MECHANICAL & MATERIAL COLLOQUIUM

Micromechanics of plastic deformation in high-temperature materials

by Giacomo Po (Department of Mechanical and Aerospace Engineering, University of Miami)

This talk examines the mechanisms of plastic deformation in three high-temperature materials: tungsten (W), zirconium (Zr), and a novel refractory dual-phase high-entropy alloy (HEA). Tungsten, a leading candidate for first-wall and divertor components in fusion energy systems, operates across a wide temperature range—from room temperature up to approximately 1000 °C. Within this regime, its plastic response changes dramatically due to thermally activated dislocation processes characteristic of body-centered cubic (bcc) metals. We investigate the deformation of W micropillars between 300 K and 900 K through combined *in situ* micropillar compression experiments and discrete dislocation dynamics (DDD) simulations. Results show that while the flow stress decreases with increasing temperature, stress fluctuations become more pronounced. Distinct statistical behaviors emerge at low and high temperatures, reflecting differences in dislocation source activation and propagation mechanisms. A DDD-based model is developed to rationalize these observations.

Zirconium, widely used in nuclear fission applications, exhibits a unique irradiation-induced “growth” phenomenon—an isochoric shape change occurring without applied stress. We explore its origin using a newly developed multiscale model coupling discrete dislocation dynamics with spatially resolved cluster dynamics simulations. Complementary micropillar compression tests on Zr single crystals reveal an unexpected inverse temperature dependence of flow stress, a behavior that also manifests in a Zr-containing dual-phase HEA. *In situ* micromechanical testing, supported by detailed TEM and APT characterization, elucidates the underlying mechanisms driving this unconventional deformation behavior.

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Dr. Giacomo Po is an Associate Professor in the Department of Mechanical and Aerospace Engineering at the University of Miami, which he joined in 2019. He earned his Ph.D. in Mechanical Engineering from the University of California, Los Angeles, where he specialized in defect micromechanics and the modeling of plastic deformation in crystalline materials. His current research integrates micromechanical modeling with *in situ* experiments to study plasticity and fracture in high-temperature metals and ceramics. Dr. Po’s work is supported by multiple federal agencies, including the NSF and DOE. He has received several prestigious awards, such as the *International Journal of Plasticity* Young Investigator Award, the Los Alamos National Laboratory Institute for Materials Science Distinguished Faculty Award, and the NSF CAREER Award.

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For questions or suggestions, contact Colloquium Organizers Dr. Jiuhua Chen (chenj@fiu.edu) or Dr. Pezhman Mardanpour (pmardanp@fiu.edu)