Applying In-Situ Heat Treatments to Improve Additively Manufactured Hot Work Tool Steel

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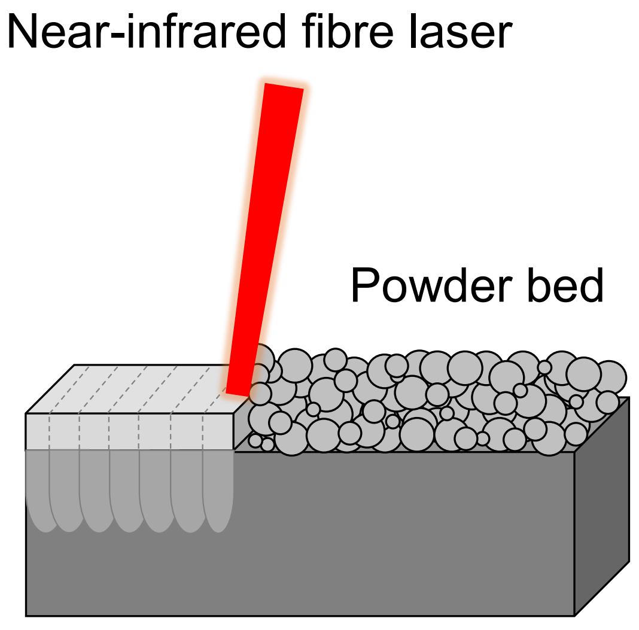
Introduction

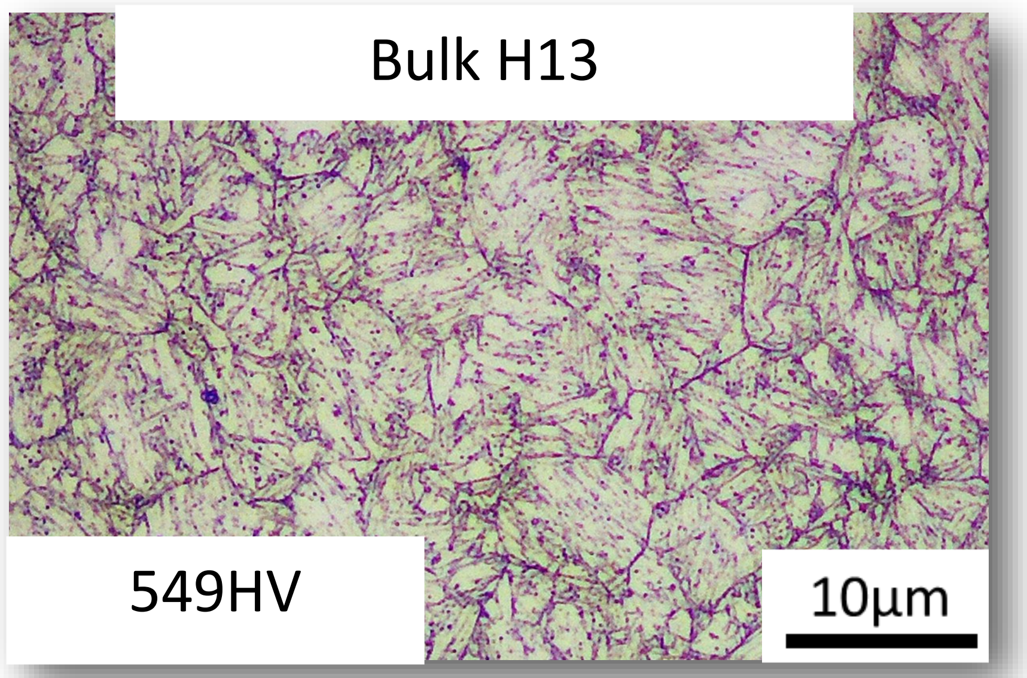
Laser powder bed fusion (LPBF) additive manufacturing (AM) is a promising process for the fabrication of hot work tool steel H13 components. Mitigating cutting tools from H13 component manufacture removes the technical challenges of machining high hardness material. However, H13 components are subject to large-scale cracking when fabricated by LPBF AM. This is due to rapid and cyclical heating and cooling rates in the process, which form a brittle and stressed component susceptible to cracking.

