Advanced Reactor Materials and Materials Performance

NE 795-010

Fall 2021

Tues./Thurs. 11:45AM-1:00PM

3108 Burlington

1. **Instructor**

Dr. Benjamin Beeler

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Office Hours: Wed. 10-11 am

1. **Course Overview**

In this course we will study the behavior of nuclear materials in advanced reactor environments. Students will be introduced to different advanced reactor systems and the materials that are either currently deployed, or plan to be deployed, within those reactors. Specific material phenomena and material evolution will be particularly emphasized, including, but not limited to: fission gas swelling, constituent redistribution, fission product attack, fission gas bubble superlattice, recrystallization, actinide salt chemistry, and radiation damage accumulation. A particular emphasis will be placed upon advanced fuel forms; however, this course will also address advanced cladding and coolant systems.

1. **Learning Outcomes**

By the end of this course, the student should be able to:

1. Identify key phenomena affecting the performance of advanced reactor materials
2. Understand the different stages of microstructural evolution in advanced reactor materials
3. Understand the role of reactor environment on material selection
4. Identify key areas delineating light water reactor and advanced reactor material evolution
5. **Pre- or Co-Requisites**

NE 509

1. **Required Text(s)**

None.

Supplemental texts:

Comprehensive Nuclear Materials, R. Konings

Light Water Reactor Materials, Vol. 1 Fundamentals, D. Olander and A. Motta

Fundamentals of Radiation Materials Science, G. Was

An Introduction to Nuclear Materials, K. Murty and I. Charit

1. **Course Requirements**

Examinations: 4 Quizzes: 12.5% each

Projects: Presentation 1: 15 %; Presentation 2: 15 %; Final presentation report 3: 20 %;

1. **Topical Outline:** 
   1. Introduction and Overview
   2. Advanced reactor systems and advanced fuel types
   3. TRISO particles
      1. CO production
      2. Fission gas release and fission product attack
      3. IPyC, OPyC and SiC stress state and fracture
   4. U-Zr (U-Pu-Zr) metallic fuel
      1. Fission gas swelling and release
      2. Constituent redistribution
      3. FCCI
      4. Alpha tearing
   5. Molten salts
      1. Coolant and Fuel Salts
      2. Thermophysical properties and phase diagrams
      3. Corrosion of structural components
   6. U-Mo and U-Si
      1. Monolithic and Dispersion Fuels
      2. Fission Gas superlattice
      3. Recrystallization, grain refinement and amorphization
   7. Advanced Reactor Cladding
      1. ODS
      2. Ferritic-Martensitic Steels
      3. SiC
      4. Concentrated Solid Solution Alloys
   8. Alternate Reactor Concepts
      1. Super critical water reactor
      2. Lead cooled reactor
      3. Micro-Reactors and Small Modular Reactors
   9. (Optional Sub-Topic) Density Functional Theory applied to Nuclear Fuels
2. **Grading**

Letter Grade Percent Grade

A+ 98-100; A 93-97; A- 90-92; B+ 87-89; B 83-87; B- 80-82; C+ 77-79; C 73-76; C- 70-72; D+ 67-69; D 63-66; D- 60-62; F Below 60

1. **COVID-19**

Due to the COVID-19 pandemic, public health measures continue to be implemented across campus.  Students should stay current with these practices and expectations through the [Protect the Pack](https://www.ncsu.edu/coronavirus/) website (<https://www.ncsu.edu/coronavirus/>). The sections below provide expectations and conduct related to COVID-19 issues.

**Health and Participation in Class**

We are most concerned about your health and the health of your classmates and instructors/TAs.

* If you test positive for COVID-19, or are told by a healthcare provider that you are presumed positive for the virus,  you should not attend any hybrid or face-to-face (F2F) classes and work with your instructor on any adjustments necessary; also follow other university guidelines, including self-reporting ([Coronavirus Self Reporting](https://healthypack.dasa.ncsu.edu/coronavirus/)):  Self-reporting is not only to help provide support to you, but also to assist in contact tracing for containing the spread of the virus.
* If you feel unwell, even if you have not been knowingly exposed to COVID-19, please do not come to a F2F class or activity.
* If you are in quarantine, have been notified that you may have been exposed to COVID-19, or have a personal or family situation related to COVID-19 that prevents you from attending this course in person (or synchronously), please connect with your instructor to make alternative plans, as necessary.
* If you need to make a request for an academic consideration related to COVID-19, such as a discussion about possible options for remote learning, please talk with your instructor.

