Course Description (3 credit hours)

Physical basis, equation, and theories of diffusion, tracer, chemical, multicomponent, and multiphase diffusion in general force fields.

Prerequisites:
EMA 4125 or equivalent.

Course Objectives
To become familiar with the fundamental concepts of diffusion and phase transformations in alloys, semiconductors, ceramics, and polymers. The atomistic and phenomenological treatment of diffusion will be introduced and applied to atomic transport under concentration, temperature, electric field and pressure gradients in a variety of technological materials. The kinetics of diffusive and martensitic phase transformations will be developed and applied to nucleation and growth of phases in vapors, liquids and solids. The course will enable students to apply theoretical concepts of diffusion and phase transformations to practical applications of evolution of materials.

Class Time
M/W/F Period 6 12:50 - 1:40 CSE E122

Text books: (recommended)
Title: Diffusion in Solids
Author: Paul Shewmon
ISBN: 978-3-319-48206-4 or 978-0873391054

Title: Phase Transformations in Metals and Alloys, Third Edition
Author: D. A. Porter, K. E. Easterling, and M. Y. Sherif
ISBN: 1420062107

Supplementary reading and links to various other resources/websites are provided and updated throughout the semester.

Course Website
The course website is on the Canvas system https://ufl.instructure.com, where you can find the syllabus, lecture notes, quizzes, homework problems, announcements, and your grades. Please check it frequently.

Lectures
Lectures are critical to success in this MS&E course. Past experience has shown that you will be able to get a better grade when regularly attending class. However, I will not require attendance. Questions are highly encouraged. It will make the class more interesting, wake up your fellow students and give me a chance to explain things better. If you do not understand
something, chances are that most of the class missed that point too. If you do not ask enough questions, I may start asking you. You are responsible for material presented in lectures, reading assignments, homework, and distributed notes.

**Homework**

Four homework exercises will be assigned. These homework questions are essential to your study and prepare you for the exams. Some exam questions will be adapted from homework. Homework is usually due back seven days before the corresponding exam. The approximate homework due dates are February 6, February 27, March 27, and April 17. The exact submission dates will be posted in the e-learning assignments. The purpose of homework is to give you an opportunity to evaluate and apply their knowledge. You may collaborate on homework; however, the submitted assignment must represent your own work and preparation. Please ask during the online class to discuss homework problems.

**Homework in its entirety must be word processed.** For some problems, you will require a suitable math package with graphing capability, e.g., Excel, Matlab, Python. Files have to be in pdf, doc, docx, or pptx. Picture files (jpg, etc.) are not accepted. Homework needs to be submitted online on e-learning. Email is not acceptable for submission of homework. Hard copies are also not accepted. Homework will be evaluated on the following basis:

<table>
<thead>
<tr>
<th>Completion</th>
<th>100</th>
<th>85</th>
<th>70</th>
<th>0</th>
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<tbody>
<tr>
<td>All assigned work is complete.</td>
<td>Most assigned work is complete.</td>
<td>Some assigned work is complete.</td>
<td>Assignment not complete.</td>
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<tr>
<th>Accuracy</th>
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<tbody>
<tr>
<td>All answers are correct.</td>
<td>Most answers are correct.</td>
<td>Some answers are correct.</td>
<td>Little to no answers are correct.</td>
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<tr>
<th>Work shown (derivations and figures)</th>
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<tbody>
<tr>
<td>All work shown in detail.</td>
<td>Most work shown in detail.</td>
<td>Several steps or figures missing.</td>
<td>Did not show any work.</td>
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No credit will be given for late unexcused submissions.

**Quizzes and Interactive Learning**

We will have online quizzes covering current and recent lecture material. The quizzes will typically consist of about 4 questions that should take about 10 minutes to answer. The quizzes serve as feedback both for you and me.