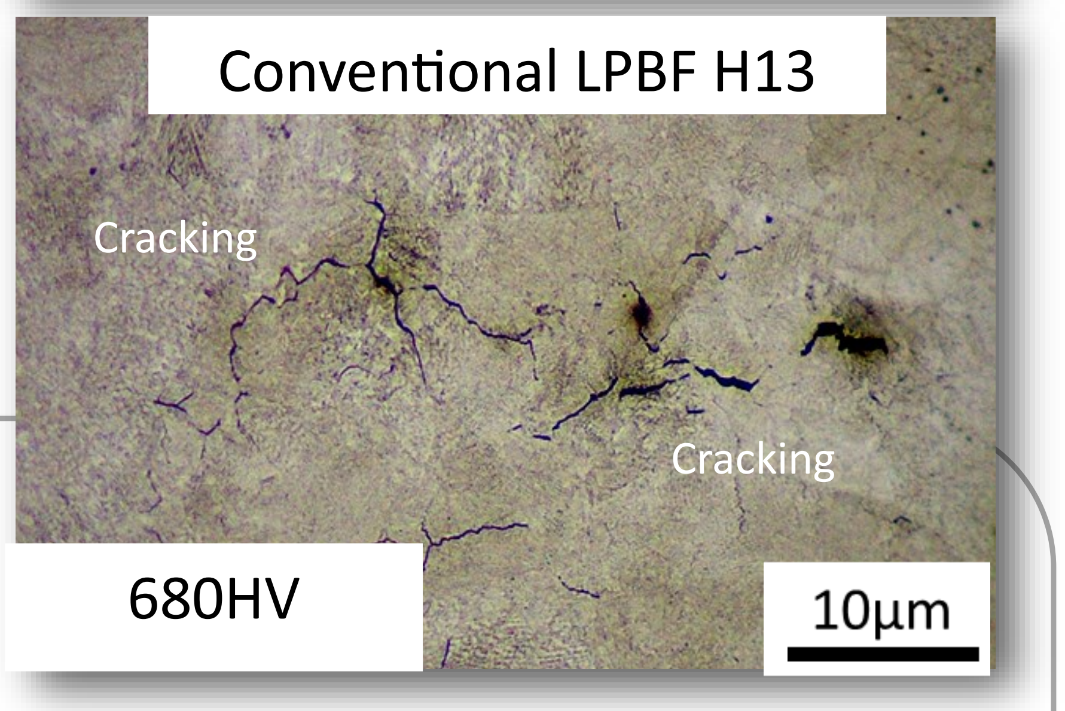
Objective: Can in-situ tempering improve the microstructure and reduce cracking in additively manufactured H13?

The LPBF AM Process



H13 Microstructure

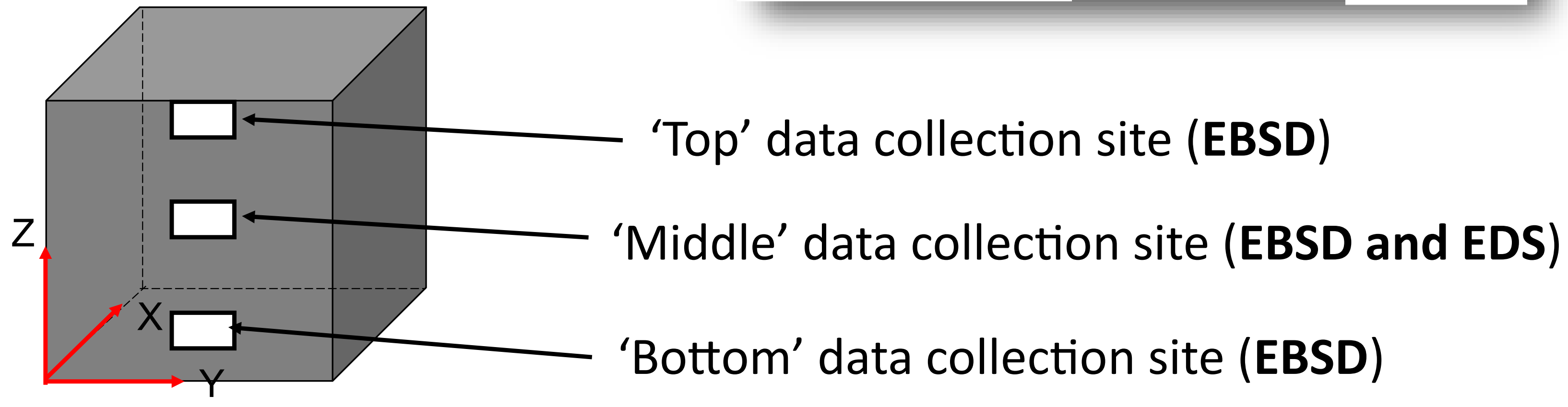




Experimental Methods

1. A Renishaw metal additive manufacturing system (RenAM500Q) was used to fabricate samples where in-situ heat treatment was applied.
2. Samples were analysed for **defect population** and **evidence of tempering**.
3. In-situ heat treated samples were compared to conventional LPBF AM H13 samples.

