SCUPI
Sichuan University - Pittsburgh Institute

MSE1063: Phase Transformations and Evolution of Microstructure
Course Syllabus Spring 2023

Catalog Description

This course introduces the thermodynamics, kinetics, mechanisms and microstructure of solid-state phase transformations. Specific studies are directed towards diffusional transformations such as precipitation transformations in alloys, ferrite, pearlite and bainite transformations in steels. Martensitic transformations in steel and shape memory alloys are also included.

Phase equilibria and kinetic phenomena relevant to the origins and stability of microstructure in metallic, ceramic, and polymeric systems. Lecture topics include: application of thermodynamics to the understanding of stable and metastable phase equilibria; interfaces and their effects on stability; defects and diffusion; empirical rate equations for transformation kinetics; driving forces and kinetics of transformations; diffusional and diffusionless phase transformations.

This course will have a deeper discussion on thermodynamics, kinetics, mechanisms and microstructure of solid state phase transformations. Specific studies are directed towards diffusional transformations such as precipitation transformations in alloys, ferrite, pearlite and bainite transformations in steels. Martensitic transformations in steel and shape memory alloys are also included. (3 credits)

Schedule: Thursday 13:50 - 16:25PM @ Zone 3 - 102
Approx.17 weeks (Feb. 23 to June 15) for 2020 MSE seniors.

Instructor **Prof. Charles Hua** charleshua@scu.edu.cn
17760422493 (WeChat ID and Mobile), Room Zone 3 -322B

Teaching Assistant **Jinlu Han,** 2019141520102@stu.scu.edu.cn

When emailing the instructors or TA, include "MSE1063" in the subject field of your message. Use your university email account (student_ID_number@stu.scu.edu.cn); mail from other accounts might be stopped by the SCU spam filter.

Q/A Office Hours Thursday 9:00am-11:50am, Room Zone 3 -322B.
If you don't understand something, and talking to your classmates doesn't help, then you should be seeking help from the instructor or teaching assistant. Office hours are times we have specifically set aside to be available to students. During office hours, you can come to our office; you do not need an appointment. We are also available at other times by appointment.

Textbook

"Phase Transformations in Metals and Alloys", D.A. Porter, K.E. Easterling and M.Y. Sherif, 3rd Ed., CRC Press, Boca Raton, FL, 2009. ISBN 13: 978-1-4398-8357-0 (eBook)

Additional Reference book

“Steels – Microstructure and Properties”, H.K.D.H. Bhadeshia and R.W.K. Honeycombe, Butterworth-Heinemann, 2016, 4th Edition, ISBN: 978-0-08-100270-4.

Prerequisite and Co-requisite:

- You *must* have taken:
  - ENGR0022 Materials Structure and Properties
- You *should* have taken:
  - MSE 1053 – Crystal Structures and Diffraction
  - MSE1059 – Phase Equilibria
- It is assumed that the student has a basic working knowledge of:
  - **Phase diagrams:** reading and understanding the diagrams, identifying phases and eutectics, solubility and relative composition of phases
  - **Basic kinetics:** equilibrium cooling (i.e. through a phase boundary) and time-temperature-transformation diagrams
  - **Microstructure:** Phases, eutectics, lamellae, connection to phase diagrams and kinetics

If these terms are fuzzy to you, review your course notes. If they are totally unfamiliar, let me know and we can arrange additional make up.

Web Site https://pibb.scu.edu.cn/

There you will find the course syllabus, homework assignments, and other materials. Current announcements and assignments will be posted on the home page. All assignments will be uploaded through the Blackboard system. Please check the class page frequently.

Class Format

This course is taught using a combined lecture, reading, review and discussion format. The class in the afternoon begins with two session lecture to review material in the literature and introduce new concepts. In the third session, the lecturer may ask questions to as many students as possible and encouraging critical reading of published papers in related field.

It is imperative that you come to class prepared. This will generally involve reading all posted literature and viewing tutorial videos. This is a three-credit hour class, which means you should expect to devote at least 3 to 6 hours of effort outside the scheduled class time every week.

