Overcoming the Strength–Ductility Trade-Off in LPBF Duplex Stainless Steel via Heterogeneous Phase Structuring

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The annealing process plays an important role in unlocking the full potential of 3D printed duplex stainless steels (DSS). While Laser Powder Bed Fusion (LPBF) enables the production of complex geometries, the process introduces a fundamental material challenge: the rapid cooling and solidification rates inherent to LPBF typically result in ferrite supersaturation [1]. This creates an "as-built" microstructure that is extremely hard and strong, often exhibiting yield strengths exceeding 1000 MPa but is compromised by significant brittleness and a deviation from the ideal 50:50 austenite-ferrite balance.

To address this, post-processing solution annealing (typically performed above 1000°C) is standard practice. This treatment successfully promotes the transformation of metastable ferrite into softer austenite and restores the protective passive film essential for corrosion resistance [2]. However, this restoration comes at a steep mechanical cost. As the material recovers and recrystallizes to relieve residual stress, the tensile strength drops often falling to 500–600 MPa in exchange for improved ductility. Consequently, current processing methods force a binary choice: the high strength of the as-printed state or the high ductility of the annealed state.

This study proposes a novel approach to bridge this trade-off by engineering a heterogeneous structured DSS. By optimizing 3D printing parameters to generate alternating layers of ferrite and austenite, we aim to retain structural strength while introducing necessary ductility without relying solely on strength-depleting annealing cycles.

To validate this methodology, a multi-faceted characterization strategy was employed. First, Scanning Electron Microscopy (SEM) was utilized to visualize the layer morphology and assess the structural integrity of the printed lattice. Following this, Electron Backscatter Diffraction (EBSD) was used to quantify the phase distribution, specifically verifying if the optimized scan strategy successfully increased the austenite volume fraction to the desired levels. Finally, the mechanical efficacy of this heterogeneous structure was tested through uniaxial tensile testing. Tensile testing increased due to the grain size difference between the alternating layers. Ferrite layer showed a coarse grain size distribution while the austenite layer showed a fine grain size distribution resulting in a more ductile DSS. The initial research demonstrated a processing route that achieves a superior balance of strength and ductility than traditional post-processing methods allow.

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