Ni-based Alloys for Molten Salt Applications

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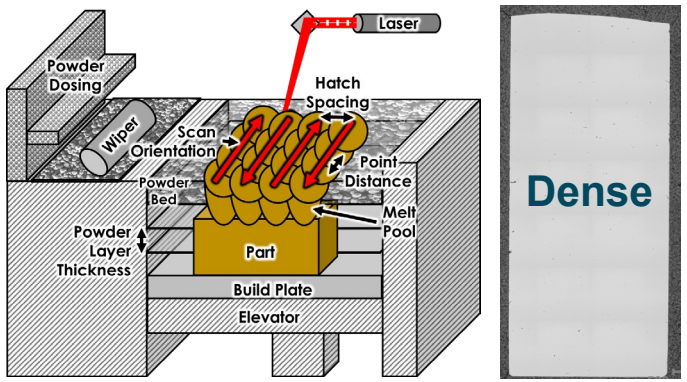
Advanced Materials and Manufacturing Technologies (AMMT) Program

MSR Campaign Program Review, April 21–24, 2026

Selection of High Potential Ni Alloys From Three Main Categories Ni-based Alloys Particularly Relevant to MSR

Low Co, demonstrated high printability

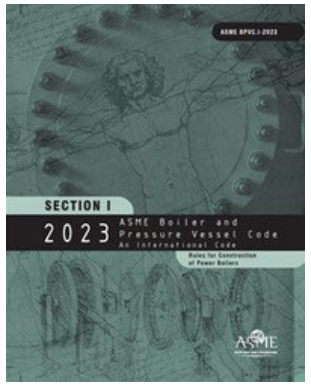


718, 625, 800H

Commercially available
Acceptable strength, industry interest

High strength

Code qualified

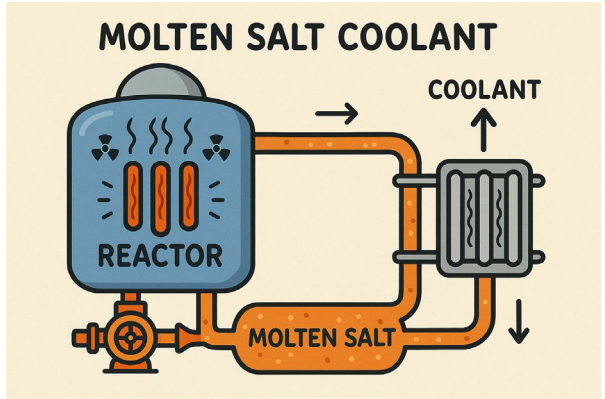


617

282, 230

Commercially available
High temp. strength

Low-Cr
Molten salt compatible



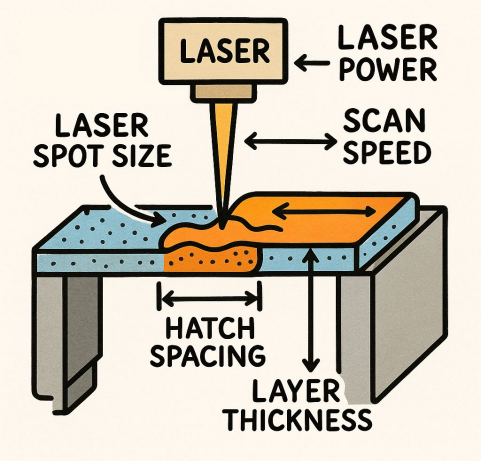
HN, 244, 625

High temp. strength, Commercially available

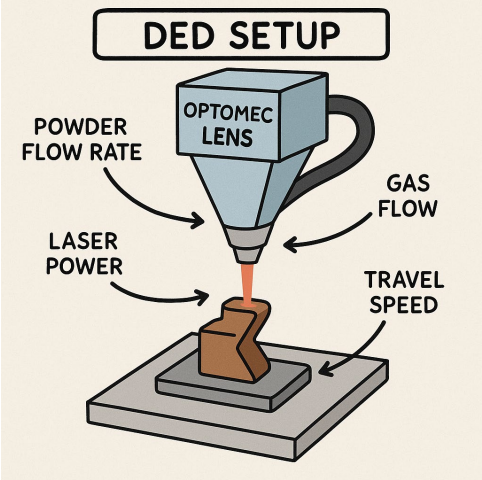
Compatibility data for wrought 625

Processing Studies to optimize Microstructure of Ni-based superalloys. Collaboration with other AMMT Projects

