Electronic Materials Processing EMA 4614/6616

Class Period: MWF, 4:05-4:55 PM (Period 9)

Locations: NEB 0102 (in-person), and Zoom (remote) links posted in Canvas

Academic Term: Fall 2023

Instructor:
Ryan F. Need (they/them)
150 Rhines Hall
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352-294-1690

Teaching Assistants
There are none for this course.

Course Description
This is a 3-credit undergraduate/graduate class (4614/6616). The course provides an overview of how semiconductors and related materials are processed into devices that enable modern information technology like computers and wireless communication. We begin by reviewing basic properties of electronic materials, then introduce several key processing techniques needed to create silicon wafers and pattern them into devices. These include crystal growth, lithography, etching, deposition, implantation, annealing and oxidation. Next, the fabrication and function of common electronic and photonic devices, like bipolar transistors (BJTs), metal-semiconductor field effect transistors (MESFETs), metal-oxide semiconductor field effect transistors (MOSFETs), and light-emitting diodes, will be described.

Course Pre-Requisites / Co-Requisites
None, but some knowledge of the electronic properties of materials is assumed.

Course Objectives
To provide students understanding of how modern semiconductor chips are fabricated; comparison of Si versus compound semiconductors; processing modules such as diffusion, ion implantation, wet and dry etching and metal deposition; materials selection requirements; yield and reliability requirements; basics of component devices such as MOSFETs, bipolar transistors, LEDs and laser diodes; introduction to emerging electronic technologies and materials.

Materials and Supply Fees: None

Required Textbooks and Software: None

Recommended Course Materials
- Main text:
  - *Fabrication Engineering at the Micro- and Nanoscale*, S. A. Campbell, fourth edition, Oxford University Press, 2012, ISBN-10: 0199861226.
  - Note: This text can rented digitally for the semester for $60 through RedShelf.
- Supplementary texts:
  - *Principles of Electronic Materials and Devices*, S. O. Kasap, third edition, McGraw-Hill, 2006, ISBN-10: 0072957913.
  - *Semiconductor Device Physics and Design*, U. K. Mishra and J. Singh, first edition, Springer, 2008, ISBN: 9781402064807
- Nanohub.org account – will be used for device simulations in the latter half of the semester

Professional Component (ABET): 3 credits Engineering Topics.

Relation to Program Outcomes (ABET)

Outcome	Coverage*
1. an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics	Medium
2. an ability to apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors	
3. an ability to communicate effectively with a range of audiences	
4. an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts	
5. an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives	
6. an ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions	
7. an ability to acquire and apply new knowledge as needed, using appropriate learning strategies.	

*Coverage is given as high, medium, or low. An empty box indicates that this outcome is not covered or assessed in the course.

Course Schedule *(subject to change)*

Module	Lecture	Approx. Date	Broad Topic	Subtopics*
	1	8/23	Course Introduction	Topics overview and motivation, syllabus
1	2	8/25	Key Materials I	Metals: Drude conduction model
	3	8/28	Key Materials II	Semis: Family trends, intrinsic vs. extrinsic semis
	4	8/30	Key Materials III	Semis: Direct vs. indirect gaps, effective mass
	5	9/1	Key Materials IV	Dielectrics: Polarization, capacitance, gate oxides
2	6	9/6	Wafer Production I	Czochralski growth
	7	9/8	Wafer Production II	Float Zone and Bridgman growth
	8	9/11	Wafer Production III	Dicing and chemical mechanical polishing
3	9	9/13	Thin Film Growth I	PVD overview, thermal evaporation, MBE
	10	9/15	Thin Film Growth II	Sputtering & PLD
	11	9/18	Thin Film Growth III	CVD overview, fluid dynamics key ideas
4	*12*	*9/20*	Characterization I	Electrical transport: conductivity, mobility
	13	9/22	Characterization II	XRD/XRR: crystal characterization
	14	9/25	Characterization III	Microscopy: defect and device quality analysis
Ex1		9/27	Exam I: Electronic Materials Growth and Characterization	
		9/29		