Fabricated sample geometry



'Top' data collection site (**EBSD**)

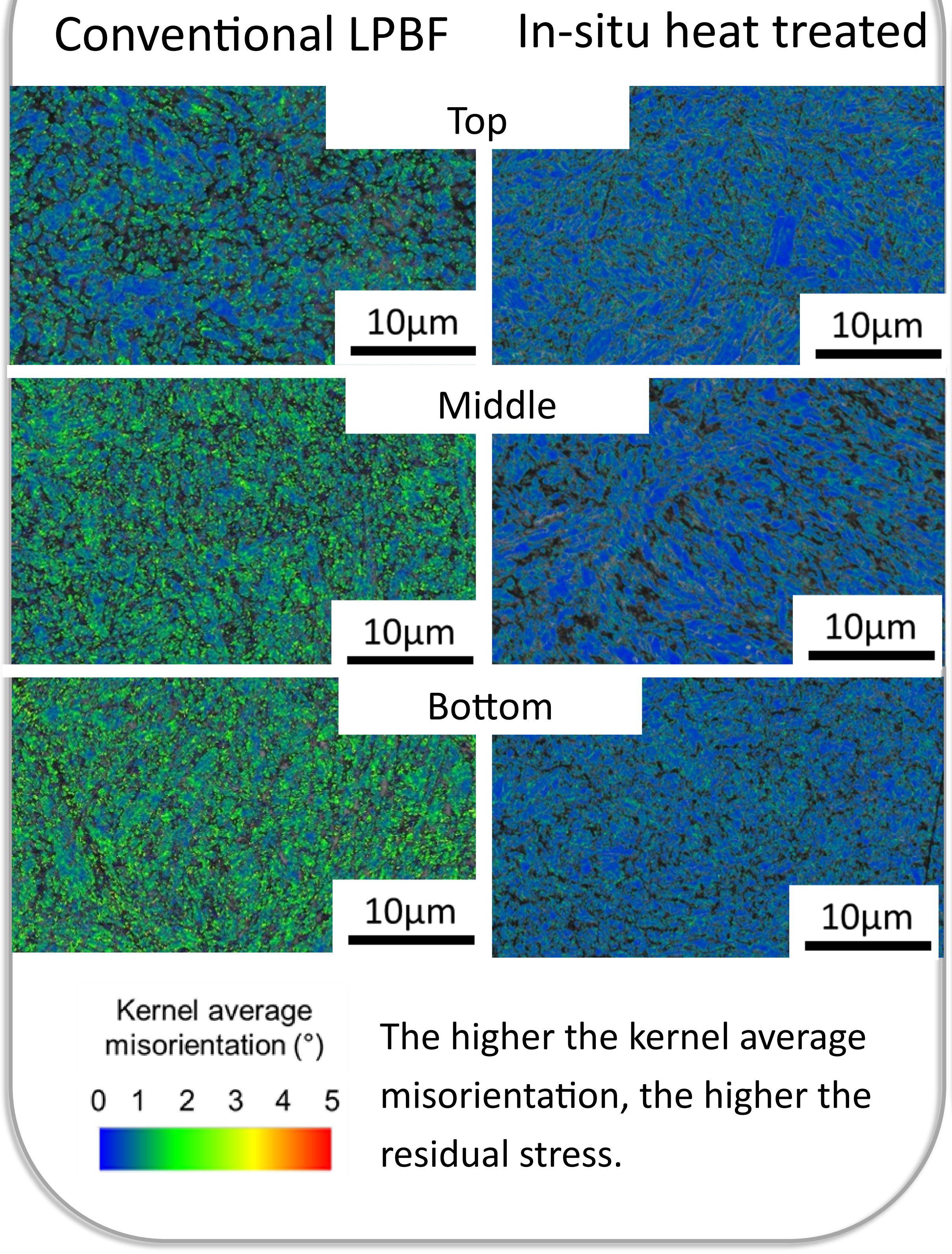
'Middle' data collection site (**EBSD and EDS**)

'Bottom' data collection site (**EBSD**)

EBSD = Electron Backscatter Diffraction **EDS** = Energy Dispersive X-ray Spectroscopy

