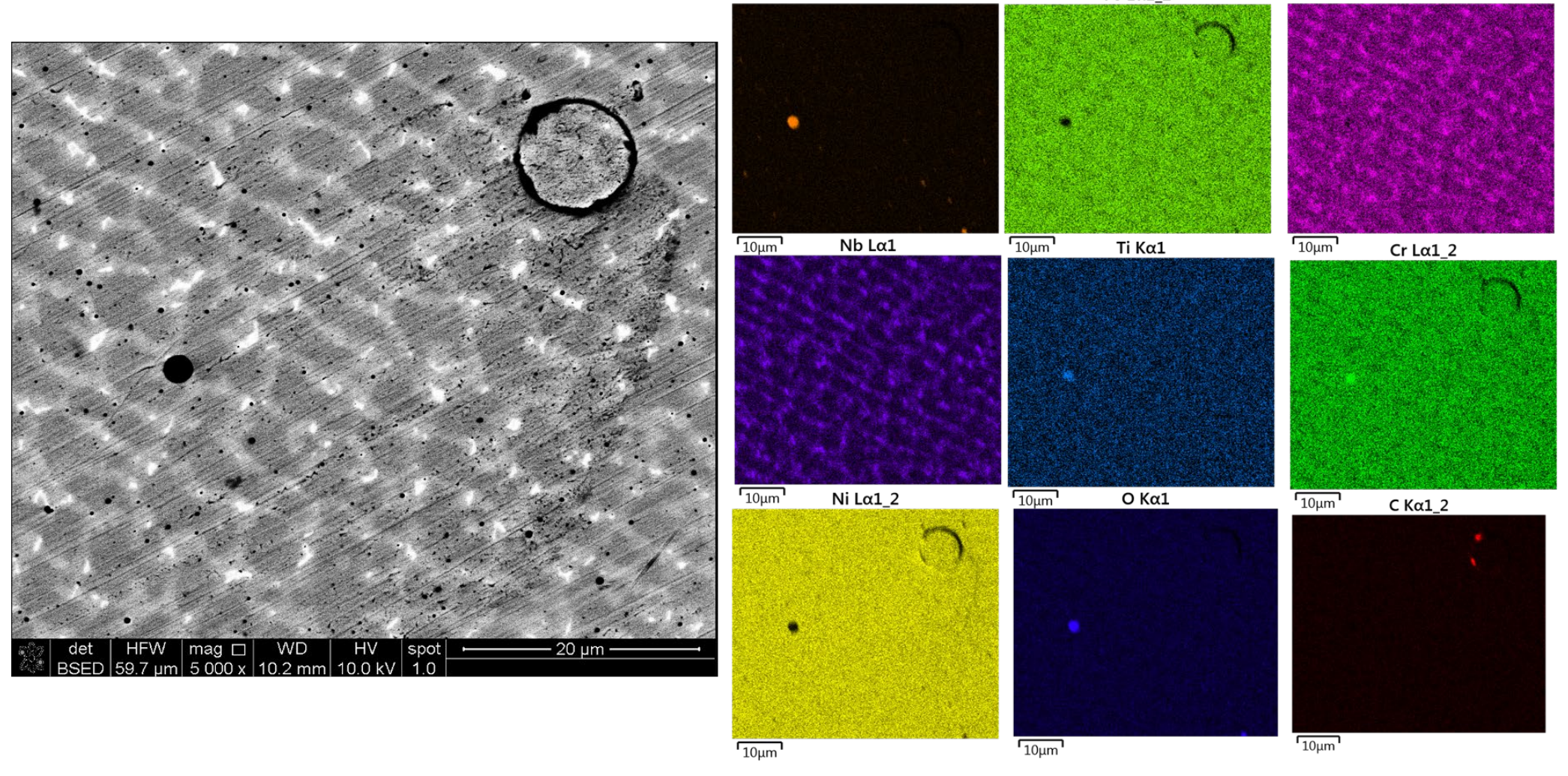
- Strong peaks are seen at (111) and (200) across all sample sets
- DED and LPBF control have similar (200) texture
- DED with ODS has more prominent (111) texture

