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3D Characterization of a Novel CoNi-superalloy for Additive Manufacturing

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Additive manufacturing (AM), in which complex 3D shapes are created in a layer-by-layer fashion, promises a nearly limitless design space to create optimized structures for a wide range of applications. Despite the promise of this emergent technology, there is a paucity of available alloy systems that are amenable to this processing approach. The repeated remelting of material as it is deposited, as well as the fast solidification times and high thermal gradients, can create enormous stresses within components, leading to premature failure and incipient cracking during the fabrication process. These extreme processing conditions have limited the applications of Ni-based superalloys in additive manufacturing processes. Particularly for superalloys with a high volume fraction of γ' strengthening precipitates, production of defect-free AM components has been difficult [1, 2]. Here we present the 3D characterization of a novel CoNi-superalloy with a high volume-fraction of γ' precipitates with a low density and intrinsic oxidation resistance that is amenable to the challenging processing conditions of AM [3,4].

Samples of the CoNi-superalloy processed via powder-bed laser melting processes were characterized in 3D via TriBeam tomography. The TriBeam is a fully-automated serial sectioning tool that utilizes a femtosecond laser for low damage micromachining within the vacuum chamber of an electron microscope, enabling multi-modal data collection of large 3D volumes on the order of a cubic millimeter [5, 6]. Electron backscatter diffraction (EBSD) data was collected in 3D from single-track melting experiments and from a bulk AM component. Laser-melting of powder on oligocrystal substrates reveals the presence of large orientation gradients that develop during solidification in AM processes (Figure 1). The amount of misorientation accumulated in single grains is found to depend on the orientation of the substrate, which can affect the tendency for cracking to occur in bulk components. 3D characterization of AM parts demonstrates the influence of scan strategy on microstructure, creating the grain morphology shown in Figure 2, which has been similarly observed in other AM components in metals with cubic crystalline symmetry [7]. Populations of much smaller grains with distinct microstructural property distributions are observed to form along the edges of builds at the part-powder interface, which has important implications for the fabrication of complex geometries and thin-walled structures [8].

