MSE1063: Phase Transformations and Evolution of Microstructure
Course Syllabus Spring 2022

Catalog Description

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 13:50pm - 16:25pm @ Zone 3 - 102
Approx. 17 weeks for MSE seniors.

Instructor **Prof. Hua charleshua@scu.edu.cn 17760422493(WeChat), Zone 3 -322B**
Teaching Assistant 罗伊雯 **Belle Luo**，2018141522067@stu.scu.edu.cn；15826068515

When emailing the instructor or TA, include "MSE1063" in the subject field of your message. Use your university email account (student_ID_number@stu.scu.edu.cn).

Office Hours Thursday morning 9-11:30am, **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 don't need an appointment. We are also available at other times - please email to schedule a time.

Textbook

"Phase Transformations in Metals and Alloys", D.A. Porter, K.E. Easterling and M.Y. Sherif, 3rd Edition, CRC Press, Boca Raton, FL, 2009. ISBN: 9780748760725.

Reference books

1. R.W.K. Honeycombe and H.K.D.H. Bhadeshia, Steels – Microstructure and Properties, 4th Edition - January 24, 2017, Elsevier, eBook ISBN: 9780081002728.
2. Robert E. Reed-Hill and Reza Abbaschian, Physical Metallurgy Principles, 3rd Edition, PWS Publishing Co., 1994.

3. J. W. Christian, The Theory of Transformation in Metals and Alloys, Part I and Part II, Pergamon, 2002.
4. M. Ferry, Direct Strip Casting of Metals and Alloys, Woodhead Publishing; 1st edition (April 7, 2006). ISBN-10: 1845690494.
5. R. E. Smallman, A.H.W. Ngan Modern Physical Metallurgy 8th Edition, Elsevier, September 4, 2013, eBook ISBN: 9780080982236
6. I. J. Polmear et al., Light Alloys: Metallurgy of the Light Metals, 5th Edition - March 29, 2017, eBook ISBN: 9780080994307.

Prerequisite and Co-requisite:

- You *must* have taken:
  - ENGR0022 Materials Structure and Properties
- You *should* have taken:
  - MSE 1053 – Crystal Structures and Diffraction
- 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 [Home Page – Phase Transformations and Microstructure ... (scu.edu.cn)]

There you will find the course syllabus, lecture slides, homework assignments, sample question solutions, announcements and other materials.

Class Format

This course is taught using a combined lecture, reading, review and discussion format. The class in the afternoon begins with two session lectures to review material 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 preview textbook, lectures and videos. You will assume basic 12 points for class attendance, plus 2 for each counted Q/A during the class (not during break or in office, not for exam questions), plus 2 for being a Q/A moderator, minus 2 for each unexcused absence, or missed sign in, or each time playing cellphone or video game during class.

Homework

will be assigned every three week and posted on Blackboard. These are to be completed by **Tuesday 1:30 PM** the following week. Late submission will be deducted 10 points per day and get no credit after 3 days.

Please adhere to these homework guidelines:

- Your assignment must be in Word format and submitted electronically through Blackboard. Handwritten or its slap shot will not be accepted.
- Put your name and ID number (last four digits) at the top of the first page.
- List the names of other people you've worked with on the assignment or report. You are to write up the homework on your own to receive credit, however.

If you're sick, or have a compelling emergency that prevents you from turning in the homework on time, inform Student Counselor, TA, and/or Prof. Hua. If you believe an error has been made in the grading (100 points full score for each assignment), bring it to the attention of our TA within ONE WEEK of its return.

Exams will cover all aspects of the course consisting of formal lectures, nominated reading material (posted on Blackboard) and assignments. It will consist of a combination of essay-style answers and calculations, with complicated background equations and diagrams provided (unless the equations and diagrams are themselves the examined items). Any derivations will assume knowledge of the previous MSE relevant material rather than memorizing equations. Formal exam time: 100 minutes.

Grading: In-Class 20%, Homework 20%, 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	g.	Not addressed.
b.	Not addressed	h.	Not addressed.
c.	Not addressed.	i.	Not addressed.
d.	Not addressed.	j.	Not addressed.
e.	Not addressed.	k.	Not addressed.
f.	Not addressed.		

Prepared by: Mingjian (Charles) Hua, Feb. 14, 2019 Updated on Feb. 9, 2022