LPBF, ORNL



INL, LP-DED

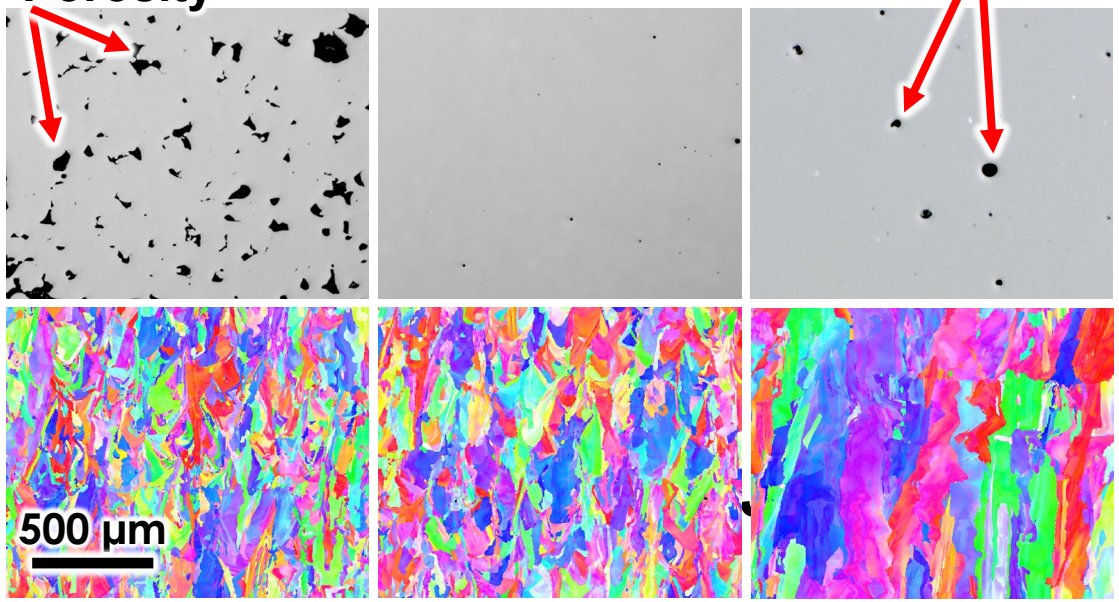


Lack of Fusion Porosity

Keyhole Porosity

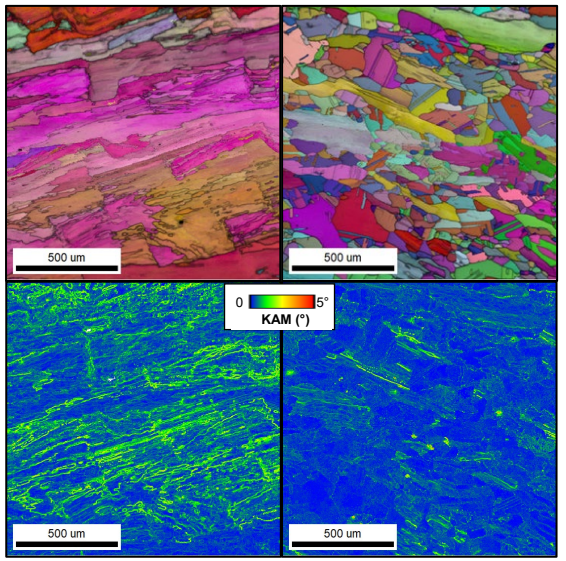
Annealing

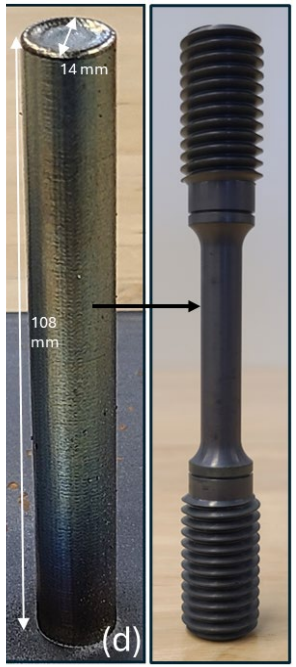
Mechanical testing



As-printed

1h at 1180°C

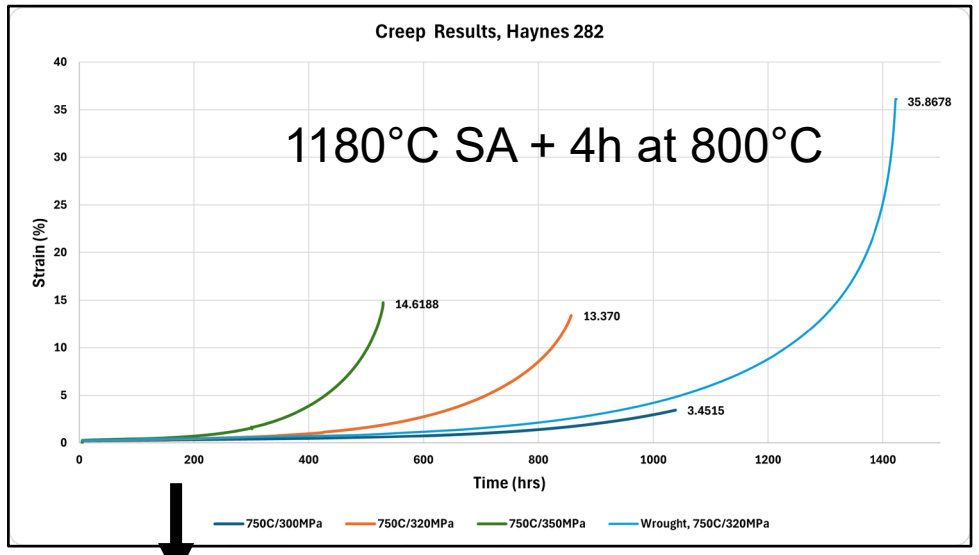


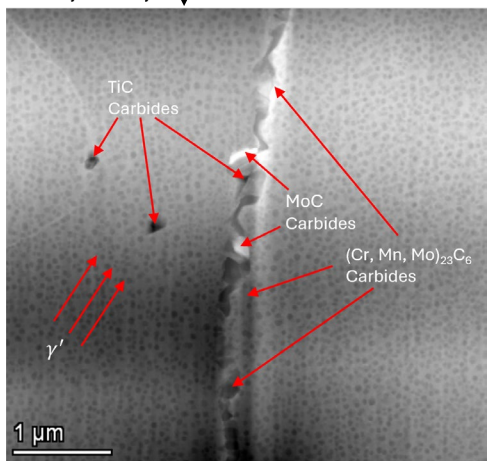


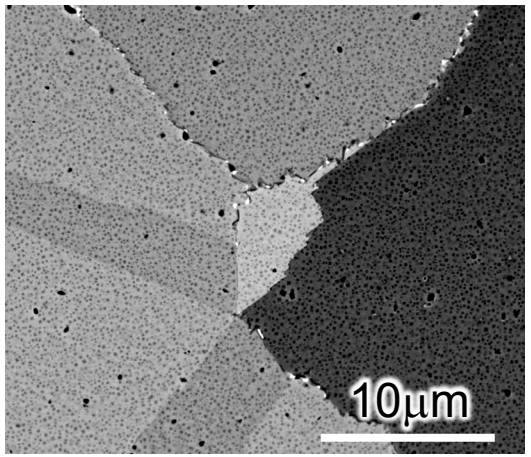
Increasing energy density

- Integrating process-properties information into Damaratern data platform
- Providing materials for advanced testing i.e. irradiation, molten salt exposure
- Learning for the LPBF 316H and Wrought 625 Code qualification tasks

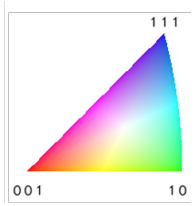
Optimization of LP DED 282 Heat Treatment to Improve Creep Performance

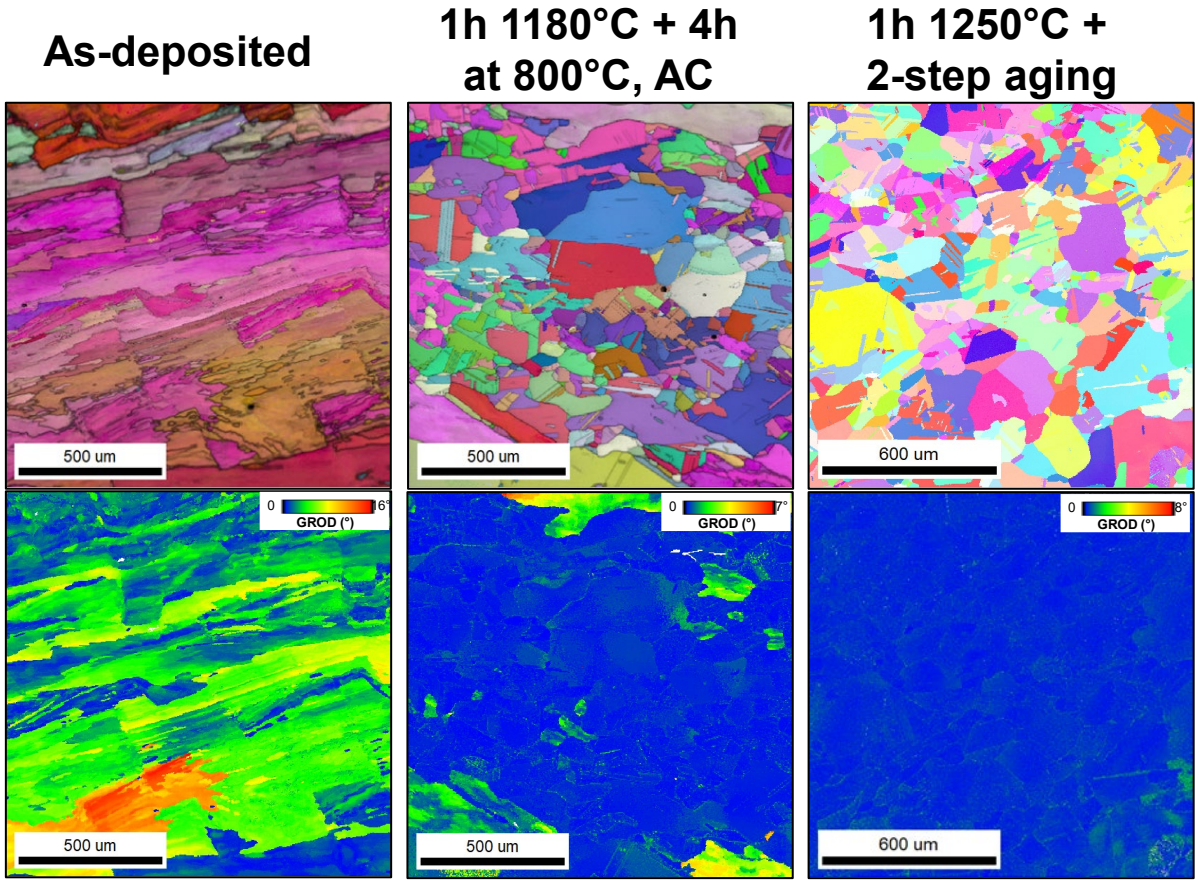






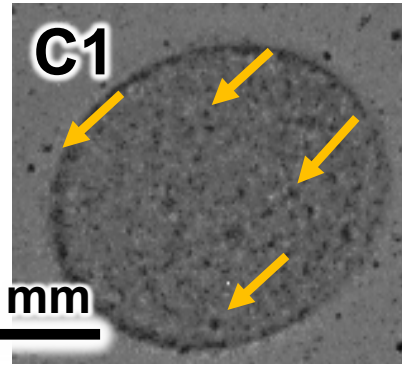
BD

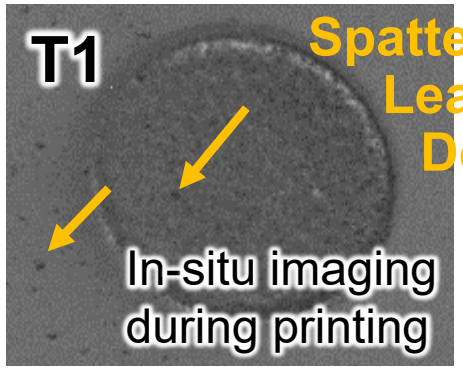




- Solution Anneal at 1250°C for full recrystallization
- Haynes 2-step aging: 1010°C/2hr/FC to 788°C/8hr/AC to control GB precipitates + larger ~150nm γ'

Identification of Flaws Leading to Failure in LPBF Creep Tested 282. Both Coalescence of Flaws & New Flaw Formation