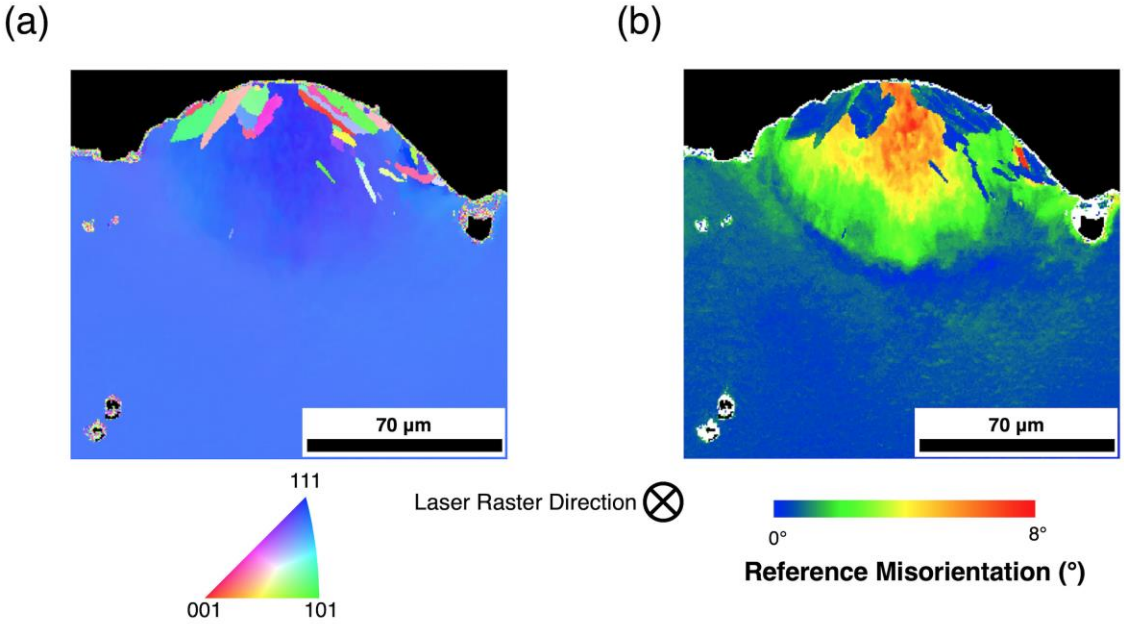

Figure 1. Cross-section of single-track melting experiment showing (a) EBSD data and (b) intra-grain misorientation. The large oligocrystal substrate accumulates misorientation as it solidifies in the melt pool, whereas nucleated grains are observed to have low internal misorientation. The laser raster direction (into the plane of the page) is used as the reference direction for inverse pole figure (IPF) coloring.

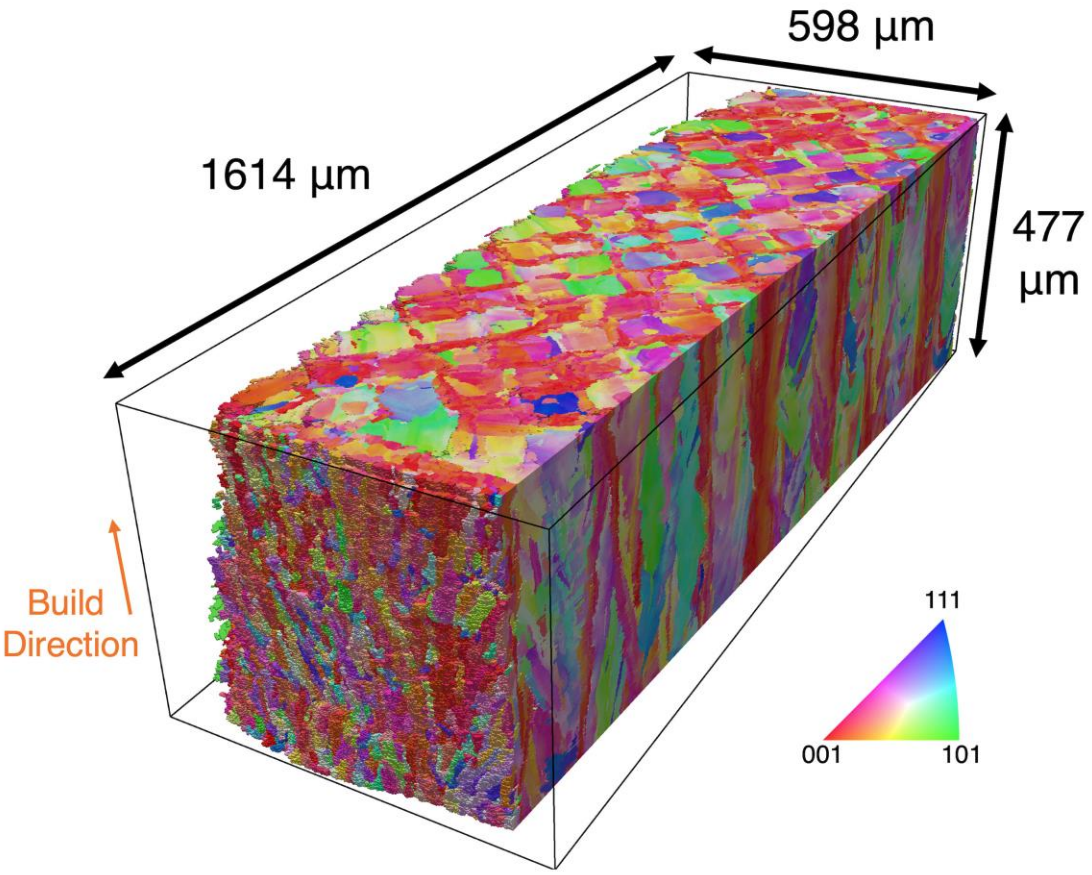

Figure 2. 3D reconstruction of AM CoNi-superalloy processed via a laser powder-bed process. Large columnar grains repeat in a regular grid throughout the bulk of the part, while finer-scale grains form on the edges of the build at the part-powder interface. The build direction is used as a reference direction for inverse pole figure (IPF) coloring.

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