**Exams**

We will have four in-class exams. The exams will consist of concept questions to evaluate your familiarity with the course content and numerical problems designed to test your ability to apply concepts to new situations, i.e. to promote critical thinking. Unless otherwise informed, one sheet of prepared personal notes may be used to assist you in completing examinations. The exams will be on Canvas and use HonorLock. Exam work must be individual and collaboration is never allowed. Observations of cheating will be promptly reported by the exam proctor. Please see UF’s statement on academic honesty: [https://www.dso.ufl.edu/%20sccr/process/student-conduct-honor-code](https://www.dso.ufl.edu/%20sccr/process/student-conduct-honor-code).

There is no final exam in this class. Exam dates are tentatively scheduled for:
Exam 1: February 13  
Exam 2: March 6  
Exam 3: April 3  
Exam 4: April 24

**EDGE Student Submission Policy**
EDGE students must submit all homework assignments electronically by the given deadlines. Exams must be received no more than four days after the in-class exam date. Please scan documents as a pdf and submit them electronically or via fax. The exams will be on Canvas and use HonorLock. If any problems occur, please let me know early. No credit will be given for late unexcused submissions.

**Exam Conflicts with other course exams**
The official UF policy on exam conflict resolution states that when two exams conflict, the course with the higher number will take priority. There will be no exceptions to this rule.

**Make-up exams**
Make up exams will be provided only with the prior approval of the instructor. Excused absences must be consistent with university policies in the Graduate Catalog (https://catalog.ufl.edu/graduate/regulations) and require appropriate documentation. Additional information can be found here: https://catalog.ufl.edu/UGRD/academic-regulations/attendance-policies/. In general, acceptable reasons for excused absence from an exam include illness, serious family emergencies, special curricular requirements, military obligation, court-imposed legal obligations, and religious holidays. In all cases, you will be required to provide written documentation, and obtain prior instructor approval. You will not be excused from any exam without following the policy above, with no exceptions. Students not in attendance for the scheduled exam will receive a score of zero. **You must notify the instructor no less than 1 week of the scheduled exam of your intent and justification for missing the exam.** Make-up exams for excused absences as well as exam conflicts must occur within 1 week of the missed exam, and may occur before the missed exam.

**Grading**
Grades will be based on your understanding and mastery of the material as demonstrated by the exams, quizzes, and homeworks.
- Homework 10%
- Online quizzes 10%
- 4 exams 80%

To account for varying performance in the exams, your best exam score will count 25% and your worst exam only 15%. The other two exams will count 20%. You have two weeks after the test results are posted to resolve any questions about scores and grades. No changes to your exam grade will be made after that time.

**Grading Scale**
This course follows current UF grading policies for assigning grade points

<table>
<thead>
<tr>
<th>Percentage</th>
<th>≥92</th>
<th>≥88</th>
<th>≥84</th>
<th>≥80</th>
<th>≥76</th>
<th>≥72</th>
<th>≥68</th>
<th>≥65</th>
<th>≥59</th>
<th>≥56</th>
<th>&lt;56</th>
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<tbody>
<tr>
<td>Letter Grade</td>
<td>A</td>
<td>A-</td>
<td>B+</td>
<td>B</td>
<td>B-</td>
<td>C+</td>
<td>C</td>
<td>C-</td>
<td>D+</td>
<td>D</td>
<td>D-</td>
</tr>
<tr>
<td>Grade Points</td>
<td>4.0</td>
<td>3.67</td>
<td>3.33</td>
<td>3.0</td>
<td>2.67</td>
<td>2.33</td>
<td>2.0</td>
<td>1.67</td>
<td>1.33</td>
<td>1.0</td>
<td>0.67</td>
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</tbody>
</table>
In order to graduate, graduate students must have an overall GPA and an upper-division GPA of 3.0 or better (B or better). Note: a B- average is equivalent to a GPA of 2.67, and therefore, it does not satisfy this graduation requirement.

