MSE 1063 – Phase Transformations and Evolution of Microstructure

Credits and contact hours (lecture/lab): 3 Credits, 3 Contact Hours (lecture)

Designated as 'Required' or 'Elective' Course: Required for MSE Specialization

Course 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.

Prerequisite and Co-requisite: MATH 290 Differential Equations
PHYS 0174 & 0175 Physics for Science and Engineering 1 & 2
MEMS 0040 Materials & Manufacturing

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.

Other required materials: None

Course Coordinator: **Grace** Qizhi Chen

Course Objectives:

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 phase equilibria and kinetics.
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.

Course learning outcomes/expected performance criteria:

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:

Phase Equilibria (~16 classes): 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.

Interfaces (~6 classes): 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).

Defects and Diffusion (~10 classes): 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.

Phase Transformations (13 classes): 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.

Class/laboratory schedule:

Three 50-minute classes per week.

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: Grace Qizhi Chen adapted from Charles Hua Date: 28 August 2020