SEM results



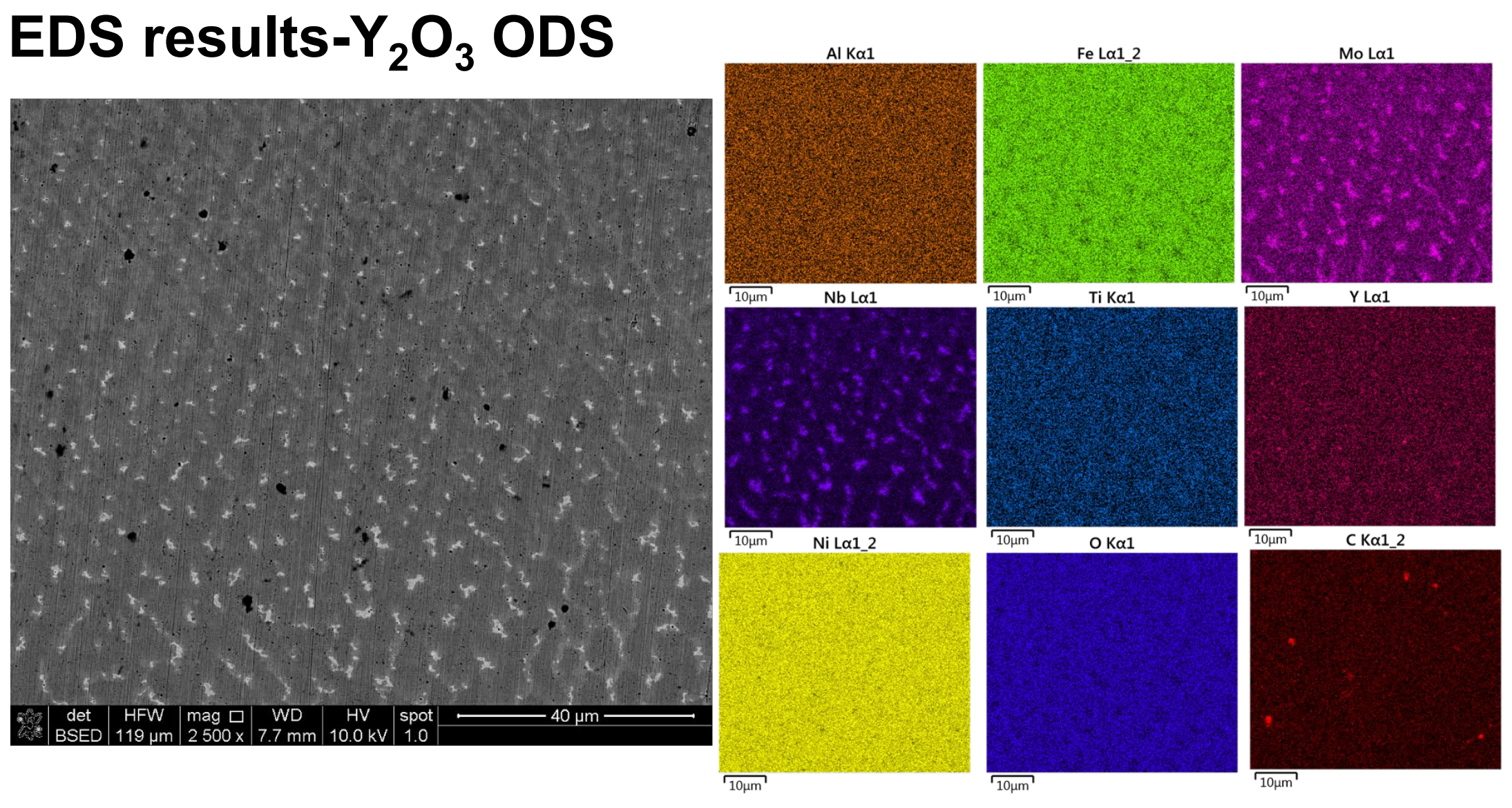
- Control sample appears to have smaller, more equiaxed grains while chromia and yttria samples have similar variation in grain size.
- On average, chromia oxides measured 270 nm in diameter while yttria oxides measured 115 nm.
- Grain boundaries in the oxide samples depicted smaller patches of grain orientations.
- Black dots found in the oxide-free control sample scaled smaller than the smallest oxide diameters. Possible contaminants formed in SEM.