**Office Hours**
Office hours are Tuesday afternoons 2:00-3:00 p.m. If you have any questions about the class or homework, please come to office hours or email me. I will try to respond to e-mail questions as fast as possible. Important e-mail questions (minus identifying information) and answers may be posted to the class either by e-mail or on the course website for the benefit of other students.

**Online Course Recording**
Our class sessions will be audio visually recorded for students in the class to refer back and for enrolled students who are unable to attend live. Students who participate with their camera engaged or utilize a profile image are agreeing to have their video or image recorded. If you are unwilling to consent to have your profile or video image recorded, be sure to keep your camera off and do not use a profile image. Likewise, students who un-mute during class and participate orally are agreeing to have their voices recorded. If you are not willing to consent to have your voice recorded during class, you will need to keep your mute button activated and communicate exclusively using the "chat" feature, which allows students to type questions and comments live. The chat will not be recorded or shared. As in all courses, unauthorized recording and unauthorized sharing of recorded materials is prohibited.

**Record keeping**
All materials from this class that students did not pick up (graded exams, etc.) within 1 year of the end of class will be shredded on or after December 31, 2022.

**Syllabus Changes**
I reserve the right to make changes in the syllabus as needed. Any changes will be clearly announced on canvas and in class.

**University Honesty Policy**
UF students are bound by The Honor Pledge which states, “We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: “On my honor, I have neither given nor received unauthorized aid in doing this assignment.” The Conduct Code ([https://sccr.dso.ufl.edu/process/student-conduct-code/](https://sccr.dso.ufl.edu/process/student-conduct-code/)) specifies a number of behaviors that are in violation of this code and the possible sanctions. If you have any questions or concerns, please consult with the instructor in this class.

**Commitment to a Safe and Inclusive Learning Environment**
The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.
If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Your academic advisor or Graduate Program Coordinator
- Jennifer Nappo, Director of Human Resources, 352-392-0904, jpennc@ufl.edu
- Curtis Taylor, Assoc. Dean of Student Affairs, 352-392-2177, taylor@eng.ufl.edu
- Toshikazu Nishida, Assoc. Dean of Academic Affairs, 352-392-0943, nishida@eng.ufl.edu

Software Use

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity. Accommodation for Students with Disabilities: Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting https://disability.ufl.edu/students/get-started/. It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

Campus Resources

Health and Wellness

**U Matter, We Care:** Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact umatter@ufl.edu so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

**Counseling and Wellness Center:** [https://counseling.ufl.edu](https://counseling.ufl.edu), and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

**Sexual Discrimination, Harassment, Assault, or Violence:** If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the Office of Title IX Compliance, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, title-ix@ufl.edu

**Sexual Assault Recovery Services (SARS):** Student Health Care Center, 392-1161.

**University Police Department** at 392-1111 (or 9-1-1 for emergencies), or [http://www.police.ufl.edu/](http://www.police.ufl.edu/).

**COVID-19:** You are expected to wear approved face coverings at all times during class and within buildings even if you are vaccinated. If you are sick, stay home and self-quarantine. Please visit the UF Health Screen, Test & Protect website about next steps, retake the questionnaire and schedule your test for no sooner than 24 hours after your symptoms began. Please call your primary care provider if you are ill and need immediate care or the UF Student Health Care Center at 352-392-1161 (or email covid@shcc.ufl.edu) to be evaluated for testing and to receive further instructions about returning to campus.
If you are withheld from campus by the Department of Health through Screen, Test & Protect, you are not permitted to use any on campus facilities. Students attempting to attend campus activities when withheld from campus will be referred to the Dean of Students Office.

UF Health Screen, Test & Protect offers guidance when you are sick, have been exposed to someone who has tested positive or have tested positive yourself. Visit the UF Health Screen, Test & Protect website for more information.

Please continue to follow healthy habits, including best practices like frequent hand washing. Following these practices is our responsibility as Gators.

