Materials Science and Engineering Department

Winter Seminar Series

A Screwy Theory on the Edge: Origins of High-Temperature Strength Retention in BCC High Entropy Alloys

Prof. William Curtin
Department of Materials Science and Engineering
Brown University

March 5, 2025
11AM-12PM | Hill Seminar Room (LeBow 240)

Refractory BCC High Entropy Alloys (HEAs) are multicomponent, high concentration, random alloys in the elemental family Cr-Hf-Mo-Nb-Ta-Ti-V-W-Zr. Alloys such as MoNbTaW and MoNbTaVW have exceptional retained strengths of 400-500 MPa up to the very high temperature of 1600C. The mechanistic origin of these outstanding properties has not yet been understood, in spite of extensive experimental studies of these and related alloys. Strengthening in BCC metals and dilute alloys has long been understood, and observed experimentally, to be entirely controlled by the motion of screw dislocations. Here, we present a parameter-free theory for the strength versus temperature of BCC HEAs based on the motion of edge dislocations through the random energy landscape created by the composition fluctuations in complex alloys. The heresy of claiming that edge dislocations control strength is supported by theory and simulation demonstrating that edge dislocations are immensely strengthened in complex alloys due to the large energy barriers, becoming competitive with screw motion. Predictions of the edge theory agree well with direct large-scale atomistic simulations for a range of model alloys and, moreover, with experiments on MoNbTaW and MoNbTaVW up to T=1600C and other alloys. Linear elasticity can reduce the edge theory to an analytic model with computable inputs that enables computationally-guided search and design for new alloys over millions of compositions. Combined with thermodynamic assessment and models for ductility, a number of attractive new compositions high-temperature alloys are identified.

Professor Curtin earned a 4 yr. ScB/ScM degree in Physics from Brown University in 1981 and a PhD in theoretical physics from Cornell University in 1986. He worked as staff researcher at British Petroleum until 1993 when he joined Virginia Tech. In 1998 he returned to Brown as Full Professor in the Solid Mechanics group, and was appointed Elisha Benjamin Andrews Professor in 2006. He joined Ecole Polytechnique Federale de Lausanne as the Director of the Institute of Mechanical Engineering in 2011 and officially as Full Professor in 2012. He retired from EPFL at the end of 2022 and rejoined Brown as Full Professor in 2023. His research successes include predictive theories of hydrogen storage in amorphous metals, strength and toughness of fiber composites, dynamic strain aging and ductility in lightweight Al and Mg metal alloys, solute strengthening of metal alloys including high entropy alloys, and hydrogen embrittlement of metals, along with innovative multiscale modeling methods to tackle many of these problems. Professor Curtin was a Guggenheim Fellow in 2005-06, was Editor-in-Chief of "Modeling and Simulation in Materials Science and Engineering" from 2006-2016, was the inaugural winner of the Distinguished Career Award from the Multiscale Mechanics Modeling community in 2022, and received the George Irwin Gold Medal from the International Conference on Fracture in 2023. He has published over 300 journal papers that have received over 30000 citations with an h-index of 93 (Google Scholar), and has been the Principal Investigator on over $36M of funded research projects.

DREXEL UNIVERSITY
College of Engineering

FOR MORE INFORMATION

Email: kn52@drexel.edu
drexel.edu/materials