EDS results-Cr_2O_3 ODS



EDS analysis shows the increased presence of aluminum, chromium, titanium, and oxygen in particles of SEM image. This shows the chemical reaction of the chromia oxide in the 718 alloy and the even dispersion of oxide particles into the nickel matrix.

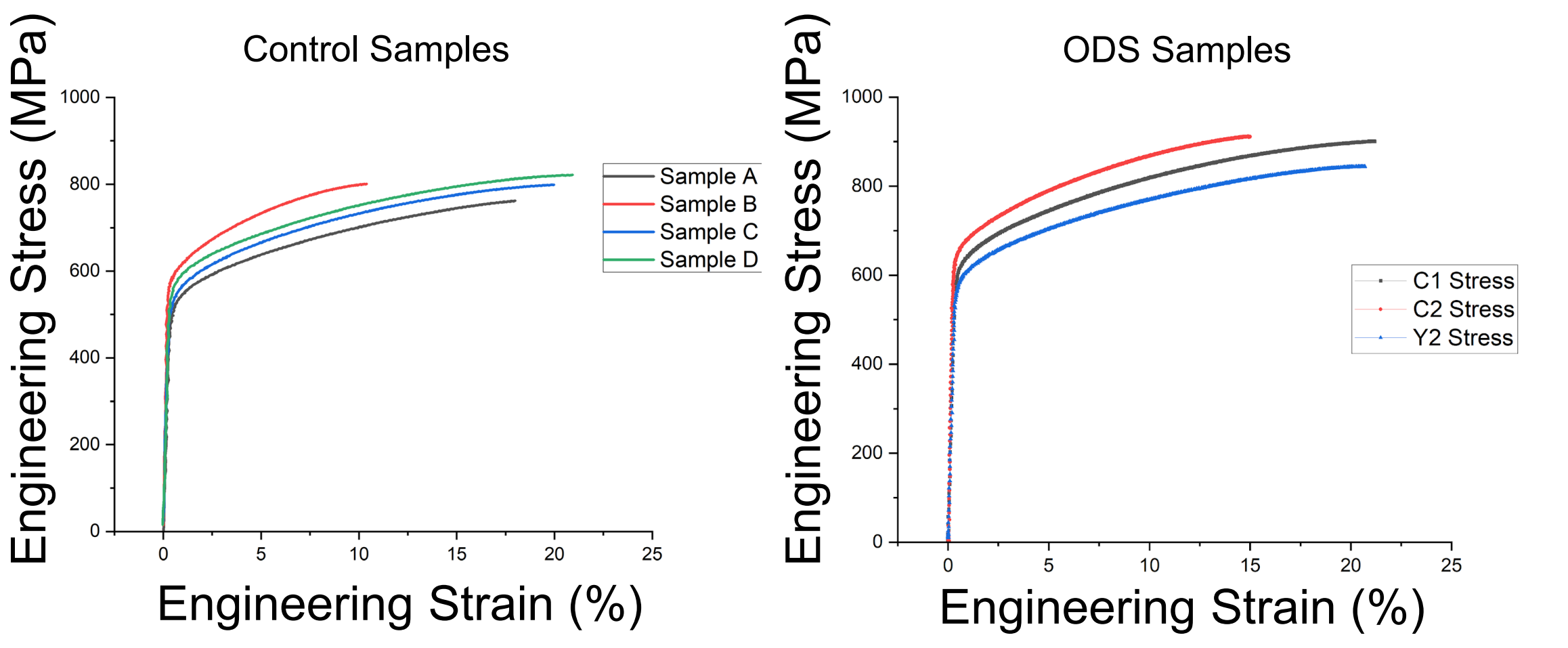
EDS results-Y_2O_3 ODS



EDS analysis shows the presence of yttria and oxygen in black particles of SEM image and no increase of other elements that were present in chromia oxide samples.

