Microstructural Engineering of Nanocrystalline Metals for High Temperature Applications

Abstract: Systems that operate at high temperatures require materials that maintain their mechanical properties, specifically strength and creep resistance in these extreme environments. In this pursuit, careful mechanism-informed alloy and process design approaches are imperative. One class of alloys known for exceptional strength is nanocrystalline (NC) metals; however, due to their large volume fraction of grain boundaries, they are very susceptible to creep and are thermally unstable against grain growth. While thermal stability mechanisms have been researched extensively, holistic strategies that limit coarsening in complex alloys beyond model binary and ternary systems still remain unexplored. In this work, a Ni-11at%W-3at%Ta-2at%Y alloy was designed to be stabilized by grain boundary segregation, secondary phase pinning, and Ni(W,Ta) solid solution induced sluggish diffusion. Microstructure/property predictions were experimentally verified: the alloy was synthesized via high-energy mechanical alloying, annealed up to $0.7T_m$ for 100 hours, and characterized using advanced electron microscopy techniques. Our main observations were that yttria particles kinetically stabilized the alloy, and that high hardness was attributed to synergistic strengthening contributions from the Hall-Petch effect, Orowan looping of dislocations around yttria particles, the Ni(W,Ta) solid solution, and secondary phases.

Bio: Mari-Therese Burton is a 5th year PhD student in Materials Science and Engineering (MSE) at Lehigh University, advised by Prof. Martin Harmer and Prof. Helen Chan. She is a National Defense Science and Engineering Graduate Fellow, and her research focuses on alloy design and electron microscopy-based characterization of mechanically alloyed nanocrystalline metals. Throughout her undergraduate MSE studies at Carnegie Mellon University (B.S. 2019), she pursued research on magnetic high entropy alloys, advised by Prof. David Laughlin and Prof. Michael McHenry, and completed several metals-related summer internships, including two in R&D at Carpenter Technology (2018 and 2019). Mari-Therese currently serves as the Communications Chair for the Lehigh Valley Chapter of ASM and is a previous Student Representative to the Board of Trustees.