MSE 1063: Phase Transformations and Microstructure Evolution

Course Syllabus – spring 2024

Catalog Description

MSE 1063: Phase Transformations and Microstructure Evolution is a 3-credit course intended for third-year undergraduate students majored in Materials Science and Engineering. This course delivers overall perspectives of phase transition and microstructural development in metals and alloys, rooting in the basis of phase equilibrium, reaction kinetics, atomic diffusion, and grain boundary migration. Upon completion of this course, it is expected that students can develop a microscopic understanding of how materials' crystal structures and their associated macroscopic mechanical properties evolve under stresses, such as thermal annealing, cooling and etc.

Course Instructor

Dr. Jue Gong, jue.gong@scupi.cn

Office hours: Monday 10:00 am – 12:00 pm, Tuesday 02:30-04:30 pm

Office

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Email

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Prerequisites

MSE 1053 – Structure of Crystals and Diffraction

MSE 1059 – Phase Equilibria in Multi-Component Materials

Course Objectives

This course aims to convey fundamental physical principles that regulate phase transition and microstructural properties of metallic materials. After learning the course, students are expected to demonstrate knowledge in explaining alloy phase formation, crystalline-amorphous-crystalline transitions as based on thermodynamic and mathematical standpoints. Finally, setting out from the conventional metals and alloys, students should also be able to compare and contrast metals with polymers, composites, novel semiconductors for energy applications (organic-inorganic hybrids, metal-organic frameworks, thermoelectric semimetals, etc.) in terms of their phase transformation profiles and similarity/difference in microstructural evolutions.

Learning Outcomes for this Course

1) To understand the physical origins of phase transition and microstructural change of metals.

2) To explicate the phase equilibrium, energy change, nucleation, interface formation, atomic diffusion using mathematical calculations.

3) To illustrate property difference between crystalline and amorphous metals, along with their corresponding applications.

4) To account for the similarity and difference between metals and non-metallic materials (polymers, biomaterials, semiconductors) regarding their detailed phase transformation profiles and morphological feature evolutions.

Lecture Schedule

Thursday: 13:50-16:25 pm, room: Zone 4-204

Textbook

David A. Porter, Kenneth E. Easterling, Mohamed Y. Sherif, Phase Transformations in Metals and Alloys, 4th Edition, CRC Press, November 2021. ISBN: 978-0-367-43034-4.

Teaching Assistant

Yinning Zhu: 2020141520019@stu.scu.edu.cn

Grading

Total score of the course grading is 100 points.

Homework: 20%

Class attendance: 5%

Midterm exam: 35%

Final exam: 40%

Exams

There will be two examinations of this course—midterm and final, which are to be tentatively scheduled on 04/22 (Monday) and 07/01 (Monday) of the spring semester, respectively. Exams are close-book, comprising questions including single-choice, Q&A, and mathematical calculation as the formats. A calculator and a double-side equation sheet are allowed for each student. Each exam weighs 30% of the course grade. Students are thus strongly suggested to study and prepare for the exams properly ahead of taking the tests.

Grading Rebuttal

If you disagree with the grading or to dispute wrongful errors made in the grading of an assignment, please bring it to the attention of TA within one week of receiving the assignment back for resolution.

Homework

Homework is based on problems after each chapter of the textbook, and will be posted on Blackboard system after the corresponding lecture. Homework score constitutes 10% of the class grading. Therefore, students are expected to submit after-class homework on time, within a week after the lecture, to avoid any deduction of credit. Collaboration with other students in the class is allowed. However, all rendered write-ups and papers must be individual works and any type of plagiarism will not be tolerated. If you have objection to the received score after getting your homework back, please notify the course teaching assistant. Please also take note of the following homework guidelines:

1) Your homework assignment must be completed in a Word format and submitted electronically through Blackboard system, with naming convention "Course#-name-student ID-Hw#". Handwritten assignments (or snapshots of handwritten works) will not be accepted.
2) Write your name, last four digits of student ID#, and class section# on top of the first page.
3) If you participate in collaboration with other students, please also put their names on the first page of the submitted homework.

