PURDUE UNIVERSITY | School of Nuclear Engineering

Nuclear Engineering Seminar

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The Use of In-Situ Transmission Electron Microscopy to Characterize the Microstructure Evolution Under Irradiation

Abstract

Structural alloys used in nuclear reactors are subject to a harsh environment comprised of irradiation, mechanical stress, high temperature and a corrosive medium. Understanding how these materials degrade under such harsh environment is crucial to (i) qualify newly developed materials for in-reactor use or (ii) to predict the lifetime of existing components. Since the changes in macroscopic properties find their roots in the changes in microstructure, characterizing the microstructure evolution is therefore key to understanding and mitigating the degradation of material properties. One of the difficulties of studying processes occurring in a system under external stimulus such as irradiation and/or mechanical stress is the lack of kinetics information, since usually samples are examined ex situ (e.g. after irradiation or after mechanical testing) so that only discrete snapshots of the process are available. Given the dynamic nature of the phenomena, direct in situ observation is often necessary to better understand the mechanisms, kinetics and driving forces of the processes involved. For this matter, using in situ Transmission Electron Microscopy (TEM) can be of great help. Indeed, the spatial resolution of the TEM makes it an invaluable tool in which one can continuously track the real-time response of the microstructure to external stimuli, which can help discover and quantify the fundamental rate-limiting microscopic processes and mechanisms governing the macroscopic properties. In this presentation, various examples will thus be given of how in-situ TEM can be used to answer material science questions for nuclear engineering applications. These examples will include (i) In-situ Ion-irradiation in the TEM for studying the basic mechanisms of irradiation-induced defects (a.k.a radiation damage) formation and evolution as a function of dose, dose rate, temperature in materials of interest such as steels, nanocrystalline metals, or oxide scales building on structural components of the reactor, and (ii) In-situ straining experiments in the TEM used to investigate deformation mechanisms such as dislocation dynamics in Ni-based alloys and the deformation induced martensitic transformation in 304 Stainless Steels.

Dr Kaoumi is an associate professor of Nuclear Engineering at North Carolina State University. His research topics are in the field of nuclear materials with an emphasis on development, characterization and testing of advanced alloys for structural and cladding applications in nuclear reactors (e.g. advanced F/M steels, nanostructured ODS steels, and high-temperature Ni-based alloys). His interest is to develop an understanding of microstructure-property relationships in these metallic systems, especially microstructure evolution under irradiation, high temperature, mechanical load and/or corrosion and how it can impact macroscopic properties which govern the materials' performance.