NE 120: Nuclear Materials

Lecture: MWF 9:00-10:00 am PT, F 10:00 am – 11:00 am PT
https://berkeley.zoom.us/j/96693590209?pwd=dndBaVVEQjBWend6OFBXd3BOVVhoUT09.
Meeting number: 966 9359 0209
Passcode: 266482

Course Units: 4

Course Instructor: Peter Hosemann (peterh@berkeley.edu)
Office hours: Wednesdays 10:00 am - 11:00 am PT & by appointment

- Zoomlink: (same as lecture)

Graduate Student Instructor: Rasheed Auguste (auguste@berkeley.edu)
Office hours: Thursdays 11:00 am – 12:00 pm PT

- Zoomlink: https://berkeley.zoom.us/j/94413430945?pwd=UHV5U3ZuUVZOYUljeVF6WU1oMzBGZz09
- Meeting ID: 944 1343 0945
- Passcode: 210654

Catalog Description

- Effects of irradiation on the atomic and mechanical properties of materials in nuclear reactors. Fission product swelling and release; neutron damage to structural alloys; fabrication and properties of uranium dioxide fuel.

Course Prerequisites

- Introductory course on properties of materials (Engin. 45)
- Upper division course in thermodynamics (Engin. 115, ME 105, or ChemE 141)

Prerequisite knowledge and/or skills

- Mathematics up to ordinary and partial differential equations
- Basic thermodynamics, including chemical equilibrium and equations of state of gases
- Knowledge of simple crystal structures
- Basic mechanisms of the interaction of high-energy particles with solids
- Basic concepts of the elastic and plastic behavior of materials
- Behavior of neutrons in light-water reactors

Textbook(s) and/or other reference material

- This class draws from multiple textbooks (listed below) for different chapters. All necessary information is also in the slides and the reader! All students are encouraged to take notes during lecture.

Materials Science Basics

    - Callister, **Materials Science and Engineering**
    - Gottstein, **Physical Foundations of Materials Science**
- Nuclear Materials
    - D. R. Olander, **Fundamental Aspects of Nuclear Reactor Fuel Elements**, TID-26711-P1, National Technical Information Services (1976)
    - Murty, **An Introduction to Nuclear Materials: Fundamentals and Applications**
    - G.S.Was, **Fundamentals of Radiation Materials Science - Metals and Alloys**
- This course contains significant contributions from: B. Wirth, G.R. Odette and G.E. Lucas (UCSB) and D.R. Olander (UCB)

Course Objectives

- Review those aspects of fundamental solid state physics that are pertinent to understanding the effects of radiation on crystalline solids
- Show how radiation, particularly by fast neutrons, affects the mechanical properties of fuel, cladding, and structural materials in a reactor core.
- Explain quantitatively the production of damage, fission products, and cavities in a fuel rod in a fuel pellet
- Give an understanding of the behavior of fission products in ceramic fuel, how they are formed, how they migrate, and how they affect properties of the fuel
- Develop an understanding of failure mechanism in materials and their impact in nuclear technology

Course Outcomes

- Solve steady heat diffusion problems beginning from Fick's law; understand how the diffusion coefficient is related to the mobility of atoms in the crystalline lattice.
- Deal with point defects in solids; how they are produced at thermal equilibrium and by neutron irradiation; how they agglomerate to form voids in metals or grow gas bubbles in the fuel. Kinchin-Pease model.
- Analyze the processes of fission gas release and swelling of reactor fuel.
- Understand how the grain structure of ceramic UO2 influences properties such as creep rate and fission product release.
- Understand the concept and quantitative properties of dislocations, and how irradiation-produced point defects influences their motion and change material properties.
- Know the principal effects of radiation on metals: the "black dot" structure, dislocation loops, voids, precipitates, and helium bubbles.