Homework Assignments

Homework problems will be assigned every two weeks and posted on Blackboard. These are to be completed and turned in by **Tuesday 1:30 PM** the following week. You may work with other people on homework, but all writeups must be individual efforts. Homework will be graded on a 0-100 point scale.

All work will be submitted electronically through the Blackboard system. Late homework will not be accepted.

Unless specifically requested, emailed homework will not be accepted.

Please adhere to these homework guidelines:

- Filename format Name-ID-HW#, for example: YZhu1234HW2
- Your assignment must be typeset using Word and submitted electronically through Blackboard. Handwritten assignments will not be accepted.
- Put your name, ID number (last four digits), and class section at the top of the first page.
- List the names of other people you've worked with on the assignment or report.

All of the homework scores will be used in your grade computation. Unless otherwise indicated, you can work with your fellow classmates in the class, but you must submit a distinct and independent write-up to receive credit.

If you're sick, or have a compelling emergency that prevents you from turning in the homework on time, email Prof. Charles Hua.

If you believe an error has been made in the grading of an assignment, bring it to the attention of your TA within ONE WEEK of its return.

Grading

Your grade will be based on the in-class Q/A (10%) and homework (30%), mid-term (30) and final exam (30%).

Course Goals

1. Obtain a sound understanding of the thermodynamic and kinetic factors affecting the origins and stability of microstructures.
2. An ability to predict the temporal and thermal stabilities of microstructure by applying the principles of kinetics and phase equilibria.
3. An ability to interpret and discuss the effects of compositional change and thermal history on the stability of microstructure and kinetics of phase transformations in material systems.
4. An ability to solve engineering-related materials problems involving kinetic phenomena and phase equilibria.

After this lecture session the students will be able to…

1. Phase equilibria in unary, binary and ternary systems (70%)
2. Departures from phase equilibria (70%)
3. Microstructure evolution during cooling or heating (70%)

4. Source and influence of interfacial energies (70%)
5. Diffusion in metals and ceramics (70%)
6. Diffusion-controlled phase transformations (70%)
7. Diffusionless phase transformations (70%)

Course topics and lecture hours devoted to each topic:

1. **Phase Equilibria (~12 hrs):** Thermodynamics of condensed systems and criteria for equilibrium; phase rule; Gibbs free-energy diagrams and their relation to binary and ternary phase equilibrium diagrams; departures from equilibrium.
2. **Interfaces (~9 hrs):** Thermodynamics of interfaces; grain boundary and interphase interfaces in solids; effects of interfacial energy on second-phase shape; effects of interfaces on phase stability; interface migration phenomena (*e.g.* recrystallization and grain growth).
3. **Defects and Diffusion (~9 hrs):** Phenomenological and atomistic treatments; interstitial and substitutional diffusion; Kirkendall effect; defects, defect reactions, and diffusion in ionic compounds; activation energies for diffusion; diffusion couples; boundary conditions and applied solutions to the diffusion equation.
4. **Phase Transformations (12 hrs):** Solidification: Homogeneous and heterogeneous Nucleation and growth; Hypo-eutectics and Eutectic alloy solidification; Scheil Equations; Diffusional transformations: Homogeneous and heterogeneous nucleation; kinetics of nucleation; effect of temperature on nucleation; spinodal decomposition; precipitate growth and coarsening; Johnson-Mehl-Avrami equation and transformation diagrams.

Contribution of course to meeting the requirements of criterion 5:

Engineering Science:	1.5 Credits
Engineering Design:	0.0 Credit
College Level Mathematics:	0 Credits
Basic Science:	1.5 Credits
Realistic Constraints:	none
Engineering Standards:	none

Mechanical Engineering and Materials Science Program outcomes addressed:

Item	How Addressed
a.	Not addressed
b.	Not addressed
c.	Not addressed.
d.	Not addressed.
e.	Not addressed.
f.	Not addressed.
g.	Not addressed.
h.	Not addressed.
i.	Not addressed.
j.	Not addressed.
k.	Not addressed.

Prepared by: Mingjian (Charles) Hua Feb. 14, 2019, Updated on Feb. 5, 2023