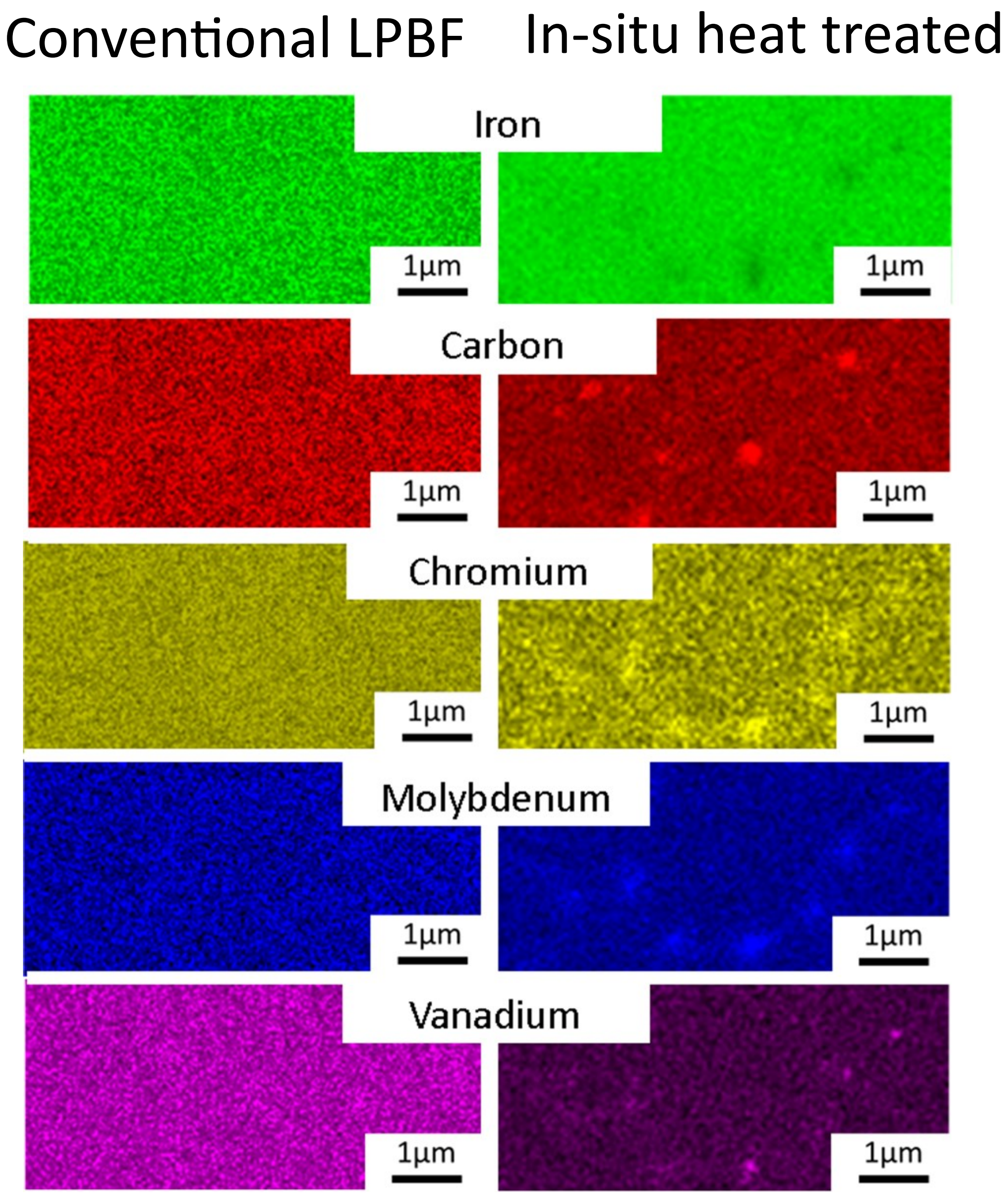
Results

Residual Stress (EBSD)



The higher the kernel average misorientation, the higher the residual stress.

