UNIVERSITY OF ILLINOIS
Grainger College of Engineering
Department of Materials Science and Engineering

Spring 2026: **MSE 501**
Kinetic Processes in Materials

Instructor:	Pascal Bellon, 312D MSEB, 265-0284, bellon@illinois.edu
Lecture:	TuTh 9:30-10:50 am, LUMEB 2045
Office Hours:	Pascal Bellon: by appointment
Websites:	https://canvas.illinois.edu/ ; www.piazza.com

Prerequisites: MSE 500 or equivalent course or instructor approval, and one undergraduate materials kinetics course.

Recommended books:

Kinetics of materials, R. W. Balluffi, S. A. Allen, W. C. Carter, 620.11292B214k

Phase transformations in metals and alloys, D. A. Porter and K. E. Easterling, 669.94P833p

Atom movements: Diffusion and mass transport in solids, J. Philibert, 530.415 P536D:E

Kinetic Processes: Crystal Growth, Diffusion, and Phase Transitions in Materials, K. A. Jackson, 530.136J132k2010

Solidification, J. A Dantzig and M. Rappaz, 669.94 D236s

Course Objectives: For students to (i) learn fundamental concepts underpinning kinetics in hard materials; (ii) become familiar with standard treatments of phase and microstructure evolutions in near-equilibrium and far-from-equilibrium alloys; (iii) apply this knowledge to practical problems, including through the use of software such as Thermo-Calc, Onsager or KineCluE; (iv) practice critical reading of scientific literature; and (v) practice developing research hypotheses and writing proposal.

Course Outline:

I. Review of expected background
- I.1 Thermodynamics (PE Chap. 1)

Ideal, regular solution models. Equivalence with pairwise interactions model.

Chemical potentials; Common tangent construction; Common binary and ternary phase diagrams

Solubility limit; equilibrium point defect concentration

- I.2 Kinetics (PE Chap. 2, sections 2.3.1 and 2.3.2)

Self-diffusion, vacancy-mediated diffusion,

II. Diffusion in Solids
- II.1 Phenomenological treatment of diffusion in alloys (PE Chap. 2, sections 2.3.3 to 2.8)
- II.2 Atomic treatment of diffusion coefficient in alloys (Mehrer, Chap. 7))
- II.3 Transport coefficients (BAC Chap. 3)
- II.4 Diffusion in non-crystalline materials (PE Section 2.7, or Mehrer Chaps. 32, 33, 34 (!))

III. Free energies for alloys and compounds
- III.1 Phase separating systems (CALPHAD free energies and ThermoCalc)
- III.2 Ordered alloys and compounds (long-range and short-range order)

IV. Precipitation in alloys
- IV.1 Nucleation and growth (BAC Chaps. 19 and 20)
- IV.2 Coarsening (BAC Chap. 15)
- IV.3 Examples: Al-Cu and Cu-Co (BAC Chap. 20; ThermoCalc)

V. Spinodal decomposition and order-disorder transitions (BAC Chap 18)
- V.1 Cahn-Hilliard model (LAS)
- V.2 Allen-Cahn model
- V.3 Phase field modeling (review articles)

VI. Solidification
- VI.1 Solidification of metals and alloys (PE Chap. 4)
  (include short coverage of scaling and boundary layer: e.g., Peclet number in Dantzig, p.70)
- VI.2 Dendritic growth (Trivedi+Kurz, 1994, 2019, 2021, Mullins-Sekerka)
- VI.3 Eutectics (Jackson and Hunt's model, 1966)
- VI.4 Equiaxed to columnar transition (Hunt's model 1984 MSEA)

VII. Microstructure and phase transitions in nonequilibrium materials
- VII.1 Materials subjected to irradiation (notes and review articles)
- VII.2 Materials subjected to plastic deformation (notes and review articles)

Grading: 33% Homework assignments: Keep 3 best scores
33% Selected literature review: 1 in-class oral presentation
33% Individual term paper: On the topic of your choice

GRADING POLICIES

You are expected to have read the Student Code section related to Academic Integrity (http://admin.illinois.edu/policy/code/article1_part4_1-401.html). All infractions listed in the Student Code, including cheating and plagiarism, will result in penalties in accordance with the Student Code. If you have any question regarding what constitutes an infraction, contact me.

HOMEWORK ASSIGNMENTS

There will be 4 homework assignments throughout the semester (roughly one every 2-3 weeks). You will complete these assignments through the Canvas website. Your overall assignment grade will be the average of your 3 best scores.

LITERATURE REVIEW

During the semester, each student will give in class one critical review of a paper selected from an extensive list provided at the beginning of the semester.

TERM PAPER

Term paper topics will be defined by students, with review and approval from the instructor. Term papers will be short research proposals, written in the style of NSF proposals, i.e., they will include a review of relevant literature, the identification of knowledge gaps, the formulation of a research hypothesis, and proposed research.

CAMPUS SAFETY AND EMERGENCIES

You are encouraged to visit the following site for information on how to respond to a campus safety emergency: https://police.illinois.edu/em/run-hide-fight/