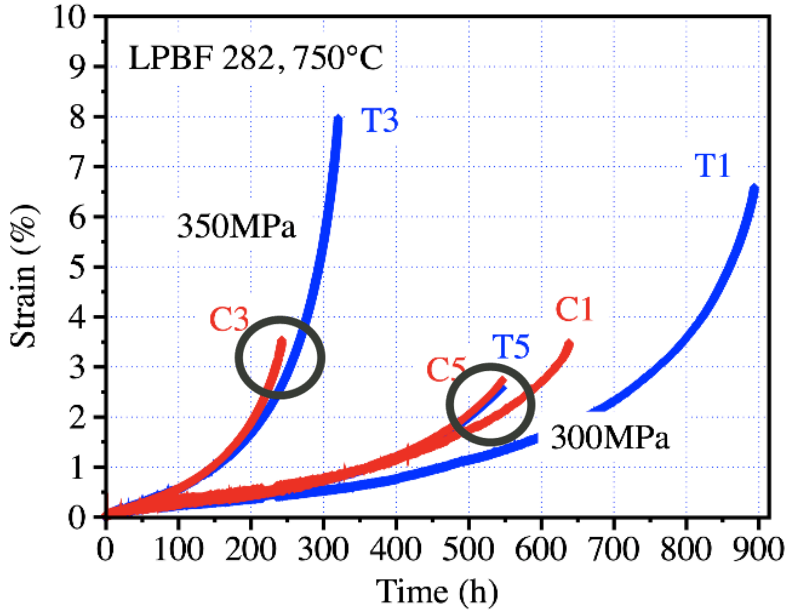




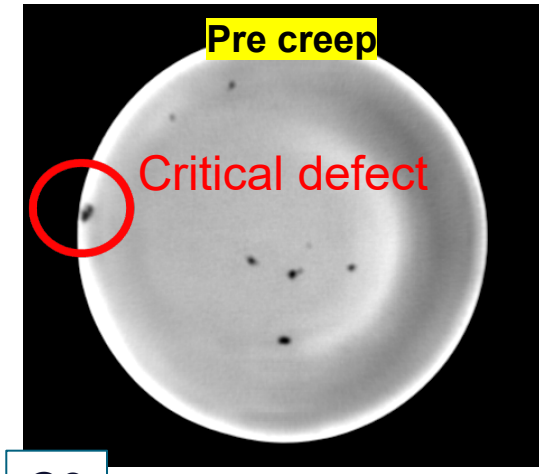
Spatter particles Leading to Defects

5 mm

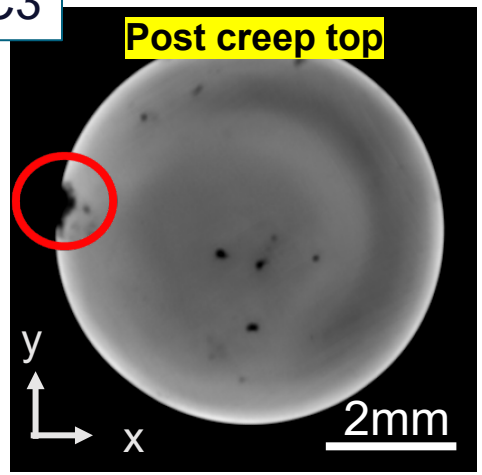
Ar flow

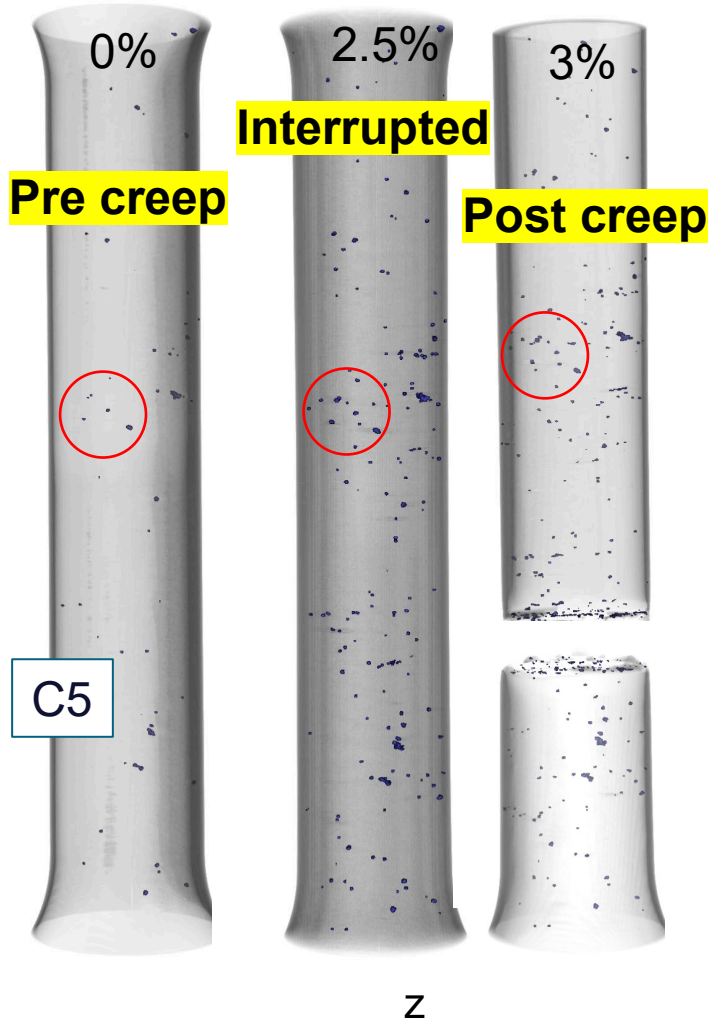


Impact of defects on creep behavior

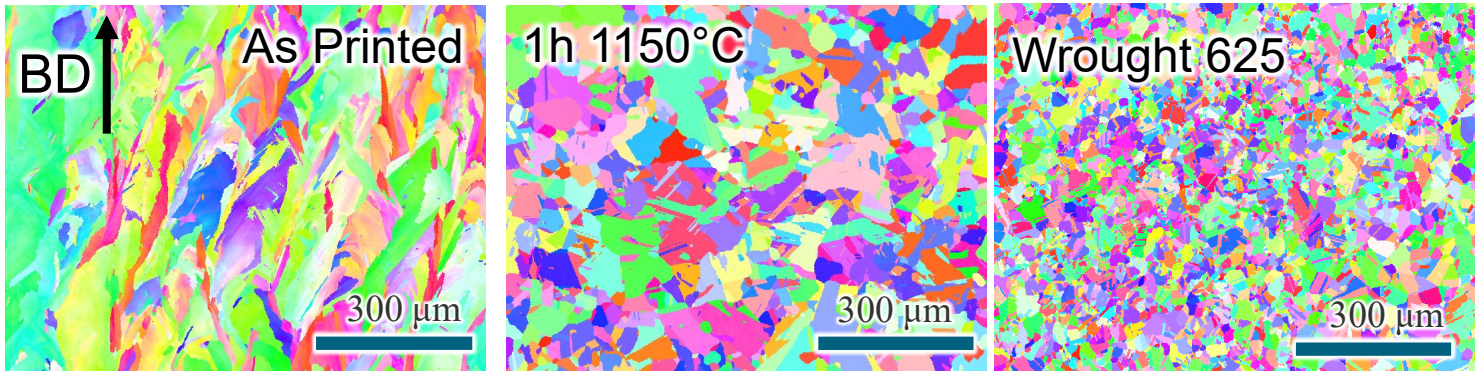


C3





Low-defect Density in LPBF 625 Led to Good Tensile Properties. HT needed to Suppress Anisotropic Creep Behavior