Topics covered

1. Introduction
2. Crystal structure and defects
3. Thermodynamics
4. Diffusion
5. Mechanical properties
6. Collision cascades and radiation damage

7. Fuel behavior
8. Reactor pressure vessels
9. Neutron damage and introduction to corrosion
10. Introduction to fusion materials

Class schedule

- Three 50-minute lectures per week; one office hour per week held by the graduate student instructor and one per week by the instructor. In addition, there is a discussion section once a week.

Contribution of course to meeting the professional component

- This course contributes primarily to the students' knowledge of engineering topics, and does provide design experience.
- Materials problems ultimately limit the performance and safety of fission power plants, particularly with the current industry emphasis on extended burn up and "hot" PWR operation. NE 120 is required for students in the General Nuclear Engineering area of emphasis in the three-part division of the Department's curriculum. This course illustrates, through specific examples, the materials performance of nuclear fuels and structures, with particular emphasis on light water reactors. Design-related features of the course include the calculations of fuel-rod temperature distributions, evolution of mechanical properties under irradiation, and the behavior of fission gases on fuel performance.

Relationship of course to undergraduate degree program objectives

- This course primarily serves students in the department and interested nuclear engineering, material science, and/or mechanical engineering students. The information below describes how the course contributes to the undergraduate program objectives.
- This course contributes to the reactor-engineering component of the Department's program objectives by providing education in the important sub discipline of nuclear materials. It prepares students for work in the materials-related groups in nuclear utilities and reactor vendors, as well as providing them with a solid background should they wish to pursue graduate work in the nuclear materials area.

Assessment of student progress toward course objectives

- Problem sets (five or six in the semester): 20%
- One midterm exam: 20%
- Virtual Laboratory Project: 20%
    - For 220M ONLY: 30% - Additional chapter on: How is the material made?
- Final exam: 40%
    - For 220M ONLY: 30% - Reduced questions

Additional Course Policies

Inclusion:

I am committed to creating a learning environment welcoming of all students that supports a diversity of thoughts, perspectives and experiences, and respects your identities and backgrounds (including race/ethnicity, nationality, gender, class, sexual orientation, gender identity, religion, ability, etc.) To help accomplish this:

- If you have a name and/or set of pronouns that differ from those that appear in your official records, please let me know.
- If you feel like your performance in the class is being impacted by your experiences outside of class (e.g., family matters, current events), please don't hesitate to come and talk with me. I want to be a resource for you.
- I (like many people) am still in the process of learning about diverse perspectives and identities. If something was said in class (by anyone) that made you feel uncomfortable, please talk to me about it.
- As a participant in this class, please strive to respect the diversity of your classmates.

Berkeley honor code:
Everyone in this class is expected to adhere to this code: "As a member of the UC Berkeley community, I act with honesty, integrity, and respect for others."

Academic honesty:
You are encouraged to form study groups and work together to understand course material, but all written work as well as responses to in-class questions should be your own. You may not copy other students' work. Academic integrity and ethical conduct are of utmost importance in the College of Engineering and at U.C. Berkeley.

Accommodation policy:
If you need religious or disability-related accommodations in this class, if you have emergency medical information you wish to share with me, or if you need special arrangements in case the building must be evacuated, please inform me immediately. Please see me privately after class or during office hours.

Land acknowledgement:
We recognize that in 1868, UC Berkeley was established on Huichin Ohlone land.

Resources

Center for Access to Engineering Excellence (CAEE)
The Center for Access to Engineering Excellence (227 Bechtel Engineering Center; https://engineering.berkeley.edu/student-services/academic-support) is an inclusive center that offers study spaces, nutritious snacks, and tutoring in >50 courses for Berkeley engineers and other majors across campus. The Center also offers a wide range of professional development, leadership, and wellness programs, and loans iclickers, laptops, and professional attire for interviews.

Disabled Students' Program (DSP)

The Disabled Student's Program (260 César Chávez Student Center #4250; 510-642-0518;
http://dsp.berkeley.edu) serves students with disabilities of all kinds. Services are individually designed and based on the specific needs of each student as identified by DSP's Specialists.

