MTEN 610 – Foundations of Materials Science and Engineering

Instructor: Dr. Mengqiang (Mark) Zhao
- email: mz24@njit.edu
- office: York 326

Teaching Assistant: Dheeban Govindan, email: dg576@njit.edu

Date, Time, and Location: Thursdays, 6 to 8:50 pm, Faculty Memorial Hall (FMH) 305

Textbook and Materials: Required: *Fundamentals of Materials Science and Engineering: An Integrated Approach*, 6th Edition (or later), W.D. Callister, Jr., and D.G. Rethwisch, John Wiley and Sons.

This will also be supplemented with material from other textbooks and peer-reviewed literature. These books are not required, and any supplemental material will be provided to you. Additional material will primarily come from:

Optional: *Materials Engineering: Bonding, Structure, and Structure-Property Relationships* – Susan Trolier-McKinstry, Robert E. Newnham

The VESTA crystal structure visualization software will be used during this class; a tutorial will be posted on Canvas. Please let Prof. Zhao know if you have issues with it. It can be downloaded for Windows, Mac, and Linux OS here: https://jp-minerals.org/vesta/en/download.html

Office Hours: Wednesdays, 9:30 to 11:30 am via Webex (or in-person by appointment)

Course Overview: This is an introductory course for graduate students interested in Materials Engineering. This course will introduce materials from an atomistic point of view and describe the relationship between their underlying structure and properties. We will first cover chemical bonding and crystal structure, and how this results in differences between families of materials (metals, ceramics, and polymers). We will then discuss phase transformations and use phase diagrams to describe the compositions and microstructure of solid solutions and discuss the thermodynamics of solid-state phase transitions. Finally, we will discuss important properties of materials (electronic, magnetic, optical, and thermal), how they are measured, how they arise, how they are influenced by crystal structure, and how the appropriate properties and materials are selected and used in various modern engineering applications.

Prerequisites: graduate standing

Course Objectives: During this course, students will:

(1) analyze the fundamental link between materials' atomistic structure, processing, and properties
(2) represent the crystal structures of materials using crystallographic points, directions, and planes
(3) understand the differences between families of materials (metals, ceramics, and polymers)
(4) utilize phase diagrams to describe transformations and microstructure of solid solutions

(5) predict elastic and plastic behavior and failure using fundamental relationships between stress and strain
(6) calculate and understand the origin of electrical, thermal, magnetic, and optical properties of materials
(7) understand how these are applied in modern areas of materials engineering research
(8) read and analyze modern scientific papers regarding recent materials engineering developments
(9) write a report and give an oral presentation detailing materials issues facing a specific area of engineering

Delivery Mode: This course will be delivered face-to-face. The MTEN 610 Canvas page will be the primary hub for class information. All homework, lecture notes, final paper and presentation details, and correspondence will take place through it.

Attendance Policy: Attendance is required at all classes; absences should be discussed with Prof. Zhao.

Academic Integrity: Academic Integrity is the cornerstone of higher education and is central to the ideals of this course and the university. Cheating is strictly prohibited and devalues the degree that you are working on. As a member of the NJIT community, it is your responsibility to protect your educational investment by knowing and following the academic code of integrity policy that is found at: http://www5.njit.edu/policies/sites/policies/files/academic-integrity-code.pdf.

Please note that it is my professional obligation and responsibility to report any academic misconduct to the Dean of Students Office. Any student found in violation of the code by cheating, plagiarizing or using any online software inappropriately will result in disciplinary action. This may include a failing grade of F, and/or suspension or dismissal from the university. If you have any questions about the code of Academic Integrity, please contact the Dean of Students Office at dos@njit.edu.