**Health and Well-Being Resources**

These are difficult times, and academic and personal stress are natural results. Everyone is encouraged to [take care of themselves](https://counseling.dasa.ncsu.edu/resources/self-help-resources/self-care/) and their peers. If you need additional support, there are many resources on campus to help you:

* Counseling Center ([NCSU Counseling Center](https://counseling.dasa.ncsu.edu/))
* Student Health Services ([Health Services | Student](https://healthypack.dasa.ncsu.edu/))
* If the personal behavior of a classmate concerns or worries you, either for the classmate’s well-being or yours, we encourage you to report this behavior to the NC State CARES team:  ([Share a Concern](https://cm.maxient.com/reportingform.php?NCStateUniv&layout_id=2)).
* If you or someone you know are experiencing food, housing or financial insecurity, please see the Pack Essentials Program ([Pack Essentials](https://dasa.ncsu.edu/pack-essentials/)).

**Community Standards related to COVID-19**

We are all responsible for protecting ourselves and our community.  Please see the [community standards](https://www.ncsu.edu/coronavirus/reactivating-campus/community-standards/?utm_source=ALL+STAFF%2FFACULTY%2FSTUDENTS+-+UCOMM&utm_campaign=0d221175c9-EMAIL_CAMPAIGN_72820_Community_Standards&utm_medium=email&utm_term=0_e7a0fd0c9f-0d221175c9-92460566) (which have been updated for 2021) and Rule 04.21.01 regarding Personal Safety Requirements Related to COVID-19  [RUL 04.21.01 – Personal Safety Requirements Related to COVID-19 – Policies, Regulations & Rules](https://policies.ncsu.edu/rule/rul-04-21-01/)

**Course Expectations Related to COVID-19**:

* **Face Coverings:** All members of the NC State academic community are expected to follow all university policies and guidelines, including the [Personal Safety Rule](https://policies.ncsu.edu/rule/rul-04-21-01/) and [community standards](https://www.ncsu.edu/coronavirus/reactivating-campus/community-standards/?utm_source=ALL+STAFF%2FFACULTY%2FSTUDENTS+-+UCOMM&utm_campaign=0d221175c9-EMAIL_CAMPAIGN_72820_Community_Standards&utm_medium=email&utm_term=0_e7a0fd0c9f-0d221175c9-92460566), for the use of face coverings.  Face coverings are required in instructional spaces. Face coverings should be worn to cover the nose and mouth and be close fitting to the face with minimal gaps on the sides.
* **Course Attendance**: NC State attendance policies can be found at:  [REG 02.20.03 – Attendance Regulations – Policies, Regulations & Rules](https://policies.ncsu.edu/regulation/reg-02-20-03-attendance-regulations/).  Please refer to the course’s attendance, absence, and deadline policies for additional details. If you are quarantined or otherwise need to miss class because you have been advised that you may have been exposed to COVID-19, you should not be penalized regarding attendance or class participation. However, you will be expected to develop a plan to keep up with your coursework during any such absences.  If you become ill with COVID-19, you should follow the steps outlined in the health and participation section above. COVID 19-related absences will be considered excused; documentation need only involve communication with your instructor.
* **Technology Requirements:** This course may require particular technologies to complete coursework.  Be sure to review the syllabus for these expectations, and see the [syllabus technical requirements](https://go.ncsu.edu/syllabus-tech-requirements) for your course. If you need access to additional technological support, please contact  the Libraries’ Technology Lending Service:  ([Technology Lending](https://www.lib.ncsu.edu/devices)).

**Course Delivery Changes Related to COVID-19**

Please be aware that the situation regarding COVID-19 is frequently changing, and the delivery mode of this course could change accordingly, including from in-person to remote.  Regardless of the delivery method, we will strive to provide a high-quality learning experience.

**NO LONGER AVAILABLE - Grading/Scheduling Changing Options Related to COVID-19**

Two policies, (1) enhanced S/U Grading Option, and (2) Late Course Drops, were put in place at the beginning of the COVID-19 pandemic to ease student stress and promote course completion. Those two policies ***have been discontinued*** and thus are no longer available to students.

For situations where relief may be needed, and depending on the details, students should explore the applicability of an “incomplete” grade in the course. If you are experiencing difficult or extenuating circumstances, you should discuss possible options with your instructor and your academic advisor.