Counseling and Psychological Services
The main University Health Services Counseling and Psychological Services staff is located at the Tang Center (http://uhs.berkeley.edu/; 2222 Bancroft Way; 642-9494) and provides confidential assistance to students managing problems that can emerge from illness such as financial, academic, legal, family concerns, and more.

To improve access for engineering students, a licensed psychologist from the Tang Center also holds walk-in appointments for confidential counseling in 241 Bechtel Engineering Center (check here for schedule: https://engineering.berkeley.edu/student-services/advising-counseling).

The Care Line (PATH to Care Center)
The Care Line (510-643-2005; https://care.berkeley.edu/care-line/) is a 24/7, confidential, free, campus-based resource for urgent support around sexual assault, sexual harassment, interpersonal violence, stalking, and invasion of sexual privacy. The Care Line will connect you with a confidential advocate for trauma-informed crisis support including time-sensitive information, securing urgent safety resources, and accompaniment to medical care or reporting.

Ombudsperson for Students
The Ombudsperson for Students (102 Sproul Hall; 642-5754;
http://students.berkeley.edu/Ombuds) provides a confidential service for students involved in a University-related problem (academic or administrative), acting as a neutral complaint resolver and not as an advocate for any of the parties involved in a dispute. The Ombudsman can provide information on policies and procedures affecting students, facilitate students' contact with services able to assist in resolving the problem, and assist students in complaints concerning improper application of University policies or procedures. All matters referred to this office are held in strict confidence. The only exceptions, at the sole discretion of the Ombudsman, are cases where there appears to be imminent threat of serious harm.

Classroom Guidelines

The purpose of these guidelines is to create an inclusive, participatory learning environment where there is safety to self-disclose, to discuss potentially charged issues, and where individuals can share their perspectives and take risks. Guidelines can be revisited at any time.

1. Use active listening and communicate respectfully, openly and honestly.

- One diva, one mic—one person at a time; don't interrupt

- Step up, step back—allow many people to talk rather than just a few
- Use “I” statements; speak from your own experience
- Be supportive through body language
- Acknowledge and understand the other side, e.g., “this is what I’m hearing, is this correct? I feel...”
- No personal attacks or put-down

2. Suspend judgment and avoid generalizations.

- Assume positive intent
- Test assumptions and inferences
- Not to be judged for making mistakes, e.g., grammar and coherence because of language issues
- Be aware of own biases/prejudices

3. Be mindful of the diversity of perspectives, communication and learning styles.

- Be considerate of diversity and the language you use. Be sensitive to dimensions of diversity
- Be open to different ideas, it’s important as to how an idea is received
- It’s okay to disagree
- When disagreeing choose words carefully and try to suspend judgment. Don’t judge yourself too harshly. Distinguish between fact and opinion
- Be patient; acknowledge style of quieter students (more time to formulate) and needs of non-English speakers

4. Support, encourage and engage each other.

- Show support for classmates; if someone needs help, offer. Promote an atmosphere of mutual learning (focus less on grades)
- Make sure you do your share of group work. Put in effort, ask for help as needed, check in with other group members if you have doubts
- Be accepting—encourage people to be open and honest. If someone criticizes a particular point, he/she should use an argument to underline the idea
    - Initiate activities that encourage socializing online safely with others so we get to know each other
    - Be willing to give and receive feedback to support each other’s growth

5. Hold yourself accountable.

- Be wary of distracting others; turn your cell phone off, limit use of computers; if you’re going to leave early—sit accordingly; if late, don’t disrupt class
- Acknowledge self-censoring and fear of judgment

6. Focus on interests, not positions.

- Use “and/both” thinking instead of “either/or”
- Ask questions to clarify points

7. Agree to confidentiality.

- We can share WHAT we learned but not WHO said what

- Class lectures and recordings are the intellectual property of the instructor. Recordings and similar, especially without the instructor's knowledge, for other purposes other studying this material by the student attending the class is now allowed.

8. Respect everyone's time and space.

- We will start the class on time (9:00) and end on time. The first 10 minutes are intended for review, and open questions not to introduce new material.