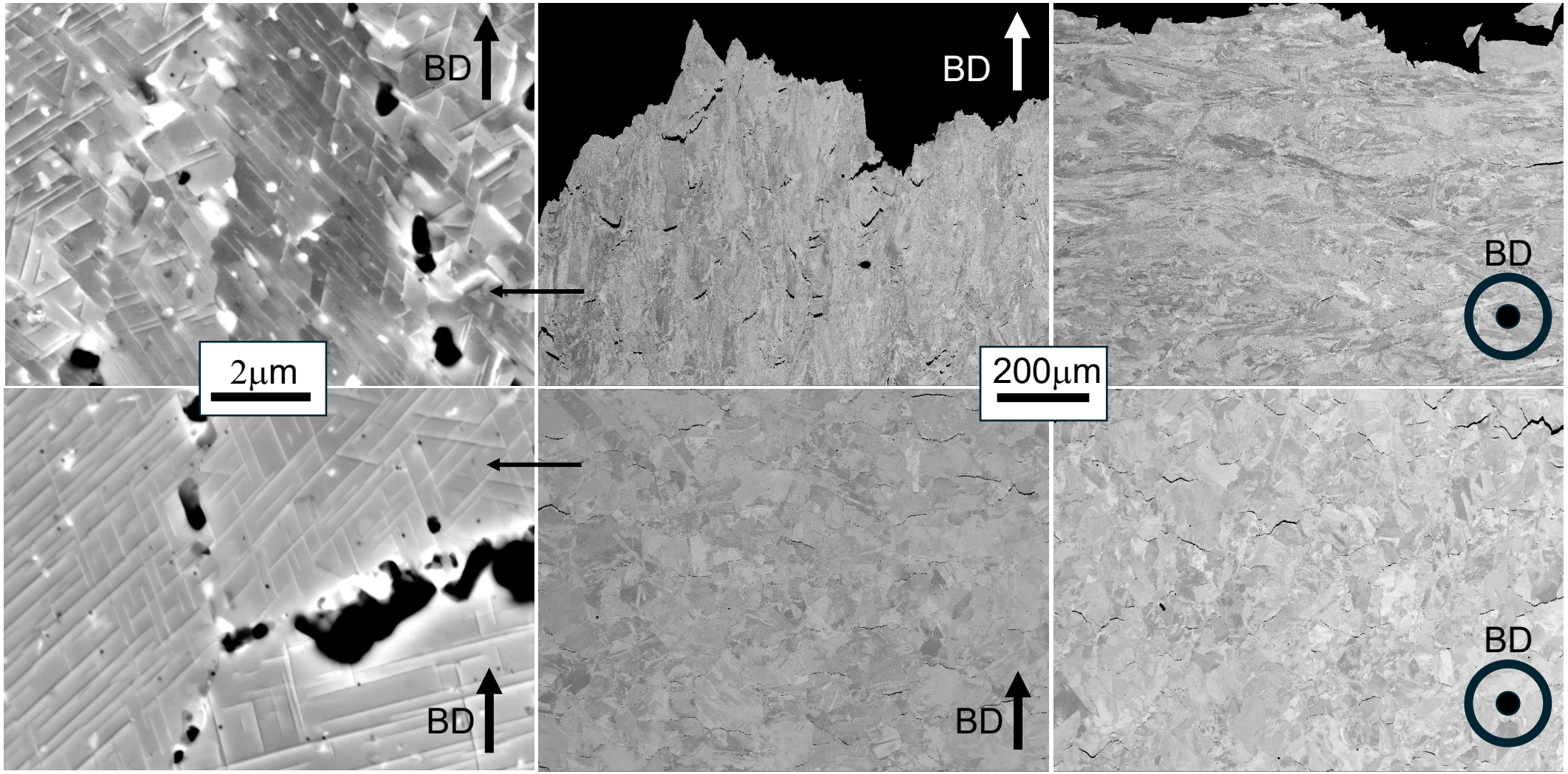
Low creep rate & ductility for LPBF 625

Very Few Cracks Observed for the As Printed Specimen Tested Per. to the BD. Cavitation Related to Precipitates at GB

δ phase and carbides in the grain & at GB

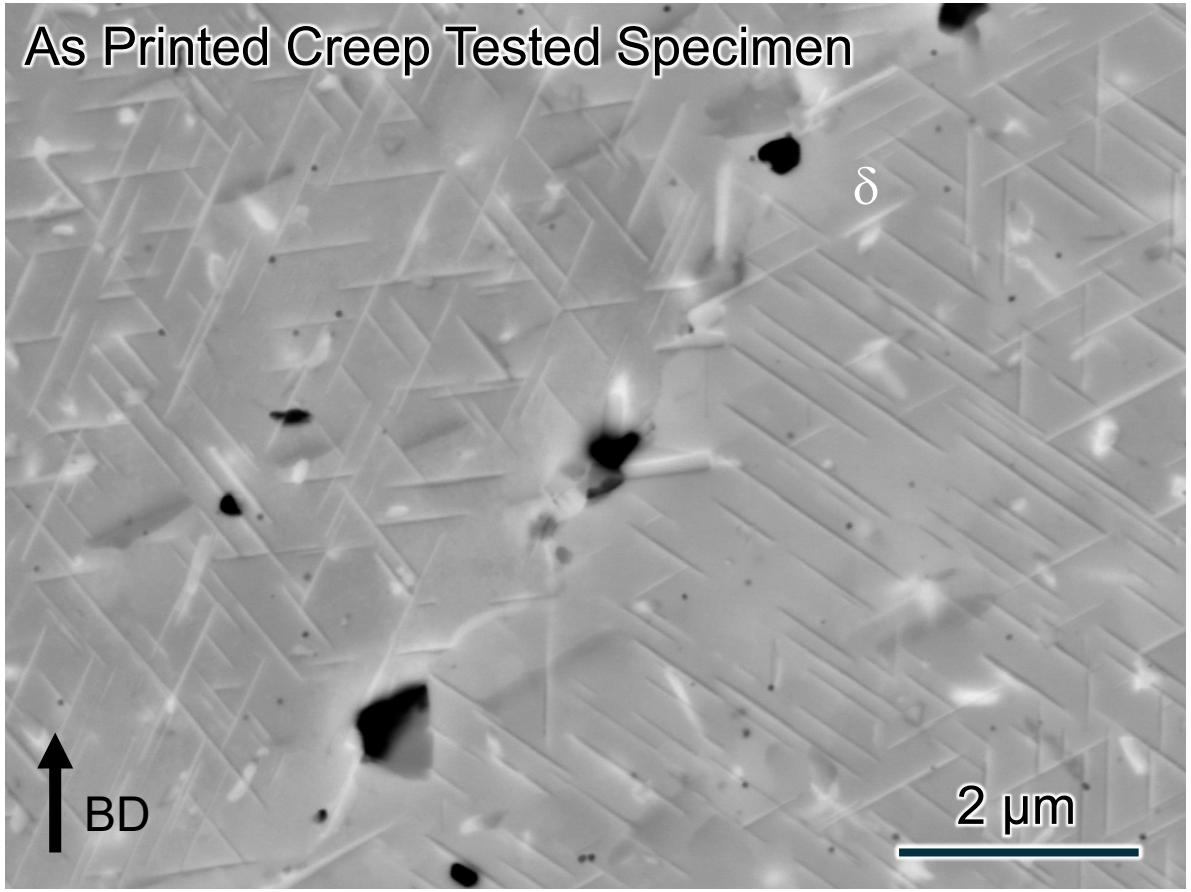
As Printed

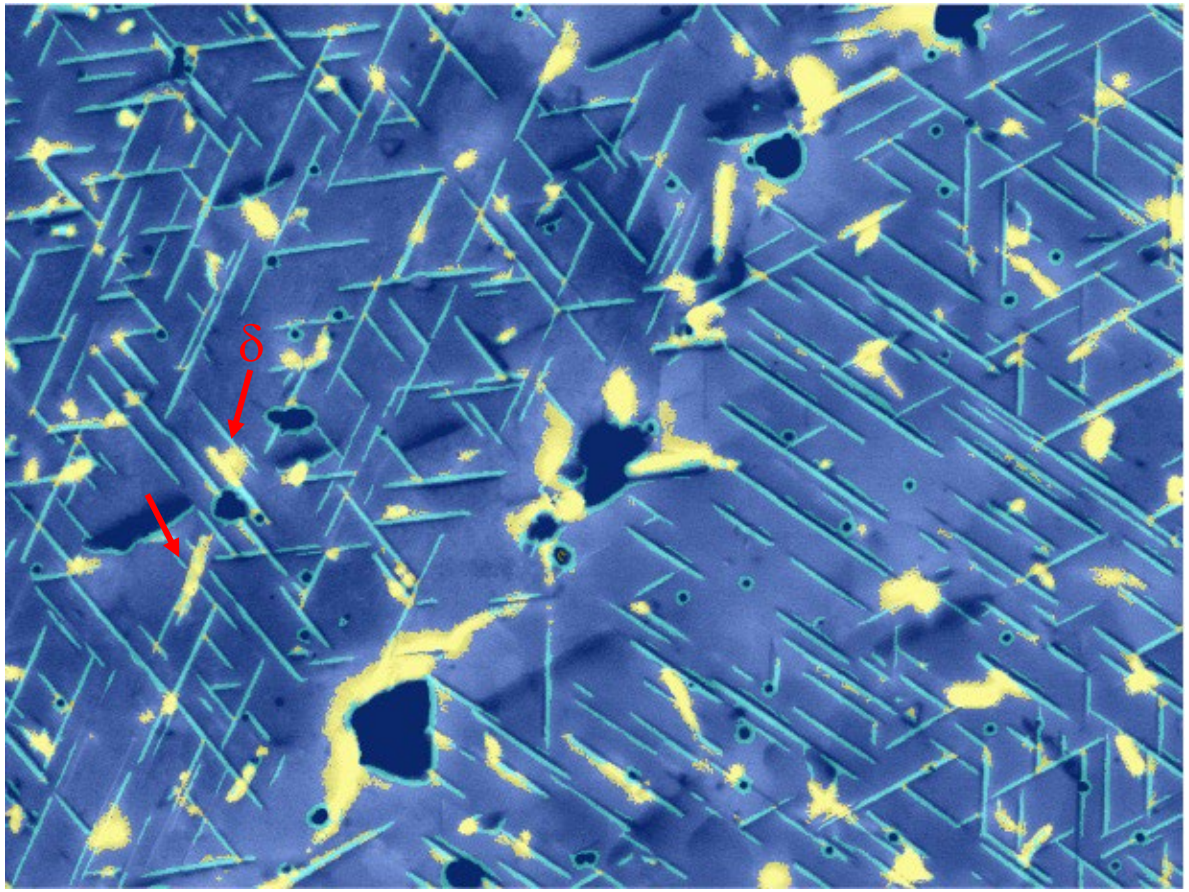
Annealed 1h 1150°C



Quantification of Carbides and δ phase Using Machine Learning. Next = Quantification of cavities at GB

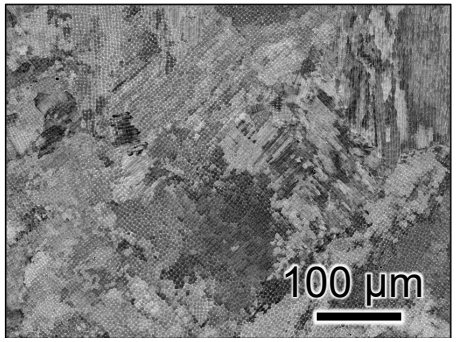
Matrix : 80.5% δ : 12.4% Carbides : 7.1%