**Academic Resources**

- **E-learning technical support**, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu. [https://lss.at.ufl.edu/help.shtml](https://lss.at.ufl.edu/help.shtml).
- **Career Resource Center**, Reitz Union, 392-1601. Career assistance and counseling; [https://career.ufl.edu](https://career.ufl.edu).
- **Library Support**, [http://cms.uflib.ufl.edu/ask](http://cms.uflib.ufl.edu/ask). Various ways to receive assistance with respect to using the libraries or finding resources.
- **Teaching Center**, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring. [https://teachingcenter.ufl.edu/](https://teachingcenter.ufl.edu/).
- **Writing Studio, 302 Tigert Hall**, 846-1138. Help brainstorming, formatting, and writing papers. [https://writing.ufl.edu/writing-studio/](https://writing.ufl.edu/writing-studio/).
## Course and Lecture Outline

<table>
<thead>
<tr>
<th>Week</th>
<th>Dates</th>
<th>Topics</th>
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<tbody>
<tr>
<td>1</td>
<td>January 9, 11, 13</td>
<td>Phenomenological description of diffusion, Fick’s first and second law, partial different equations</td>
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<tr>
<td>2</td>
<td>January 18, 20</td>
<td>Special solutions to the diffusion equation, Boltzman-Matano analysis of interdiffusion experiments</td>
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<tr>
<td>3</td>
<td>January 23, 25, 27</td>
<td>Atomistic theory of diffusion: Random walk and Einstein’s relation, diffusion mechanisms, temperature and pressure dependence of diffusion</td>
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<tr>
<td>4</td>
<td>January 31, February 2, 4</td>
<td>Diffusion in alloys: Geometrical and physical correlation effects, Impurity diffusion, diffusion in dilute binary alloys</td>
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<tr>
<td>5</td>
<td>February 6, February 8, February 10</td>
<td>1st Homework, Diffusion with traps, Exam Review</td>
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<tr>
<td>6</td>
<td>February 13, February 15, 17</td>
<td>Interstitial diffusion and anelasticity, High-diffusivity paths: Grain boundary diffusion, dislocation effects, surface diffusion</td>
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<tr>
<td>7</td>
<td>February 20, 22, 24</td>
<td>Diffusion in concentration gradients: General transport theory, fluxes and driving forces</td>
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<tr>
<td>8</td>
<td>February 27, March 1, 3</td>
<td>2nd Homework, Kirkendall effect, Darken equations, Exam Review</td>
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<tr>
<td>9</td>
<td>March 6, 8, 10</td>
<td>Relationship between chemical and tracer diffusion coefficient</td>
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<tr>
<td>10</td>
<td>March 11-18</td>
<td>Spring Break</td>
</tr>
<tr>
<td>11</td>
<td>March 20, 22, 24</td>
<td>Diffusion in ionic solids and semiconductors, Crystal Interfaces: Surface energy and surface tension, interfaces and crystal growth</td>
</tr>
<tr>
<td>12</td>
<td>March 27, 29, 31</td>
<td>Solidification: Homogeneous and heterogeneous nucleation in pure solids, growth of a pure solid, Exam Review</td>
</tr>
<tr>
<td>13</td>
<td>April 3, 5, 7</td>
<td>Alloy solidification: Solidification of single phase alloys, eutectic and peritectic solidification</td>
</tr>
<tr>
<td>14</td>
<td>April 10, 12, 14</td>
<td>Diffusional transformations: Homogeneous and heterogeneous nucleation, precipitate growth, transformation kinetics illustrated by TTT diagrams</td>
</tr>
<tr>
<td>15</td>
<td>April 17, 19, 21</td>
<td>Spinodal decomposition, eutectoid transformation, ordering transformations, Review</td>
</tr>
<tr>
<td>16</td>
<td>April 24, 26</td>
<td>Martensitic transformations: Crystallography, Bain path for fcc to bcc transformation</td>
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</table>