Mechanical Property Observations

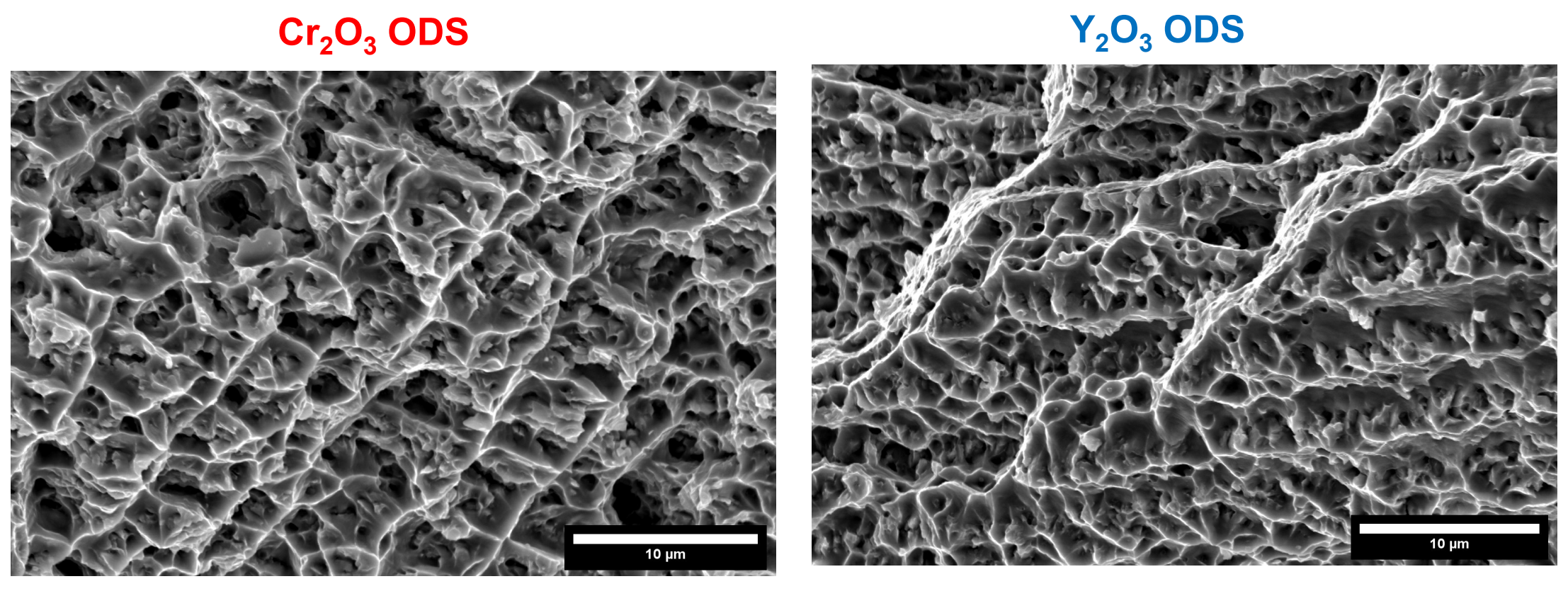
Tensile testing results



Sample	UTS (MPa)
Control A	762
Control B	801
Control C	802
Control D	821
Control Avg.	797

Sample	UTS (MPa)
C1 (Chromia)	901
C2 (Chromia)	912
Y2 (Yttria)	844

- Compared to control alloy, ODS alloys have greater ultimate tensile strength (UTS) and similar uniform strain.