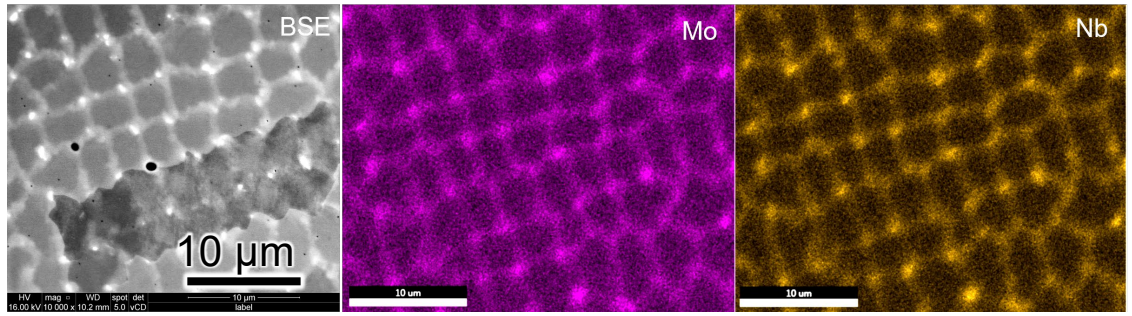




Recrystallization of LP-DED 625 After 30min at 1200°C but Low Creep Ductility

As built cellular grain structure

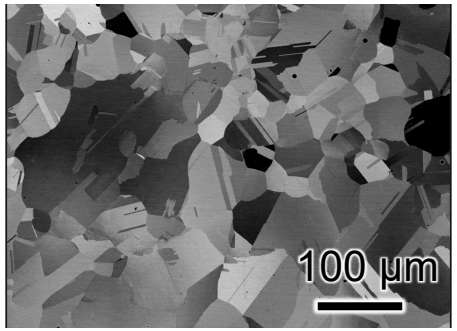


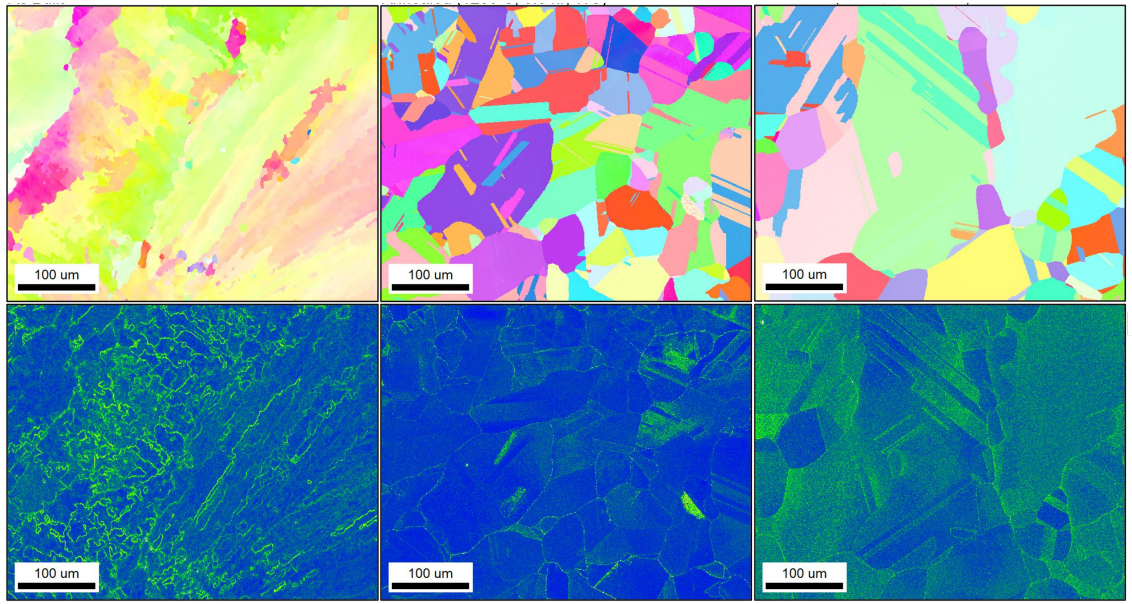


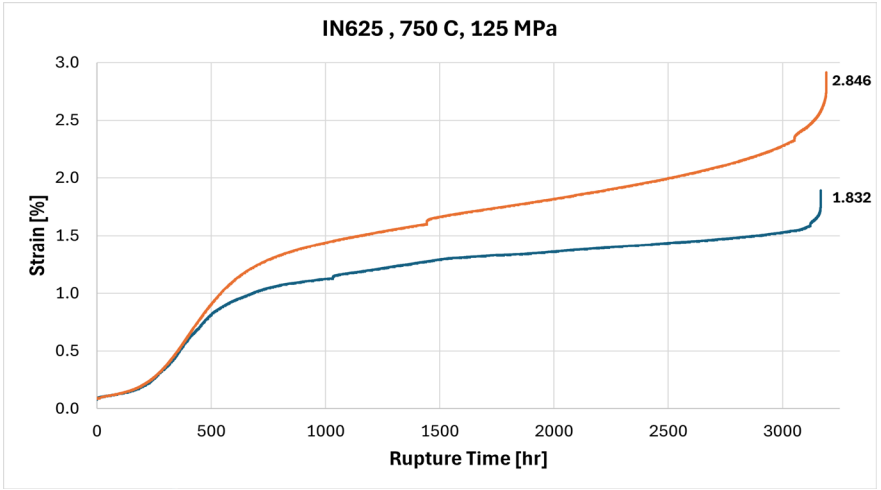
As Built

0.5h 1200°C, WC

SA + 50h at 650°C

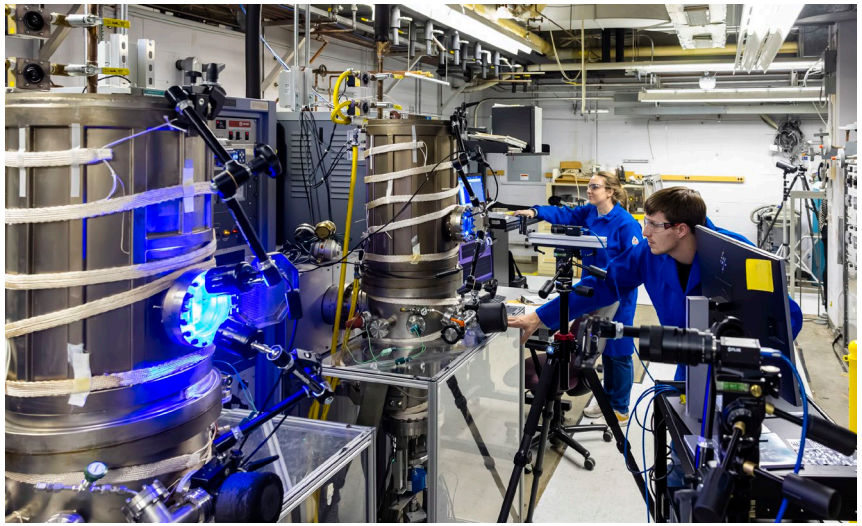


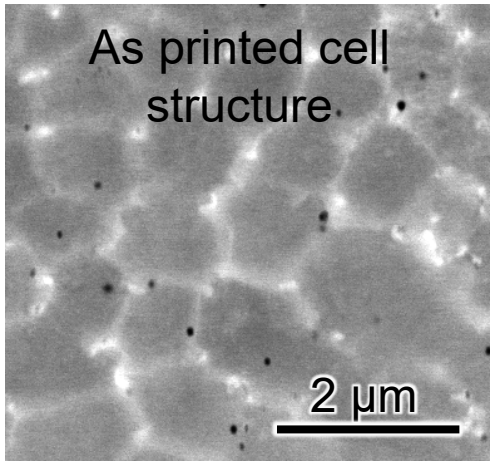




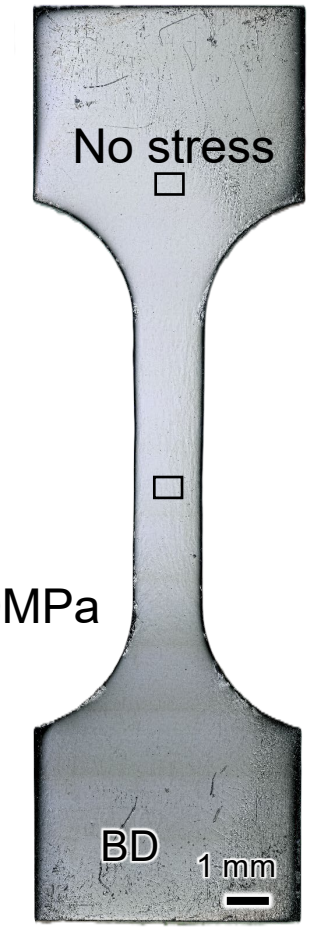
- Ongoing effort to optimize heat treatments

Interrupted Creep Testing in Vacuum to Follow the Evolution of Microstructural Features: Carbides, δ Phase, Cavities, Cracks