5	15	10/2	Lithography I	Photolithography, proximity v. contact methods
	16	10/4	Guest Lecture/Buffer	Topic TBD
		10/9	*- No Class - Indigenous People's Day -*	
	17	10/11	Lithography II	Masks and photoresists
	18	10/13	Lithography III	Advanced lithography (projection, e-beam, EUV)
6	19	10/16	Etching I	Wet etching
	20	10/18	Etching II	Plasma etching, high-density plasma etching
	21	10/20	Etching III	Reactive ion etching, ion milling
7	22	10/23	Implantation I	Ion implantation, ion sources, Coulomb scattering
	23	10/25	Implantation II	Channeling, shallow junctions, implantation damage
8	24	10/27	Thermal Treatments I	Dopant diffusion, Fick's laws
	25	10/30	Thermal Treatments II	Thermal oxidation, Deal-Grove model
	26	11/1	Thermal Treatments III	Rapid thermal processing (RTP)
Ex2		11/3	Exam II: Nanofabrication Processes	
		11/6		
9	28	11/8	Device Contacts	Ohmic vs. Schottky contacts, transmission lines
	28	11/13	Diodes I	pn-junction physics and transport
	29	11/15	Diodes II	Applications: Solar cells and LEDs
10	30	11/17	Logic Devices I	Bipolar junction transistors (BJTs)
	31	11/20	Logic Devices II	Planar MOSFETs
	32	*11/27*	Logic Devices III	CMOS scaling, non-planar MOSFETs
11	33	11/29	Memory Devices I	DRAM, SRAM
	34	12/1	Memory Devices II	Flash, ReRAM, MRAM
Ex3		12/4	Exam III: Device Technologies	
		12/6		

Class Format, Lectures & Office Hours

This course is offered as part of UF's Electronic Delivery of Gator Engineering (EDGE) curriculum for distance learning. Therefore, all lectures for this class will be delivered electronically with lecture videos posted to the course Canvas page *approximately* two days before the corresponding MWF class time.

For example, the first class of this term is Wednesday, 8/23. The first lecture will be posted roughly Monday, 8/21. The second class is Friday, 8/25, and the corresponding lecture will be available on Wednesday, 8/23, and so on.

Saturday	**Sunday**	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**
				Class 1		Class 2
		Lecture 1 Posted		Lecture 2 Posted		Lecture 3 Posted

Students are to watch the lecture *before* the synchronous MWF class times. These synchronous class sessions will reinforce the recorded lectures through group discussion and practice problems. Synchronous classes can be attended in person or via Zoom, or viewed as a recording through a link shared a day or two later.

Office hours will be held virtually and in person this term. Time and date of office hours will be determined via poll at the start of classes. Reoccurring Zoom links for office hours and the synchronous classes are shared on Canvas.

Recording Notification

Online 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. If you are attending in person and do not want to be recorded, I will *try* to seat you in a portion of the room not on camera. Students who participate orally, in-person and online,

are agreeing to have their voices recorded. The Zoom chat will not be recorded or shared. As in all courses, unauthorized recording and unauthorized sharing of recorded materials is prohibited by law.

Attendance Policy

Attendance to synchronous classes (either in-person or online) is *not* required, but it is strongly encouraged. Data shows that live teaching interactions significantly improve students' understanding and retention of the course material. If you attend the classes, please be on time as a courtesy to me and the other students.

Make-Up Policy

Generally, at least one-week advance notice is required for assignment or exam extension request. In accordance with university attendance policy, acceptable reasons for failure to participate in class include illness, serious family emergencies, special curricular requirements, military obligation, severe weather conditions, religious holidays, and participation in official university activities such as music performances, athletic competition or debate. For more detail on excused absences, refer to the undergraduate catalog (https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx).

Absences from class for court-imposed legal obligations (e.g., jury duty or subpoena) must be excused. Other reasons also may be approved. Please note that assignment deadlines for other courses will not be considered. Students who do not follow the approved procedure and timeliness for an assignment or exam will receive a score of zero. Assignments or exams missed for excused reasons must be re-scheduled in consultation with the lecturer.

Class Expectations

Contacting the Professor: Students should use Canvas to contact me. While you may email me at my UF email account, the university strongly encourages we communicate via Canvas to avoid the potential of violations of student confidentiality protected by FERPA. I strongly encourage students to attend office hours or schedule a meeting to discuss any questions or concerns regarding the course.

Messaging/Email Hours: You may contact me via Canvas or email at any time that is convenient to you. I will respond within two business days. If you do not receive a reply from me after 48 hours, please resend your message. Responses are not guaranteed after 5 PM on weekdays, on weekends, or on academic holidays. Please plan accordingly to have your questions answered in advance of assignment and exam deadlines.

Interpersonal Conduct: All class members are expected to treat each other with respect and decency at all times. This includes in the classroom, physical and virtual, and in all communication relating to this course. Any harmful or disruptive behavior, in-person or online, will result in the student being removed from the classroom and, depending on the nature of the behavior, reported to the department, college, or university for misconduct.

