MASC 504: Diffusion and Phase Equilibria
Spring 2021

Lectures: Monday and Wednesday 2:00 – 3:50 PM, OHE 132 & Online

Instructor: Dr. Jayakanth Ravichandran
Office: VHE 714
Office hours: After class or by appointment
Email: jayakanr@usc.edu.

TA: Mr. Shantanu Singh
Office: VHE 710
Office hours: TBD
Email: ssingh23@usc.edu

Objectives: The objective of the course is to introduce the science and applications of thermodynamics and kinetics in materials systems. Specifically, we will address the relevance of thermodynamics and kinetics for the synthesis, physical properties and phase evolution in these systems. The content will cover a range of materials systems with the primary focus on metals, alloys, ceramics, and covalent semiconductors. Special topics on polymers, quasi-crystalline, and metastable phases will also be included.

Books: Lecture slides will be provided and will contain all the information and necessary references to learn the material. In some cases, lecture notes and excerpts from textbooks will be supplemented. Significant material will be covered from these two textbooks.

1. Phase Transformations in Metals and Alloys by David Porter and Kenneth Easterling. ISBN: 9781420062106
2. Diffusion in Solids: Fundamentals, Methods, Materials, Diffusion-controlled Processes by Helmut Mehrer. ISBN: 9783540714866.

The following books are recommended for advanced reading.

Recommended list of books:

1. Kinetic Processes: Crystal Growth, Diffusion and Phase Transitions in Materials by Kenneth Jackson. ISBN: 9783527327362
2. Phase Transitions in Materials by Brent Fultz. ISBN: 9781107067240.
3. Phase Diagrams and Heterogeneous Equilibria by Bruno Predel, Michael Hoch and Monte Pool. ISBN: 9783662092767
4. Diffusion in Condensed Matter: Materials, Methods, Models by Paul Heitjans and Jorg Karger. ISBN: 9783540720812

Course website:

We will use the Desire2learn website for all the students enrolled in the class (on campus and DEN). The link to the site is: https://courses.uscden.net/d2l/login. If you have any

trouble registering and accessing the website, please contact the DEN@Viterbi technical support at dentsc@usc.edu or 213-740-9356.

Grading:

Exam (1):	Best of the two (1 x 30%)	=	30%
Problem Sets (3)	10% each	=	30%
Notes (1 or 2)	2 x 10 or 1 x 20%	=	10%
Final Term Paper (20%) & Presentation (10%)		=	30%

Topics covered:

1) Introduction:

Kinetics and thermodynamics; Basics of Phase Transitions and Transformations.

2) Phase diagrams:

Theory of phase transitions; classifications; single component phase diagram, binary and ternary Phase diagram.

3) Diffusion:

Continuum theory of diffusion; defects and mechanisms of diffusion; mass diffusion in different materials systems (metals, alloys, semiconductors, ionic crystals and amorphous materials); beyond mass diffusion; applications of diffusion.

4) Crystals and Interfaces:

Coherent and incoherent interfaces; Grain boundaries; Domain boundaries.

5) Phase Transformations:

Nucleation and Growth; Diffusional and Diffusion-less transformation; Precipitation; Bulk processing of materials and low dimensional materials processing.

5) Meta-stability and advanced topics:

Amorphous Materials; Non-equilibrium materials processing.

Problem sets and Exam policy:

There will be one problem set made available early February, March, and April. The solutions to the problems will be due 2 weeks after the homework is posted. Each problem set will have 5 questions. Typically, these questions will have multiple parts, and will derive questions from 6-8 weeks of lecture.

The scores will be made available typically within 2 weeks of submitting the problem sets and exams. The exams will be held for 100 minutes each (+10 minutes for reading the question paper at the beginning of the exam) and will have 4 problems. More information about the exams will be provided in the class. All the exams will have 10 minutes of reading time and 100 minutes of time to write the answers. There will be two mid-term exams roughly at the half and towards the end of the lectures. The best of the two exams will be used for the grading.

The two exams will be tentatively held on the following days.

March 8, Monday 2:00 - 3:50 pm
April 21, Wednesday 2:00 - 3:50 pm

Modeling/Simulation:

The course will have small simple modeling exercises, typically in the form of simple programs using Matlab or Mathematica. These exercises will be aimed at helping you visualize diffusion profiles *etc.* and so, they are not expected to be extensive programming exercises. If you have trouble using either of these softwares, and prefer to use a different one, please get in touch with the instructor at the beginning of the class.

Notes:

Instead of included descriptive and thought type questions, each student will be tasked with preparing notes about a specific lecture (~5-10 pages). There will be no notes preparation assignment for the first and last week. Each week, I will be assigned 1-4 people to prepare the notes (depending on the strength of the class). I will post the schedule for the notes preparation after the first lecture. There may be subtle changes in the schedule depending on the changes in class strength during add/drop deadlines. Your notes will be posted to the course page without any editorial changes for all the students to use. We will evaluate and assign scores to each submitted notes.

Final Term Paper & Presentation policy:

The final term paper & presentation will be used as a method to evaluate the student's final summative performance.