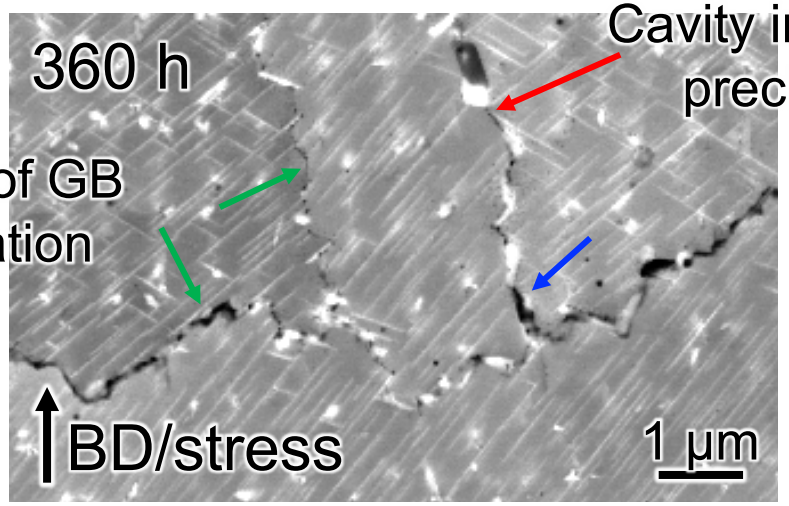


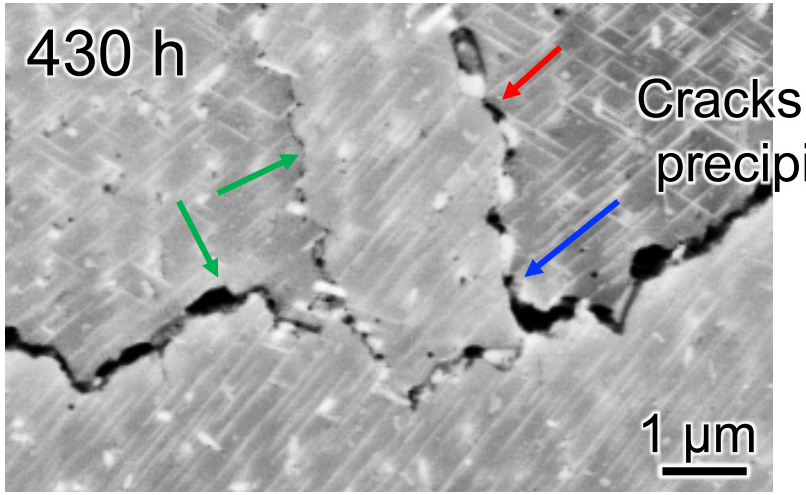
725°C, 200MPa



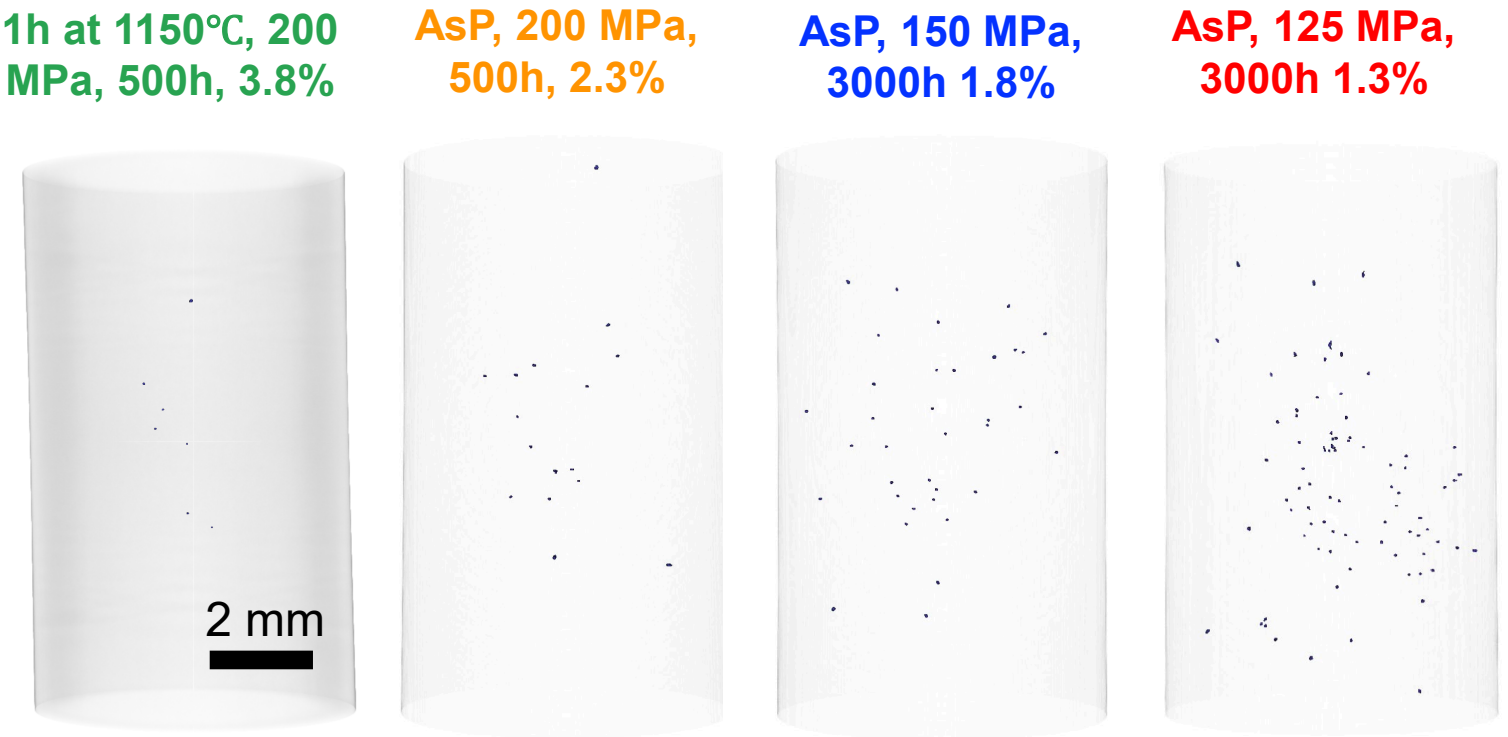
Mirror finish specimen

Impact of GB orientation



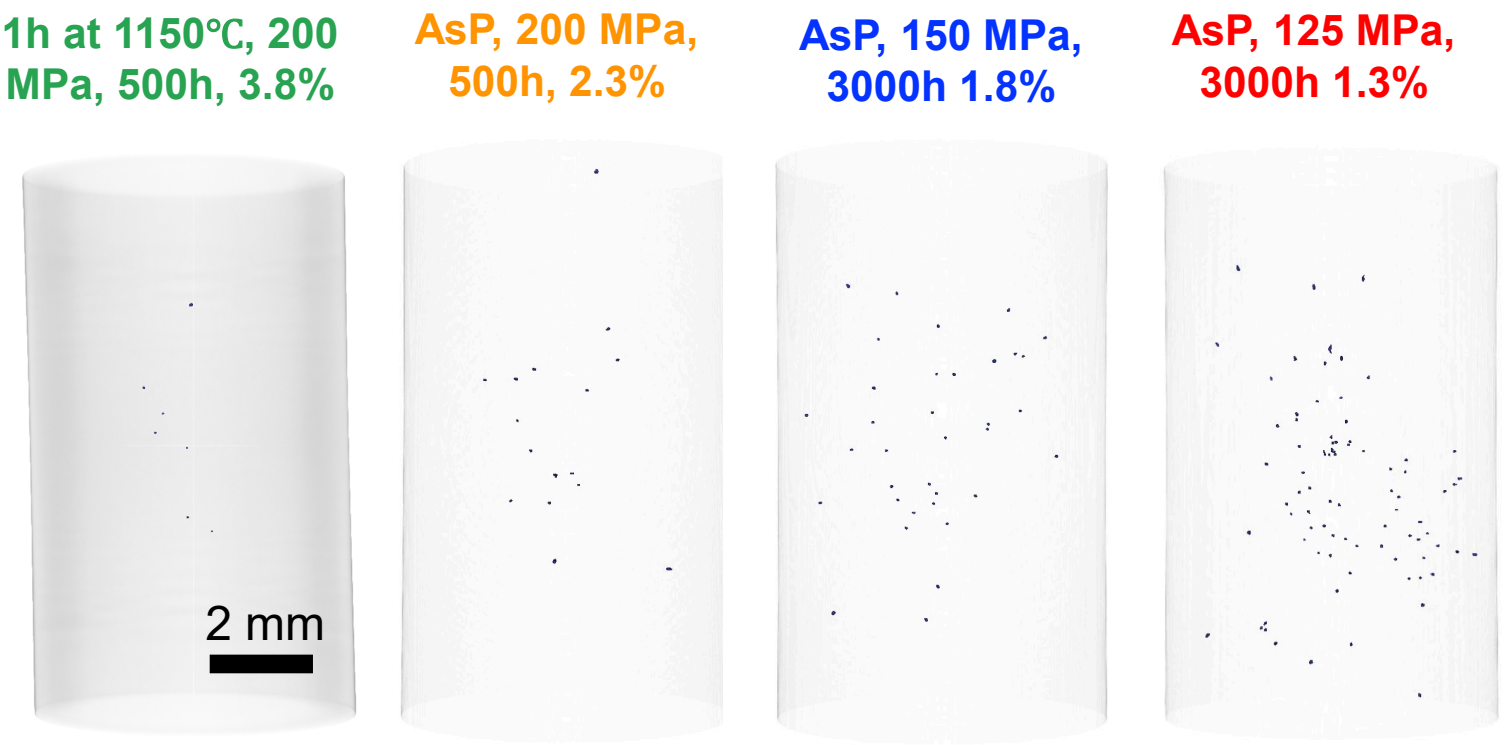


Creep Cavity Formation Observed by XCT During Creep Testing Greater Impact of Test Duration Compared to Strain

