MSE 3002: Structural Transformations in Metallic and Ceramic Materials

Credit hours and contact hours: 3-0-0-3

Instructor: Mark Losego

Textbook: D. A. Porter and K. E. Easterling, *Phase Transformations in Metals and Alloys*, 2nd Edition, CRC Press, 2009.

Specific course information

Catalog description: Principles that govern the important structural transformations that occur in engineering materials.

Prerequisites: MSE 3001 - Chemical Thermodynamics of Materials and MSE 3210 - Transport Phenoma

Course: Required

Specific goals for the course

Outcomes of instruction:

Outcome 1: The student learns to apply thermodynamic theory to (1) predict the equilibrium phase assemblage in a materials system, (2) predict the microstructural development in a materials system that undergoes a change in state, (3) calculate unary and binary phase diagrams for materials, and (4) describe the energetic driving force for phase transformations in materials not at the equilibrium transformation temperature.

Outcome 2: The student learns phenomenological theory to describe (1) the structure and energy of surfaces and interfaces in materials, (2) solid state diffusion in materials, and (3) the nucleation and growth processes of structural transformations in materials.

Outcome 3: The student combines their understanding of thermodynamics and kinetics to develop an understanding of the total transformation rates for a given process and applies these methods to important phase transformations including solidification, crystallization, solid state precipitation, spinodal decomposition, and diffusionless transformations.

Student Outcomes:

(1) An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
(6) An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.

(7) An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.

Topics covered:

Part 1: Thermodynamics & Phase Equilibria (Chapter 1 [mostly])
Review of Thermodynamics (pg 1 – 9)
Classification of Phase Transformations (pg 175 – 179)
Thermodynamic Solution Theory & Phase Diagram (pg 11 – 30)
Unary & Binary Phase Diagrams (pg 31 – 41)

Part 2: Surfaces, Interfaces, and Nucleation (Chapters 3, 4, & 5)
Surfaces & Interfaces (Chap 3)
- Energetics (pg 115 – 121, 128 - 133, 158 – 167, 172 – 174))
- Description of atomic structure (pg 121-128, 146 – 158)

Nucleation Theory (Chap 4 & 5)
- Thermodynamic considerations (pg 189 – 201, 261 – 276)
- Kinetic description of nucleation rate (same: pg 189 – 201, 261 – 276)

Part 3: Mechanisms of Diffusion (Chapter 2)
Statistical description (pg 65 – 72)
Atomic-scale mechanisms (pg 72 – 98)

Part 4: Kinetics of Crystal Growth (Chapters 3, 4, & 5)
Interfacial controlled growth (pg 175 – 184, 201-205 & handouts)
Diffusion controlled growth (pg 276 – 285 & handouts)
Thermal diffusion-controlled growth (pg 215 – 220)

Part 5: Total Transformation Kinetics (Chapter 5)
JMAK Equation (pg 285 – 288)
TTT Curves (same: pg 285 – 288)

Part 6: Important Examples of Phase Transformations (Chapters 4, 5, & 6)
Solidification / Zone Refining (pg 209 – 215)
Spinodal Decomposition (pg 65 – 66, 302 – 309)
Diffusionless Transformations / Martensitic (pg 383 – 415)

*All page numbers are from Porter, Easterling and Sherif 3rd Ed.

Correlation between Outcomes of Instruction and Student Outcomes:

Outcomes of Instruction	Student Outcomes						
	1	2	3	4	5	6	7
1. The student learns to apply thermodynamic theory to (1) predict the equilibrium phase assemblage in a materials system, (2) predict the microstructural development in a materials system that undergoes a change in state, (3) calculate unary and binary phase diagrams for materials, and (4) describe the energetic driving force for phase transformations in materials not at the equilibrium transformation temperature.	X					X	X
2. The student learns phenomenological theory to describe (1) the structure and energy of surfaces and interfaces in materials, (2) solid state diffusion in materials, and (3) the nucleation and growth processes of structural transformations in materials.	X					X	X
3. The student combines their understanding of thermodynamics and kinetics to develop an understanding of the total transformation rates for a given process and applies these methods to important phase transformations including solidification, crystallization, solid-state precipitation, spinodal decomposition, and diffusionless transformations.	X					X	X

School of Materials Science and Engineering Student Outcomes:

(1) An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
(2) An ability to apply engineering design to produce solutions that meet specified needs with consideration for public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
(3) An ability to communicate effectively with a range of audiences.
(4) An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
(5) An ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
(6) An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
(7) An ability to acquire and apply new knowledge as needed, using appropriate learning strategies.