

NRE/ME 4803 Special Topics Course: Nuclear Reactor Materials

Fall 2012

Catalog Description:	This course investigates the relationship between the structure and properties of materials used in nuclear reactors - specifically nuclear cladding and fuel under irradiation.	
Prerequisites	MSE 2001 or equivalent	
Textbook:	Gary Was "Fundamental Radiation Materials Science", Wiley, 3540494715	
References:	Don Olander "Fundamental Aspects of Nuclear reactor Fuel elements" Arthur Motta and Don Olander "Light Water Reactor Materials" - new book not yet published	
Instructor	Chaitanya S. Deo	
Goals	This course provides a background on the types of materials used in nuclear reactors and their response to neutron irradiation. Materials problems encountered in the operation of nuclear power reactors for energy production are discussed here. The objective of the course is to give nuclear engineering students a background in materials, so they understand the limitations put on reactor operations and reactor design by materials performance.	
Grading	Homework	30%
	Tests	70%

Topics Covered:**The Radiation Damage Event**

Neutron–Nucleus Interactions
 Interactions Between Ions and Atoms
 Interatomic Potentials
 Collision Kinematics
 Ionization Collisions
 Energy Loss Theory
 Range Calculations

The Displacement of Atoms

Elementary Displacement Theory
 Displacement Probability
 The Kinchin and Pease Model for Atom Displacements
 The Displacement Energy
 The Electron Energy Loss Limit .
 Energy Transfer Cross Sections
 Energy Loss by Electronic Excitation

Effects of Crystallinity
The Displacement Cross Section
Displacement Rates

The Damage Cascade

Displacement Mean Free Path
Primary Recoil Spectrum
Cascade Damage Energy and Cascade Volume
Stages of Cascade Development .
Behavior of Defects within the Cascade

Point Defect Formation and Diffusion

Properties of Irradiation-Induced Defects
Thermodynamics of Point Defect Formation
Diffusion of Point Defects
Correlated Diffusion
Diffusion in Multi-component Systems
Diffusion along High Diffusivity Paths

Radiation-Enhanced and Diffusion Defect Reaction Rate Theory

Point Defect Balance Equations
Radiation-Enhanced Diffusion
Defect Reactions
Reaction Rate-Controlled Processes
Diffusion-Limited Reactions
Defect–Grain Boundary Reactions

Examples of Materials in Nuclear reactors -Light water reactors and Gen IV designs

Oxide fuels - LWR
Zirconium Alloys LWR
Metal, Carbide and Nitride fuels Gen IV
Steel and other metallic alloys Gen IV

Phenomena encountered in nuclear reactors (pick 2-3 topics)

Voids and cavities in Solids
Fission Product Behavior
Water Chemistry and its Influence on Corrosion
Waterside Corrosion and Hydriding of Zr Cladding
Fuel Rod Failure Mechanisms
Phase Transformations under irradiation
Inter Granular Stress-Corrosion Cracking (IGSCC)
Irradiation Induced Mechanical Property Changes: Hardening and Embrittlement
Irradiation Creep and growth