Grading: The final grade for the course is divided as follows:

- Homework Problem Sets = 25% of grade
- Attendance and Class Discussion = 10% of grade
- Midterm Report = 15% of grade
- Final Written Report = 25% of grade
- Final Presentation = 25% of grade

Grades will be assigned with the following rubric:

90% and above	A
85-89%	B+
80-84%	B
75-79%	C+
70-74%	C
60-69%	D
Below 60%	F

Homework:
- Students will be assigned 10 homework sets of exercises, each equally weighted. The homeworks will contain different types of problems.
- **In the problem sets you will practice calculations of material properties, analyze materials crystal structures in VESTA, use scientific modeling software, and read academic-level scientific articles.**
- Homework sets should be turned in by uploading an electronically formatted *or* legibly handwritten and scanned document to Canvas *before* class begins. Homework turned in after 6 pm on the due date will be automatically reduced by 10%, with an additional 10% reduction per day late. *You should begin problem sets early.*
- Working with your peers on the homework is allowed and encouraged. You should acknowledge your collaborators when submitting your assignments. Each student must provide their own solutions to problems and submit their own assignment, with their own written answers to the questions. It is not acceptable (and a violation of course policies) to use the same written answers as your collaborators.

Class Discussion:
- Often part of the homework will be to read a scientific article; we will discuss these articles in more detail in each class and how they related to the topics under study.
- Throughout the semester, your input to these discussions is expected.

Class Project:
- The class project makes up the bulk of the grade for this class and is intended to help bridge the gap between what is expected at undergraduate versus graduate level.
- **For this project, you will select a scientific or engineering application and compose a literature review detailing the materials used for it.**
- This will involve determining the properties required for the application, what materials were used in the past and why, what materials constitute cutting edge technology in this area, and how these improvements were made.
- This is an individual project.

The project consists of three parts:

1. Midterm Report: The first part is to (1) decide on a topic, (2) justify the choice, (3) describe why it is important, and (4) do a cursory background literature review. During week 6, you will receive details about the report and a list of potential topics; you do not have to choose a topic from the list, but it would be best to discuss the topic beforehand with Prof. Zhao. The midterm report is a minimum of 5 pages (not including references). The report should cover the 4 topics listed above.

2. Final Report: The final report is an extension of the midterm report. It is a minimum of 15 pages (not including references). In addition to the points listed above, the final report should detail (1) what material properties are needed for the application, (2) state-of-the-art materials used in the application, and (3) why these materials are used (in terms of crystal structure, properties, etc.).

3. Final Presentation: The final presentation will be 15 minutes to the class describing your selected topics and your findings. The presentation will be in the style of a Materials Research Society meeting, with 12 minutes for the presentation and 3 minutes for questions.

- A rubric for each part will be provided to you before the assignments are due. Both reports will be graded not only on content, but also style, clarity, organization, and formatting. The presentation will be graded on content, organization, time, and question answering.

Schedule of Topics:

Week	Topics	Assignment
1 – Sep. 5 2024	- Course Objectives - Introduction to Materials Engineering - Atomic Structure and Bonding	Download VESTA
2 – Sep. 12, 2024	- Atomic Structure and Bonding - Crystal Structure Basics	HW1 assigned
3 – Sep. 19, 2024	- Advanced Crystal Structure Topics - Symmetry and Tensor Properties	HW1 due HW2 assigned
4 – Sep. 26, 2024	- Metals and Ceramics - Electronic Structure (band gaps, etc.) - Defects	HW2 due HW3 assigned
5 – Oct. 3, 2024	- Polymers - Diffusion - Midterm report details and project topics	HW3 due HW4 assigned
6 – Oct. 10, 2024	- Phase Transformations I: Phase Diagrams and Microstructure	HW4 due
7 – Oct. 17, 2024	- Phase Transformations II: Solidification, Nucleation and Growth	Midterm Report due HW5 assigned
8 – Oct. 24, 2024	- Mechanical Properties - Dislocations - Failure	HW5 due HW6 assigned
9 – Oct. 31, 2024	- Electronic Properties - Electronic Devices	HW6 due HW7 assigned
10 – Nov. 7, 2024	- Magnetic Properties	HW7 due HW8 assigned
11 – Nov. 14, 2024	- Optical Properties	HW8 due HW9 assigned
12 – Nov. 21, 2024	- Thermal Properties - Corrosion and Degradation of Materials	HW 9 due HW10 assigned
13 – Nov. 26, 2024 (Thursday Classes Meet)	- Modern materials engineering research areas - Guest presentations	HW 10 due
14 – Dec. 5, 2024	**FINAL PRESENTATIONS**	
15 – Dec. 12, 2024	**NO CLASS**	
16 – Dec. 19, 2024	**FINAL EXAM WEEK**	Final Report due