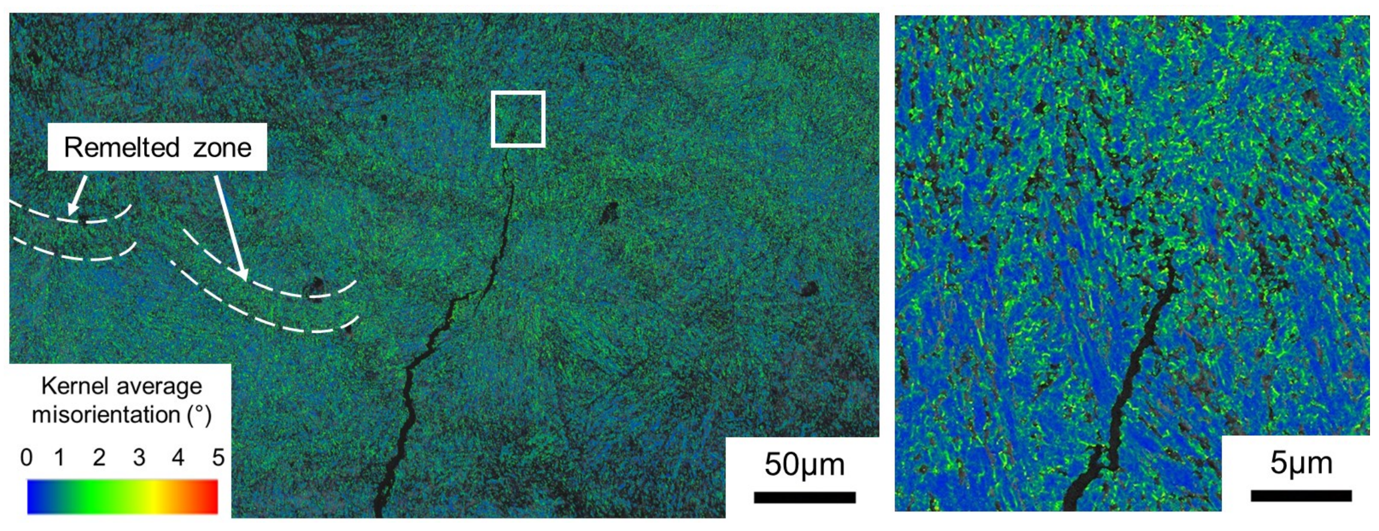
Carbide Presence (EDS)



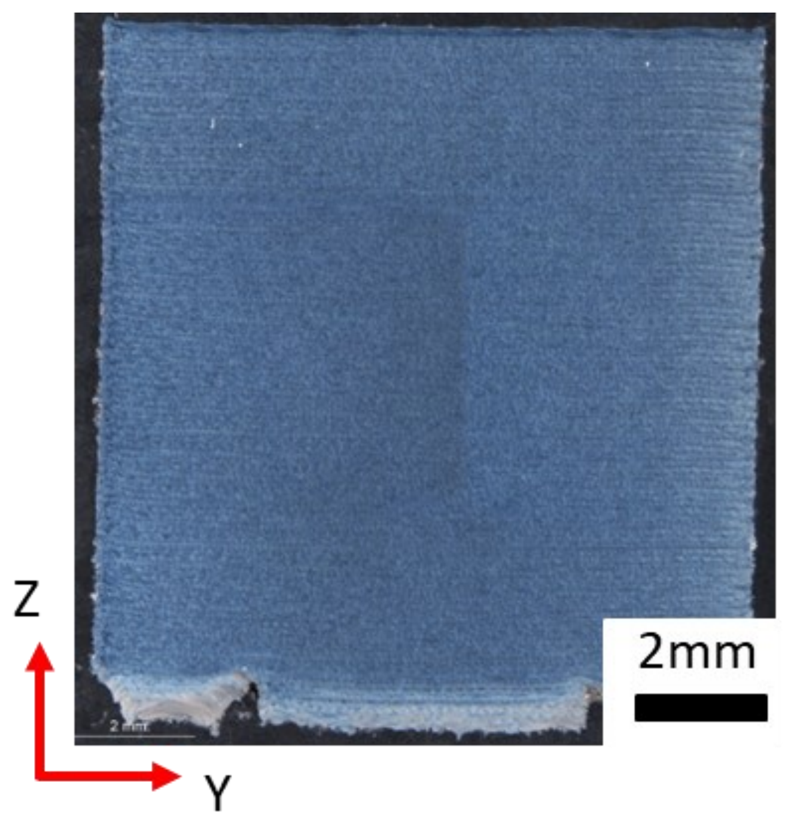
Local concentrations of carbon, chromium, molybdenum and vanadium indicates precipitation of carbides within the microstructure.

Defect Population

Conventional LPBF: Cracks exceeding 1mm in length in Y and Z directions



In-situ heat treated: Large-scale cracking eliminated



In-situ heat treated sample hardness: **552 HV**

Summary of findings

- Defect population was reduced to 0.001% in the YZ plane, and large-scale cracking was eliminated.
- Residual stresses were reduced and homogenised, indicated by the EBSD kernel average misorientation data.
- Evidence of chromium-, molybdenum– and vanadium-rich carbides was seen, indicated by the EDS data.
- Hardness was reduced to 552 HV2, indicative of optimal H13 wear properties.

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