MSE 6403: Kinetics of Phase Transformations- Part 1 Diffusional Phase Transformations

Spring, 2017

INSTRUCTOR: Dr. Tom Sanders

OFFICE HOURS: By appointment

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LECTURES: The lectures will follow the outline and will be supplemented with additional concepts and readings from the literature for clarification. Please retain and follow the attached outline. **You should read all material prior to class.**

HOMEWORK: Homework will be regularly assigned and will be collected. Problems on the examinations will be motivated by the problems assigned for homework.

EXAMINATIONS: There will be 2 in-class, closed book and notes examinations during the first 2/3 of the semester.

Examination 1	February
Examination 2	March

GRADE: Two thirds of the grade for the semester will be determined by the two in-class examinations (80%) and the homework (20%).

CATALOG DATA for MSE 6403: Part 1 Diffusional phase transformations.

Credits 3 (3-0-3).

Prerequisites: Graduate standing and a graduate course in thermodynamics.

Description: **The course will rely on the application of Gibbs molar diagrams and will be cover during the first part of the course.** The basic principles necessary to describe the evolution of microstructure of engineering materials with time and temperature occurring will be introduced. These changes can occur during either processing or while in-service. One emphasis of the course will be to identify the driving forces and define the pathways by which the microstructure is evolving. In general thermodynamics is a compromise between enthalpy and entropy whereas kinetics of phase transformations is a compromise between capillarity length and diffusion. Topics will include the use of molar Gibbs free energy diagrams, empirical kinetics, nucleation theory, spinodal decomposition, diffusion, growth and dissolution, coarsening, sintering and morphological changes. Diffusional and non-diffusional phase changes will be studied.

REFERENCES:

An essential starting point-

Phase Transformations in Metals and Alloys, D. A. Porter and K. E. Easterling, Chapman and Hall, 1981.

This text accompanies MSE 3002 the undergraduate phase transformation course taught in our program. You should get a copy of this text to help prepare you for the topics in this class.

Lectures on the Theory of Phase Transformations, 2nd edition, Edited by Hubert I. Aaronson,

Chapter 1, Applications of Gibbs Energy-Composition Diagrams, by Mats Hillert, pp. 1-33.
Chapter 4, The Kinetics of Solid to Solid Nucleation Theory and Comparisons with Experimental Observations, H. I. Aaronson and J. K. Lee, pp. 165-225.
Chapter 3, Theory of Capillarity, Rohit K. Trivedi, pp.135-164.

The Theory of Transformations in Metals and Alloys, J. W. Christian, Pergamon Press, Oxford, 1965.

Stability of Microstructure in Metallic Systems, J. W. Martin, R. D. Doherty, and B. Cantor, 2nd edition, Cambridge University Press, 1997.

Kinetics of Materials, by, Robert W. Balluffi, Samuel M. Allen, W. Craig Carter, Wiley, 2005, ISBN 13 978-0-471-24689-3.

Chemical Thermodynamics of Materials, by C. H. P. Lupis, Prentice-Hall, Reproduced by MIT copy technology Center, Cambridge, MA 02139, USA, ISBN 0-13-050238-3.

Thermodynamics in Materials Science, by Robert T. DeHoff, McGraw-Hill, 1993, ISBN 0-07-016313-8.

Selected references from the literature will be included.

GOALS: Apply the fundamentals of thermodynamics and mathematics to the kinetics of diffusional phase transformation in engineering materials.

PREREQUISITES BY TOPIC:

1. Application of fundamental laws and theories of thermodynamics to materials systems.
2. Application of solution thermodynamics to the Gibbs free energy of a system.
3. Phase equilibrium and phase diagrams and the calculations of these diagrams from Gibbs free energy curves.

CORE TOPICS:

DIFFUSIONAL PHASE TRANSFORMATIONS

1. The general problem of microstructural stability
   The connection between phase diagrams and phase transformations and equilibrium phase diagrams
   Driving forces for microstructural change, application of Gibbs molar diagrams
   Construction of Gibbs molar diagrams for order/disorder systems

2, Structural instability due to chemical free energy

- Homogeneous nucleation
- Spinodal decomposition
- Heterogeneous nucleation
- Instability due to nonuniform solute distributions
- Diffusion process as related to the Gibbs free energy of the system
- Diffusion equations
- Atomic theory of diffusion
- Diffusion in concentration gradients
- Diffusion along crystal imperfections
- Diffusion in noncrystalline materials
- Coring during solidification
- Steady-state solidification, the concept of constitutional supercooling
- Growth and dissolution

3. Microstructure instability due to interfaces
    - Surface energy and surface tension
    - Anisotropy of surface energy
    - Ostwald ripening
    - Sintering
    - Grain boundary reactions
    - Phase morphology