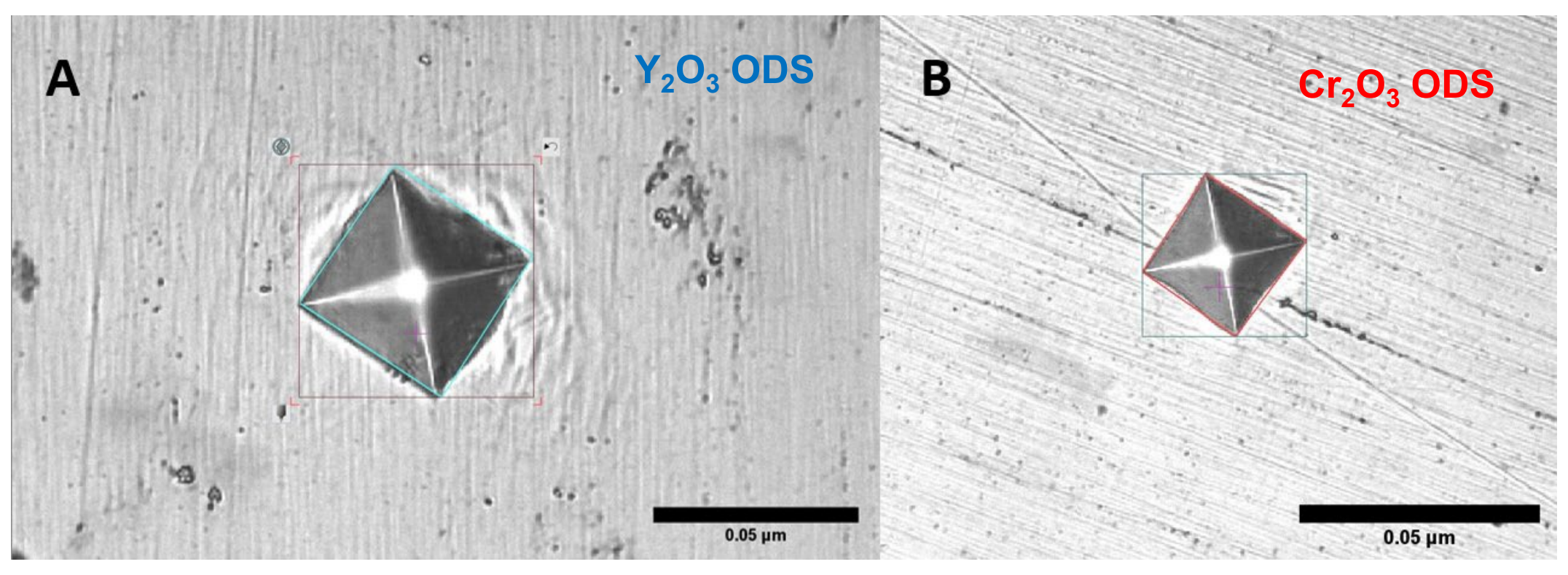


- The chromia ODS alloy has a more homogenous surface dimple
- The yttria ODS alloy shows a non-homogenous breakage as shown by the stress-centered ridgelines.

Microhardness results

	Average Hardness (HV)	Standard Deviation (HV)	Hardening
Control	230.9	16.2	--
Yttria	288.2	15.6	24.8%
Chromia	326.2	24.2	41.3%

- The ODS alloys are stronger than the control samples.
- Chromia ODS showed a greater hardening by 41.26%.



- The yttria ODS (A) shows more rippling around the indents.
- The chromia ODS sample (B) does not show prominent rippling.

Conclusions

- Chromia and yttria particles added through ODS resulted in increased tensile strength and hardness of Alloy 718
- SEM showed uniform dispersion of oxide particles throughout the nickel matrix.
- Improvements suggest that ODS techniques could be employed in industry for high strength applications.

Future work

- High temperature mechanical properties of ODS alloys.
- Heat treatment of ODS alloys.

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1. Guan, X., & Zhao, Y. F. (2020). Modeling of the laser powder–based directed energy deposition process for Additive Manufacturing: A Review. *The International Journal of Advanced Manufacturing Technology*, *107*(5-6), 1959–1982. https://doi.org/10.1007/s00170-020-05027-0
2. Carr, M., Hope, M., Wellborn, O., Starr, D. (2021, April 27). *Additive Manufacturing of Nickel Alloy 718* [13]. School of Materials Engineering, Purdue University

MSE Senior Design