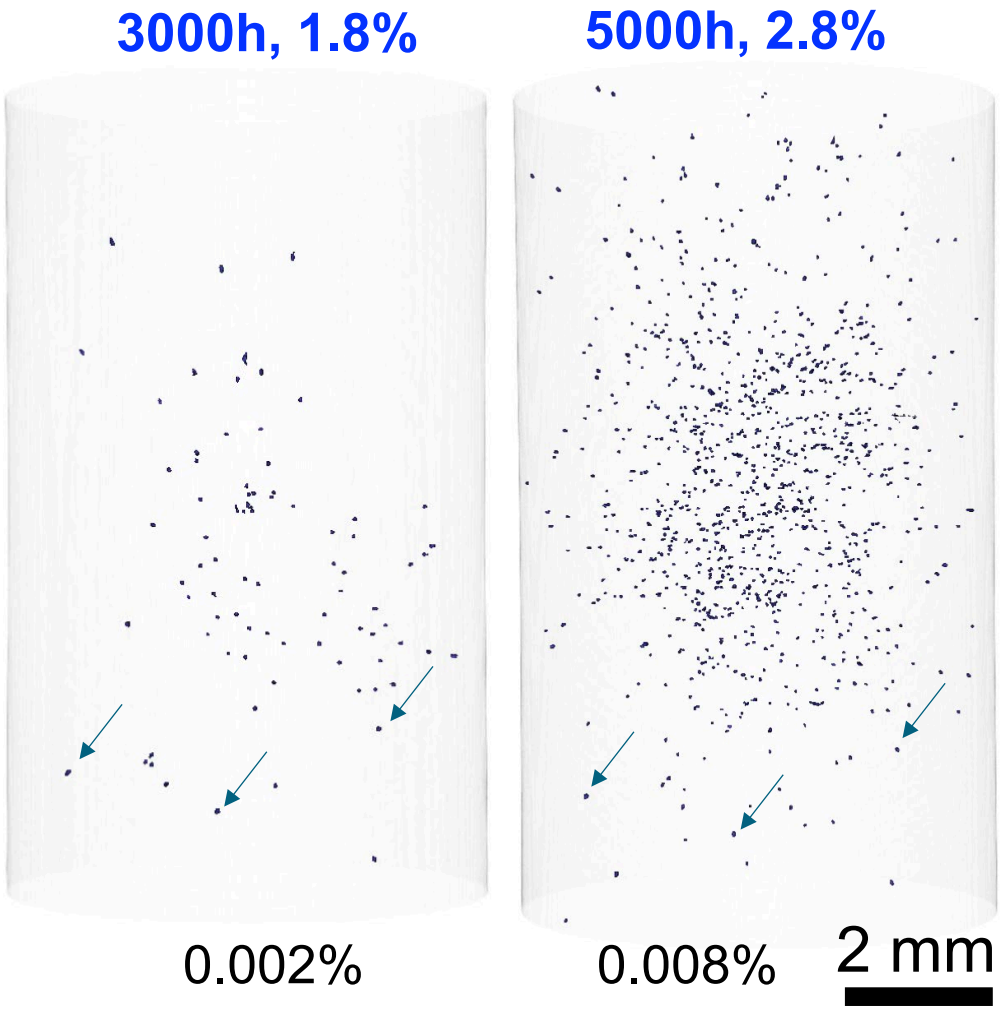


Resolution: ~ 3 pixels x 6.5 um

Greater Impact of Initial Heat Treatment and Test Duration Compared to Strain



XCT Analysis After 5,000h Confirmed Cavity Detection. Drastic Increase in Cavity Number Density Due to Tertiary Creep Onset

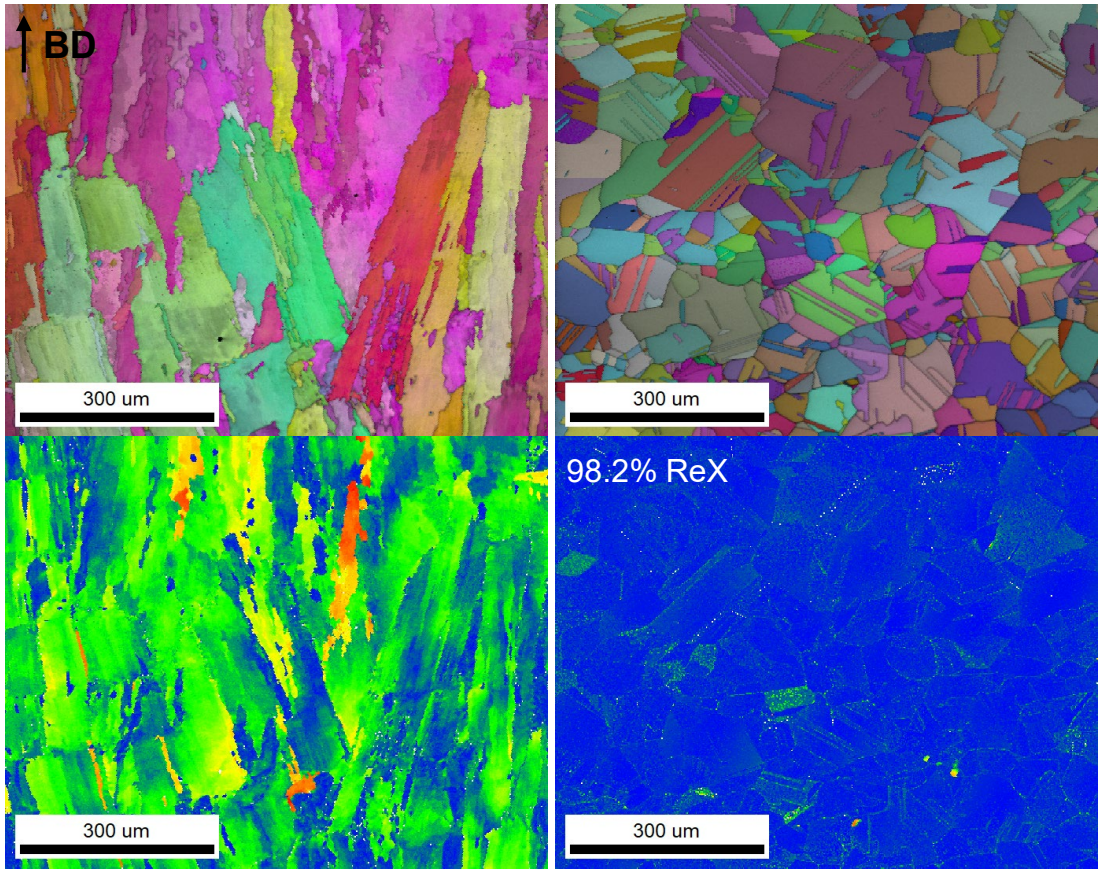


Cavity growth will be estimated from individual cavity observed after 3,000h

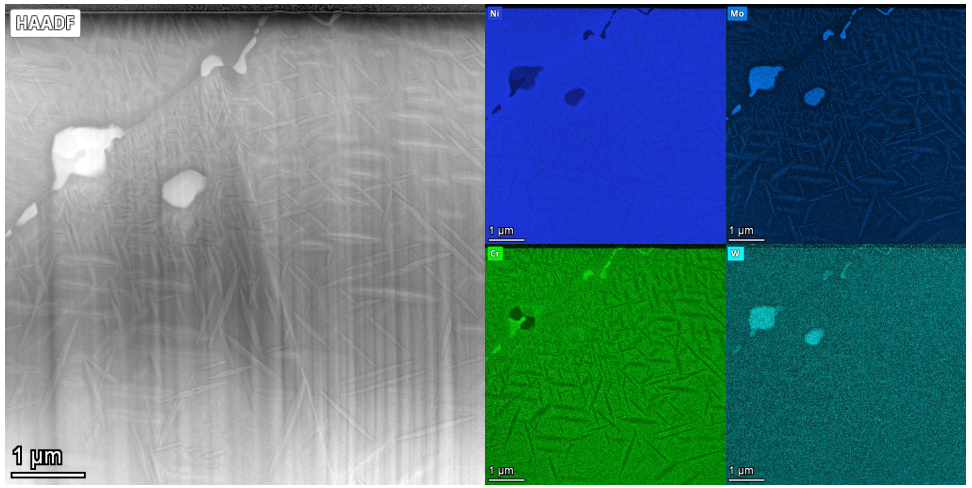
Crack-free LP-DED 244 ((Ni-8Cr-22.5Mo-6W) Has Been Produced. Ongoing Optimization of the Heat Treatment

