Department of Materials Science and Engineering
University of Maryland, College Park, Maryland

ENMA 471: Kinetics, Diffusion and Phase Transformations

Course Description: Fundamentals of diffusion, kinetics of reaction including nucleation, growth and phase transformations are discussed. Topics include diffusion in substitutional solid solutions, interstitial diffusion, nucleation and growth theories, solidification, diffusional transformations and growth of crystalline solids.

Prerequisites: ENMA 461

Textbook: "Phase Transformations in Metals and Alloys", D. A. Porter and K. E. Easterling, 2nd ed. (New York, Chapman & Hall, 1992) (required).
"Crystal Growth for Beginners", I.V. Markov (World Scientific, Singapore, 2003) (suggested).

Other Useful References: "Diffusion in Solids", 2nd ed., Paul Shewmon (Minerals, Metals, & Materials Society, 1989); "Lectures on the Theory of Phase Transitions", ed. H. Aaronson, (American Institute of Mining, Mineralogical and Petroleum Engineers, New York, 1975); "Fractal Concepts in Surface Growth", A. L. Barabasi and H. E. Stanley, (Cambridge University Press, 1995); "Physics of Crystal Growth", A. Pimpinelli and J. Villain (Cambridge University Press, 1998).

Journal Articles: Research articles related to the content of this course from the current scientific literature will be assigned to individuals to read and critique, with in class presentations and a written 1-2 page written summary/critique, scheduled approximately once per week. These will be chosen from a number of journals, including Physical Review Letters, Science, and Nature.

Website: Class materials and assignments will be posted at http://md.blackboard.com.

Course Objectives (Mapable to ABET Criteria): A student who takes this course should learn (1) about thermal activation and the relationship to kinetics (2) to solve diffusion problems, both steady state and transient, (3) about coarsening and grain growth and (4) about the role of interfaces on transformations. An additional objective involves mastering the ability to read and analyze journal articles from the scientific literature, and to write and present a critique of them.

Course Goals to meet ABET 2005 Criteria:

1. Student learns about thermal activation across energy barriers in understanding the rate of a kinetic process.

2. Student learns to solve diffusion problems, both steady state and transient

3. Student learns about thermal activation across energy barriers in understanding the rate of a kinetic process.
4. Student learns to solve diffusion problems, both steady state and transient
5. Student learns about the Gibbs-Thomson effect, coarsening and grain growth.
6. Student learns about the effect of interfaces on phase transformations.
7. Student learns about how processing allows control of microstructure and nanostructure.
8. Student learns to read and analyze journal articles from the scientific literature and to write and present a critique.

Topics Covered:

I Diffusion
- Atomic Mechanisms of Diffusion
- Interstitial Diffusion
- Substitutional Diffusion
- Atomic Mobility
- Diffusion along Grain boundaries, Surfaces and Dislocations

II Crystal Interfaces
- Interfacial Free Energy
- Solid/Vapor Interfaces
- Boundaries in Single-Phase Solids
- Interphase Interfaces
- Interface Migration

III Solidification
- Nucleation in pure materials
- Growth of a pure solid
- Heteroepitaxial Growth
- Alloy Solidification

IV Diffusional Transformations in Solids
- Homogeneous Nucleation
- Heterogeneous Nucleation
- Precipitate growth
- Transformation Kinetics: TTT Diagrams
- Precipitation in Age-Hardening Alloys
    - Spinodal Decomposition
    - Particle Coarsening
- Ordering Transformations

V Growth
- Growth from Vapor
- Growth from Solution
- Step Flow vs. Island Growth
- Kinetic Instabilities during Growth

Grading:

Homework	20%	
In Class Presentations		30%
Midterm Exam	20%	
Final Exam	30%	

Relationship of course to program objectives: This course is one of the senior-level required courses in Materials Science and Engineering at the University of Maryland, and is intended to contribute toward the program objectives of (1) producing high quality graduates, (2) making sure that students can define and solve engineering and science problems, and (3) providing fundamental knowledge of materials to allow graduates to function professionally as materials scientists and engineers.

Assignments, Classroom Etiquette and Academic Ethics: Homework and outside reading is essential to master the material covered in this class. Readings should be done in advance to allow discussion during the class periods. Homework is generally due at the beginning of class one week after being assigned.

Attendance is suggested, but not required, outside of exams and when in-class presentations are scheduled. Classroom etiquette includes switching off cellular phones and leaving reading of unrelated material (newspapers, etc…) to outside of class.

Working together on homework assignments is strongly encouraged, but copying answers from previous years is not allowed, and considered to be cheating. Cheating and plagiarism on homework, exams and presentations are violations of the University Code of Academic Ethics, and will not be tolerated. Please see http://www.shc.umd.edu/code.html for a detailed discussion of this important issue.

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Office Hours: Tuesdays, Thursdays 15:30-16:30, or by appointment

Class Meets: Tuesday, Thursdays from 14:00-15:15
CHE 2116