The students are expected to write a brief review of a selected topic in this term paper. For example, topics relevant to phase transition, and/or diffusion in novel materials. You are also expected to typeset this article in a scientific journal format (*e.g.* Nature, Science, Advanced Materials, Physical Review Letters *etc.*) and mention the journal name in the review. You are expected to write this article in under 5 pages. Use any suitable schematics derived from any source (with suitable citations). This final term paper will be due during the assigned day of the final exam for the course during the finals week.

The final presentation will be held in the last week of the classes before the term paper is due. The presentation will be used as an opportunity to provide critique on the content of the term paper by your fellow students and me in the audience.

The breakdown for the evaluation for the term paper is as follows:

Selection of topic, and its relevance to the course	– 10%
Formatting per the journal guidelines	– 10%
Content of the review	– 60%
Figures and Caption	– 10%
References	– 10%

The breakdown for the evaluation for the presentation is as follows:

Formatting	– 20%
Content	– 50%
Delivery	– 30%

Course Schedule: A Weekly Breakdown

	Topics/Daily Activities	**Readings and Homework**	**Deliverable/ Due Dates**
Week 1	Review of Thermodynamics	**Class Notes**	
Week 2	Single component systems	Ch 1, Porter	
Week 3	Multi component systems	Ch 1, Porter	
Week 4	Fick's laws of Diffusion and Applications	Ch 2, Porter	Problem Set 1 is posted
Week 5	Ionic Materials	Notes	
Week 6	Semiconductors	Notes	Problem Set 1 is due
Week 7	Surfaces and beyond point defects	Ch 3, Porter	Problem Set 2 is posted
Week 8	Surfaces and beyond point defects	Notes	**Exam 1**
Week 9	Nucleation	Ch 4, Porter	
Week 10	Diffusional Phase Transformation	Ch 4 & 5, Porter	Problem Set 2 is due
Week 11	Diffusional Phase Transformation	Ch 4 & 5, Porter	Problem Set 3 is posted
Week 12	Diffusional Phase Transformation	Ch 4 & 5, Porter	
Week 13	Crystal Growth	Notes	Problem Set 3 is due
Week 14	Non-equilibrium Processing	Notes	**Exam 2**

Week 15	Advanced Topics	Notes	**Final Presentation**
FINAL			**No Final Exam/ Final Paper to be submitted in Finals Week**

Statement on Academic Conduct and Support Systems

Academic Conduct:

Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in SCampus in Part B, Section 11, "Behavior Violating University Standards" policy.usc.edu/scampus-part-b. Other forms of academic dishonesty are equally unacceptable. See additional information in SCampus and university policies on scientific misconduct, policy.usc.edu/scientific-misconduct.

Support Systems:

Student Health Counseling Services - (213) 740-7711 – 24/7 on call
engemannshc.usc.edu/counseling
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention.

National Suicide Prevention Lifeline - 1 (800) 273-8255 – 24/7 on call
suicidepreventionlifeline.org
Free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week.

Relationship and Sexual Violence Prevention Services (RSVP) - (213) 740-4900 – 24/7 on call
engemannshc.usc.edu/rsvp
Free and confidential therapy services, workshops, and training for situations related to gender-based harm.

Office of Equity and Diversity (OED) | Title IX - (213) 740-5086
equity.usc.edu, titleix.usc.edu
Information about how to get help or help a survivor of harassment or discrimination, rights of protected classes, reporting options, and additional resources for students,

faculty, staff, visitors, and applicants. The university prohibits discrimination or harassment based on the following protected characteristics: race, color, national origin, ancestry, religion, sex, gender, gender identity, gender expression, sexual orientation, age, physical disability, medical condition, mental disability, marital status, pregnancy, veteran status, genetic information, and any other characteristic which may be specified in applicable laws and governmental regulations.

Bias Assessment Response and Support - (213) 740-2421
studentaffairs.usc.edu/bias-assessment-response-support
Avenue to report incidents of bias, hate crimes, and microaggressions for appropriate investigation and response.

The Office of Disability Services and Programs - (213) 740-0776
dsp.usc.edu
Support and accommodations for students with disabilities. Services include assistance in providing readers/notetakers/interpreters, special accommodations for test taking needs, assistance with architectural barriers, assistive technology, and support for individual needs.

USC Support and Advocacy - (213) 821-4710
studentaffairs.usc.edu/ssa
Assists students and families in resolving complex personal, financial, and academic issues adversely affecting their success as a student.
Diversity at USC - (213) 740-2101
diversity.usc.edu
Information on events, programs and training, the Provost's Diversity and Inclusion Council, Diversity Liaisons for each academic school, chronology, participation, and various resources for students.

USC Emergency - UPC: (213) 740-4321, HSC: (323) 442-1000 – 24/7 on call
dps.usc.edu, emergency.usc.edu
Emergency assistance and avenue to report a crime. Latest updates regarding safety, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible.

USC Department of Public Safety - UPC: (213) 740-6000, HSC: (323) 442-120 – 24/7 on call
dps.usc.edu
Non-emergency assistance or information.