Design of modern structural materials for extreme environments /Journey from Brno to The Ohio State University and collaboration with NASA/

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Abstract

Our recent work (Nature 617, 513 (2023)) has introduced a new design strategy in the field of alloys for high-temperature applications. Enabled by additive manufacturing (AM), it combines oxide-dispersion-strengthening (ODS) and multi-principal element alloy (MPEA) concepts further opening up a vast unexplored compositional space to develop new 3D printable structural materials. One of new superior compositions, AM produced CrCoNi-based ODS-MPEA called GRX-810, exhibits extraordinary tensile strength, oxidation resistance and over 1000-fold better creep performance at temperature of 1093°C than the traditional polycrystalline wrought Ni-based alloys.

The present study investigates origins of the superior high-temperature capabilities of GRX-810 through identification and detailed characterization of all relevant microstructural features and their evolution during creep testing. For the first time, a state-of-the-art multi-scale, multi-modal approach was used based on various high-resolution characterization techniques. Detailed characteristics of oxide nanoparticle dispersoids were accurately quantified as well as the secondary phases both before and after creep testing. The evolution of the original hierarchical lattice defect substructures and the dislocation-dispersoid interactions was analyzed in detail and correlated with the macroscopic creep response. The extensive datasets obtained via comparative analyses are discussed in context of conventional strengthening models to understand the exceptional properties of GRX-810 alloy, and to provide guidelines for future design and optimization of 3D printable ODS alloys potentially enabling even higher temperature capabilities or specific service targeted performance abilities.