MATERIALS ENGINEERING SEMINAR

"Mesoscale Dislocation Plasticity in Inhomogeneous Alloys"

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ABSTRACT

The question of how the plastic strength of alloys depends on composition is critical to alloy design. Numerous classical works have tackled this question in the past. Yet, the models available to date primarily focus on the strength of alloys at the onset of yielding and seldom address the role of alloy composition in the hardening and dislocation microstructure evolution regime. The above question becomes even more important in situations in which the alloys are compositionally nonuniform at the mesoscale, as in spinodally decomposed alloys, irradiated alloys, high entropy alloys, and additive-manufactured alloys. In this work, the interaction between alloy plasticity and compositional inhomogeneity is addressed from a discrete dislocation dynamics (DDD) perspective. A framework comprising of three components: (1) analysis of the 3D composition morphology in inhomogeneous alloys with tendency to undergo spinodal/spinodal-like instability, (2) atomistic simulations of the dislocation mobility as a function of the local composition, and (3) dislocation dynamics simulations, has been utilized to understand the collective dynamics of dislocations and mesoscale plasticity in inhomogeneous alloys. Irradiated FeCrAl has been used as a model alloy for the implementation of the current framework and subsequent investigations. The investigation reveals that the composition inhomogeneity plays a crucial role in influencing microplasticity and macroscopic plasticity in inhomogeneous alloys. This happens due to the motion of dislocations taking place in a wavy fashion due to coherency stresses and locally varying dislocation velocities.

To further understand alloy microplasticity from a single dislocation perspective, Cahn's theory of hardening in compositionally modulated alloys based on coherency stresses has been modified to account for superposition of solid solution strengthening on hardening due to composition modulation. A new definition for the CRSS in compositionally modulated alloys is provided. This definition of CRSS is determined as a function of dislocation line direction, amplitude, and wavelength of the composition fluctuations.

Lastly, an application of the developed framework is demonstrated where plasticity in irradiated FeCrAl nanopillars is investigated using DDD, with a comparison to transmission electron microscopic in situ tensile tests of ion and neutron irradiated commercial FeCrAl C35M alloy.

Date: Thursday, July 20, 2023
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Place: ARMS 1021 or via this link: https://purdue.webex.com/join/aelazab

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