Class Attendance

Attendance of lectures is mandatory as it constitutes 10% of the course's total grading. It is highly suggested that you come to class prepared, which includes reviewing last lecture's content, previewing lecture's content, reading online handouts, and going through potential problems, so as to enhance learning efficacy.

Make-up Policy

If you are retaking the course, TOEFL/IELTS test schedule, sick leave with justified approval, or other issues that make you miss homework, reports, and/or exams, please inform TA and course instructor at your earliest convenience.

Accommodations

If you sustain disability or sickness that requires testing and/or classroom accommodations, please notify the course instructor, TA, and the university's Disability Resources and Services in time. You may be asked to present proof of disability or sickness to be provided the accessibility accommodations.

Academic Integrity

Plagiarism of any forms that include copying peers' works, writings, literatures, and online references without appropriate paraphrasing or full citations, cheating within an exam, infringing copyrighted works or other improper conducts constitutes academic dishonesty. It is a requirement that every student performs independent and collaborations under the academic guidelines set forth by the SCUPI, Sichuan University, and University of Pittsburgh to ensure rightful learning performance.

Tentative Schedule of Course Contents

Sequence of sections covered in this class:

Week	Contents	Descriptions
1 (02/29)	1.1 – 1.3	Equilibrium, single-component systems, binary solutions
2 (03/07)	1.4 – 1.6	Equilibrium in heterogeneous systems, binary phase diagrams, influence of interfaces on equilibrium
3 (03/14)	1.7 – 1.10	Ternary equilibrium, kinetics of phase transitions, additional thermodynamic relationships for binary solutions
4 (03/21)	2.1 – 2.4	Atomic mechanisms of diffusion, interstitial diffusion, substitutional diffusion, atomic mobility
5 (03/28)	2.5 – 2.9	Tracer diffusion in binary alloys, diffusion in ternary alloys, high-diffusivity paths, diffusion in multi-phase binary systems
7 (04/11)	3.1 – 3.3	Interfacial free energy, solid/vapor interfaces, solid/liquid interfaces
8 (04/18)	3.4	Boundaries in single-phase solids (low-angle, high-angle, and special grain boundaries, grain boundary energy, equilibrium in polycrystalline materials, thermally activated migration of grain boundaries, kinetics of grain growth, etc.)
9 (04/25)	3.5 – 3.7	Interphase Interfaces in solids (fully, partly, incoherent, and complex partly coherent interfaces, interface migration, second-phase shape, coherency loss, etc.)
10 (05/02)	4.1 – 4.3	Nucleation in pure metals, growth of pure-phase solid, alloy solidification
11 (05/09)	4.4 – 4.6	Solidification macrostructures and microstructures, solidification of fusion welds, solidification during melt quenching
12 (05/16)	4.7 – 4.9	Glassy metals, case studies of practical castings and welds, etc.
13 (05/23)	5.1 – 5.4	Homogeneous nucleation in solids, heterogeneous nucleation, precipitate growth, overall transformation kinetics using TTT diagrams
14 (05/30)	5.5 – 5.8.2	Precipitation in age-hardening alloys, precipitation of ferrite from austenite, cellular precipitation, pearlite and bainite in Fe-C alloys and steels, etc.
15 (06/06)	5.8.3 – 5.12	Effect of alloying elements, continuous cooling diagrams, fibrous and interphase precipitation in alloy steels, massive and ordering transformations, etc.

16 (06/13)	6.1 – 6.4	Martensite in ferrous systems, ferrous martensite morphologies and crystallography, mechanical twinning in bcc metals, athermal nucleation and growth: FCC→HCP
17 (06/20)	6.5 – 6.7	Athermal nucleation and growth: FCC→BCC, thermally activated α'-martensite, carbon diffusion phenomena in ferrous martensites
18 (06/27)	6.8 – 6.11	Athermal nucleation and growth in ordered alloys, phenomenological theory of martensite crystallography, etc.