

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
Phase transformations in materials, B. Fultz,
<https://doi.org/10.1017/9781108641449.001>
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

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.

AI POLICIES

Generative AI tools, such as ChatGPT, Co-pilot, and Gemini are welcome in this class, provided that you cite when and how you use the tool. You will be provided with examples of how to cite your use of this tool for your assignments.

There are a variety of AI programs available to assist students. AI programs are not a replacement for critical thinking, analysis, creativity, originality, and problem-solving. Engineering is a craft that you must develop over time by learning skills and building intuition. However, AI tools may be used to assist with engineering design as long as proper attribution is provided.

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/>

ACADEMIC INTEGRITY

Academic dishonesty may result in a failing grade. Every student is expected to review and abide by the Academic Integrity Policy detailed in The University of Illinois Urbana-Champaign *Student Code*. Students should pay particular attention to Article 1, Part 4: Academic Integrity. Read the Code at the following URL: <https://studentcode.illinois.edu/article1/part4/1-401/>. Ignorance is not an excuse for any academic dishonesty. It is your responsibility to read this policy to avoid any misunderstanding. Do not hesitate to ask me if you are ever in doubt about what constitutes plagiarism, cheating, or any other breach of academic integrity.

FAMILY EDUCATIONAL RIGHTS AND PRIVACY ACT (FERPA)

Please visit <http://registrar.illinois.edu/ferpa> for information about the Family Educational Rights and Privacy Act (FERPA).

MENTAL HEALTH

Significant stress, mood changes, excessive worry, substance/alcohol misuse or interferences in eating or sleep can have an impact on academic performance, social development, and emotional wellbeing. The University of Illinois offers a variety of confidential services including individual and group counseling, crisis intervention, psychiatric services, and specialized screenings which are covered through the Student Health Fee. If you or someone you know experiences any of the above mental health concerns, it is strongly encouraged to contact or visit any of the University's resources provided below. Getting help is a smart and courageous thing to do for yourself and for those who care about you.

Counseling Center (217) 333-3704

McKinley Health Center (217) 333-2700

National Suicide Prevention Lifeline (800) 273-8255

Rosecrance Crisis Line (217) 359-4141 (available 24/7, 365 days a year)

If you are in immediate danger, call 911.

COMMUNITY OF CARE

As members of the Illinois community, we each have a responsibility to express care and concern for one another. If you come across a classmate whose behavior concerns you, whether in regard to their well-being or yours, we encourage you to refer this behavior to the Connie Frank CARE Center (formerly the Student Assistance Center) in the Office of the Dean of Students. You may do so by calling 217-333-0050 or by submitting an [online referral](#). Based on your report, staff in the Student Assistance Center will reach out to offer support and assistance.

Further, as a Community of Care, we want to support you in your overall wellness. We know that students sometimes face challenges that can impact academic performance (examples include mental health concerns, food insecurity, homelessness, personal emergencies). Should you find that you are managing such a challenge and that it is interfering with your coursework, you are encouraged to contact the [Connie Frank CARE Center](#) (formerly the Student Assistance Center) in the Office of the Dean of Students for support and referrals to campus and/or community resources.

STUDENTS WITH DISABILITIES

The University of Illinois is committed to ensuring that all students, including those with disabilities, do not experience barriers to learning and participating fully in class. If you have a letter of accommodation from DRES and have not already given it to me, please do so as soon as possible to ensure your accommodation needs are met.

To obtain disability-related academic adjustments and/or auxiliary aids, students with disabilities must contact Disability Resources and Educational Services (DRES) as soon as possible. To contact DRES, you may visit [1207 S. Oak St., Champaign](#), call [333-1970](#), email: disability@illinois.edu, or go to the [DRES website](#).

DISRUPTIVE BEHAVIOR

Behavior that persistently or grossly interferes with classroom activities is considered disruptive behavior and may be subject to disciplinary action. Such behavior inhibits other students' ability to learn and an instructor's ability to teach. A student responsible for disruptive behavior may be required to leave class pending discussion and resolution of the problem and may be reported to the Office for Student Conflict Resolution (<https://conflictresolution.illinois.edu>; conflictresolution@illinois.edu; 333-3680) for disciplinary action.

EMERGENCY RESPONSE RECOMMENDATIONS

Emergency response recommendations and campus building floor plans can be found at the following website: <https://police.illinois.edu/em/run-hide-fight/>. I encourage you to review this website within the first 10 days of class.

RELIGIOUS OBSERVANCES

It is the policy of the University of Illinois Urbana-Champaign to reasonably accommodate its students' religious beliefs, observances, and practices that conflict with a student's class attendance or participation in a scheduled examination or work requirement, consistent with state and federal law. Students should make requests for accommodation in advance of the conflict to allow time for both consideration of the request and alternate procedures to be prepared. Requests should be directed to the instructor. The Office of the Dean of Students provides an optional resource on its [website](#) to assist students in making such requests.

SEXUAL MISCONDUCT REPORTING OBLIGATION

The University of Illinois is committed to combating sex-based misconduct. Faculty and staff members are required to report any instances of sex-based misconduct to the University's Title IX Office. In turn, an individual with the Title IX Office will provide information about rights and options, including accommodations, support services, the campus disciplinary process, and law enforcement options.

A list of the designated University employees who, as counselors, confidential advisors, and medical professionals, do not have this reporting responsibility and can maintain confidentiality, can be found here: wecare.illinois.edu/resources/students/#confidential.

Other information about resources and reporting is available here: wecare.illinois.edu.