As-printed material

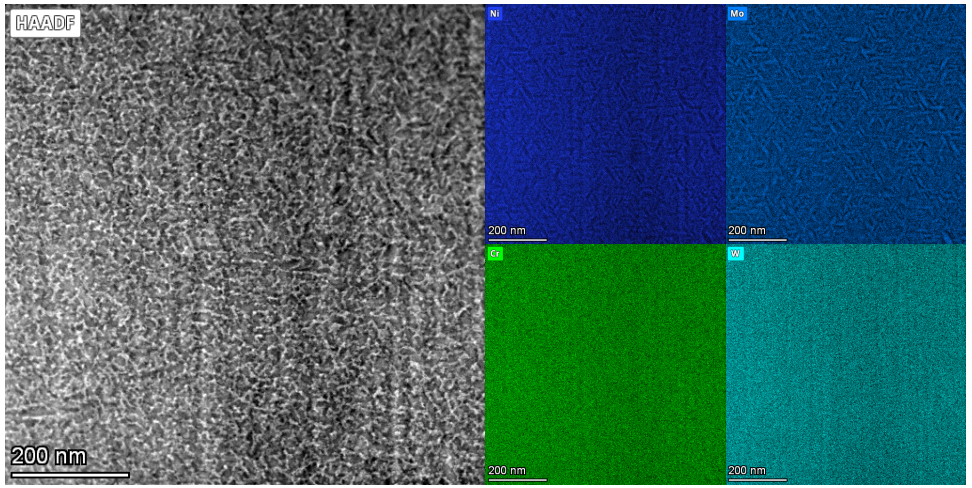
Standard 244 Heat treatment, 1135°C/30 min/WQ
760°C/16hr/FC to 650°C/32hr/AC



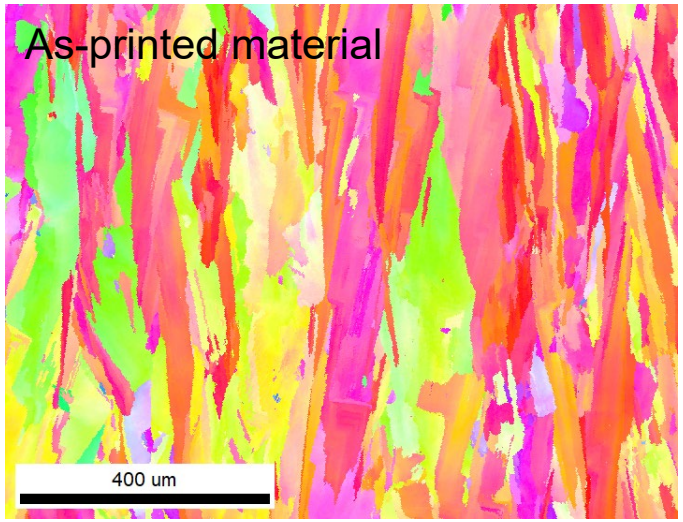
Ni(Mo,W) μ phase and $(Mo,W)_6C$ carbides at GB

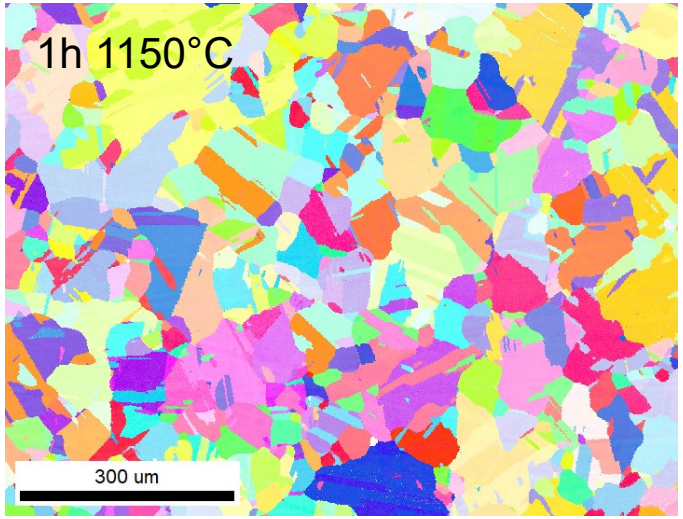


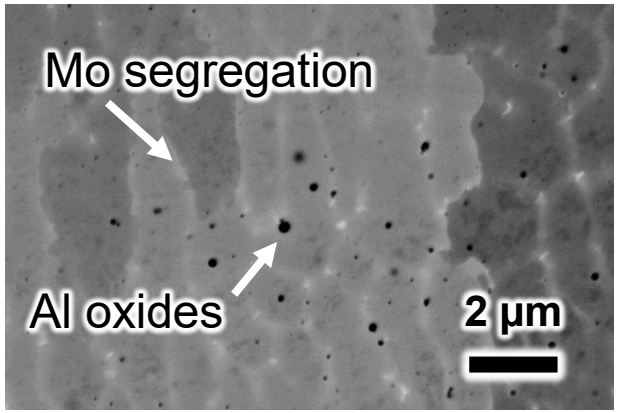
$Ni_2(Cr,Mo,W)$ γ''' and μ phase in grain interior



Similarly, Crack-free LPBF 244 Has Been Fabricated & Evaluation Was Initiated





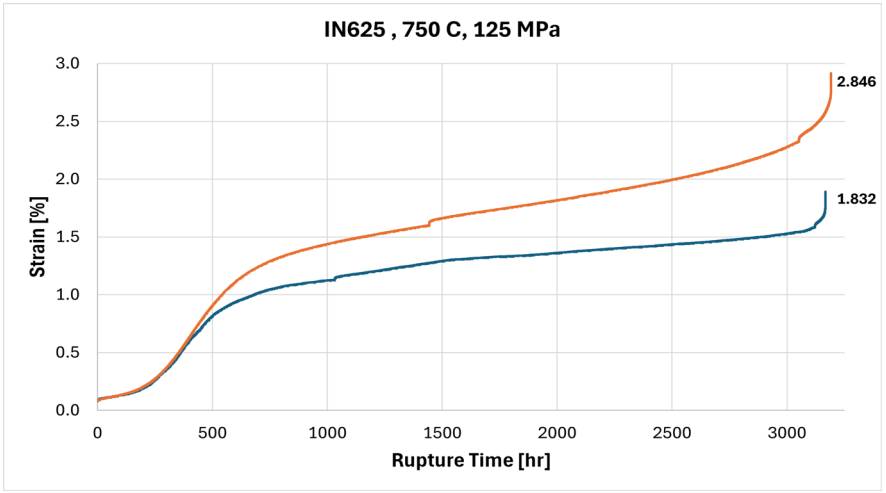


- High strength at 750°C likely due to the formation of $Ni_2(Cr,Mo,W)$ γ'''
- Ongoing optimization of heat treatment

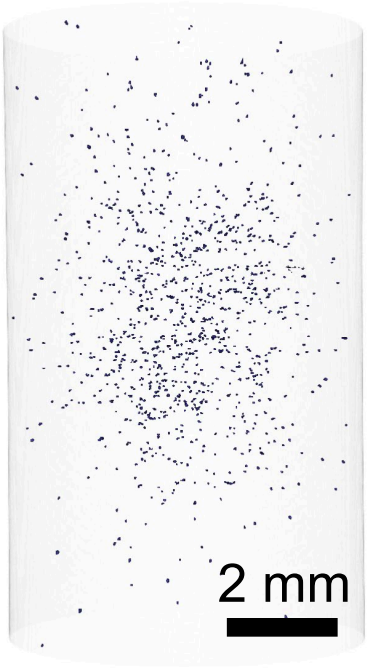
Future Work to Accelerate the Deployment of Ni-based Alloys

Generate MSR-relevant properties for LPBF/DED 625 Properties

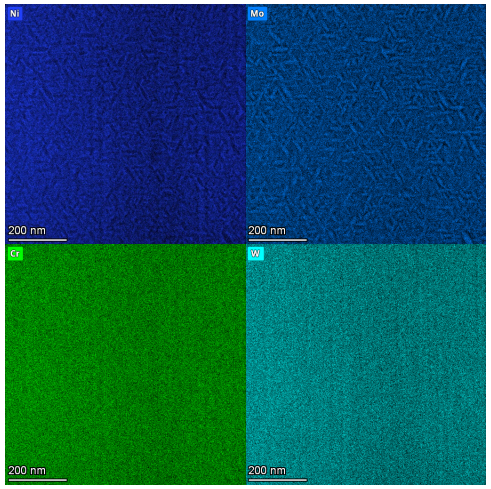
Heat treatment optimization



advanced characterization to accelerate qualification



Extensive characterization of low-Cr molten salt compatible Wrought/LPBF/DED 244



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