

**MATERIALS ENGINEERING
SEMINAR**

“Radiation Response and Mechanical Properties of FeCrAl Alloy”

**By Tianyi Sun
Purdue MSE PhD Dissertation
Advisor: Professor Xinghang Zhang**

ABSTRACT

Nuclear fission energy has developed for more than five decades and become one of the most important low-carbon energy forms. The extreme environment in the advanced reactors, including high operating temperature and high neutron radiation dose, raises new challenges for structural materials. To date, no materials are immune to radiation damage. Bombardment by energetic particles displaces atoms from their original sites, leaves various forms of defect aggregates after cascade, and degrades the properties of the irradiated materials. FeCrAl alloys, known for their excellent high-temperature oxidation resistance, were developed under the accident tolerant fuel program in hope to replace the Zr cladding alloys in future reactors. The radiation response and mechanical properties of FeCrAl alloy have attracted great attention. The objective of this thesis is two-fold. First, investigate the high temperature mechanical behaviors of coarse-grained FeCrAl alloys with and without irradiation from the perspective of small-scale testing. Second, develop a fine-grained FeCrAl alloy variant and evaluate its mechanical properties and radiation tolerance.

Critical resolved shear stress of pristine and proton irradiated CG FeCrAl alloy was quantified at elevated temperatures. $\{112\}\langle 111\rangle$ slip system exhibited higher irradiation induced hardening compared with the $\{110\}\langle 111\rangle$ slip system. Gradient FeCrAl alloy was fabricated through surface mechanical grinding treatment. *In situ* pillar compression tests revealed an excellent combination of strength and deformability of ultra-fine-grained (UFG) FeCrAl alloys. Activation energy for plastic deformation of nanolaminate (NL) FeCrAl alloy was determined through strain rate jump tests. *Ex situ* Fe-ion irradiation showed the interplay between dislocation loops and grain coarsening and their contributions to the mechanical properties of the irradiated UFG FeCrAl alloys. *In situ* Kr ion irradiation studies on the helium pre-injected NL FeCrAl and CG FeCrAl show that the helium induced swelling was effectively reduced in NL alloy due to their abundant grain boundaries serving as defect sinks. The findings in this thesis may provide innovative perspectives on the design and manufacture of novel FeCrAl alloys with outstanding mechanical properties and radiation tolerance.

Date: Monday, July 11, 2022

Time: 9:30am

Location: HAMP 2123 or via WebEx

<https://purdue.webex.com/purdue/j.php?MTID=maa2f5f6c11b707d2c75bdc5d84444d51>



School of Materials Engineering