Nuclear Engineering Seminar

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Oak Ridge National Laboratory

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Going to Extremes: From Atomic Defects to Structural Performance in Nuclear Materials

Abstract

Radiation damage alters material microstructures and can profoundly degrade mechanical and other physical properties. Understanding how microstructures evolve under irradiation and how they govern material performance is therefore central to predicting operational lifetimes and enabling the design of radiation-tolerant materials for advanced nuclear reactors. This challenge is particularly urgent for fusion energy, whose commercial viability depends critically on the development of materials capable of surviving some of the most extreme environments—arguably one of the greatest challenges in the history of materials and nuclear engineering.

This seminar introduces the fundamental irradiation effects in nuclear materials and underscores their importance in the quest for materials capable of operating reliably in advanced fission and fusion reactor environments. We will discuss key scientific questions in irradiation effects, with particular emphasis on recent progress in microstructure-informed approaches to predicting mechanical performance. Emerging strategies for designing radiation-tolerant materials, including developments in nanostructured alloys and ultra-high-temperature ceramics for nuclear applications, will also be highlighted. The presentation will further examine advances in electron microscopy and the potential of integrating techniques such as 4D-STEM, weak-beam dark-field STEM, electron tomography, flash electropolishing, in-situ TEM, and AI/ML-assisted analysis to enable mechanistic insight through multiscale microstructural characterization.

Together, these advances point toward a future in which radiation effects evolve from a limiting constraint into a controllable design dimension, reshaping how materials are developed for the most demanding nuclear energy systems of the future.

Yan-Ru Lin is an R&D Scientist in the Radiation Effects and Microstructural Analysis Group (REMAG) at Oak Ridge National Laboratory and holds a joint faculty appointment with the Bredesen Center at the University of Tennessee. His research focuses on understanding radiation damage in nuclear materials under neutron and ion irradiation, with particular emphasis on advanced transmission electron microscopy techniques. Dr. Lin earned his Ph.D. in Materials Science and Engineering from the University of Tennessee, Knoxville. He also holds both a Master's and a Bachelor's degree in Nuclear Engineering from National Tsing Hua University, Taiwan.