Effort: The university recommends that students typically spend 9 to 12 hours per week for a 3-credit class. This can of course vary but is a good initial guideline as the term begins.

Evaluation of Grades

Assignment	Percentage of Final Grade	Frequency	Date
Module Wrap-Up	5%	End of every module	**3 days** after the last synch. class of the module
Module Homework	25%		
Exam I	15%	Once	9/27 – 9/29
Exam II	15%	Once	11/3 – 11/6
Exam III	15%	Once	12/4 - 12/6
Video Project	25%	First Draft: 10/20 Final Draft: 12/6	
Total	100%		

Module Wrap-Up: After each module, there is a short, three-question Wrap-Up activity that is part reflection for you, part feedback for me. It asks about the clearest and least clear lectures in each module. Wrap-Ups are graded only for completion and due by 11:59PM three days after the last class of the module.

Homework: After each module, there will be a Canvas homework about 10 questions long that tests your knowledge of that module and gives you examples for what to expect on the exams. All homeworks are open note and can be done collaboratively. They are due by 11:59PM three days after the last class of the module.

Exams: There will be three take-home exams in this course which you will have ~2 days each to complete. Exams will be given out and turned in through Canvas on or about the dates listed in the tables above. Exams are open note *must* be completed individually with no collaboration.

Teaching Video Project: You will make a 5-minute video lecture with slides to develop communication skills and teach your peers something new about one of the subtopics from the course schedule, or a closely related topic to be approved by me. First-draft videos will be uploaded to Canvas mid-semester. You will receive graded feedback from peers and the instructor. If you are happy with your initial grade, you can skip the final submission. If you want to improve your grade, you can incorporate that feedback and turn in a revised draft at the end of the semester for a final grading by the instructor. More details can be found on Canvas on the assignment page.

All unexcused missed assignments will be accepted within the first 24 hrs after the deadline for maximum 50% credit. Maximum credit drops to 25% between 24-48 hrs overdue, and 0% after 48 hrs.

Grading Policy - Grades in this course are absolute and are not curved.

Percent	Grade	Grade Points
93.4 - 100	A	4.00
90.0 - 93.3	A-	3.67
86.7 - 89.9	B+	3.33
83.4 - 86.6	B	3.00
80.0 - 83.3	B-	2.67
76.7 - 79.9	C+	2.33
73.4 - 76.6	C	2.00
70.0 - 73.3	C-	1.67
66.7 - 69.9	D+	1.33
63.4 - 66.6	D	1.00
60.0 - 63.3	D-	0.67
0 - 59.9	E	0.00

For EMA 4614 students:
A "C" will not be a qualifying grade for critical tracking courses. In order to graduate, students must have an overall GPA and an upper-division GPA of 2.0 or better (C or better). Note: a C- average is equivalent to a GPA of 1.67, and therefore, it does not satisfy this graduation requirement. For more information on grades and grading policies, please visit: https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx

For EMA 6616 students:
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. For more information on grades and grading policies, please visit:
http://gradschool.ufl.edu/catalog/current-catalog/catalog-general-regulations.html#grades

More information on UF grading policy may be found at:
https://catalog.ufl.edu/ugrad/current/regulations/info/grades.aspx

Students Requiring Accommodations
Students with disabilities requesting accommodations should first register with the Disability Resource Center (352-392-8565, https://www.dso.ufl.edu/drc) by providing appropriate documentation. Once registered, students will

receive an accommodation letter which must be presented to the instructor when requesting accommodation. Students with disabilities should follow this procedure as early as possible in the semester.

Course Evaluation
Students are expected to provide feedback on the quality of instruction in this course by completing online evaluations at https://evaluations.ufl.edu/evals. Evaluations are typically open during the last two or three weeks of the semester, but students will be given specific times when they are open. Summary results of these assessments are available to students at https://evaluations.ufl.edu/results/.

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 Honor Code (https://www.dso.ufl.edu/sccr/process/student-conduct-honor-code/) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs 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
- Robin Bielling, Director of Human Resources, 352-392-0903, rbielling@eng.ufl.edu
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, taylor@eng.ufl.edu
- Toshikazu Nishida, Associate 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.

Student Privacy
There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: https://registrar.ufl.edu/ferpa.html

Campus Resources
Technology Resources
The entirety of our course will take place virtually, requiring the use of a working computer and access to audio-visual resources (webcam, microphone, speakers). If you are struggling to use Zoom or Canvas, please review these UF Quick Start guides. This link also connects to UF resources regarding internet connectivity.

The UF Computing Help Desk can assist you with any of your technical issues. You can access the Help Desk 24/7 at https://helpdesk.ufl.edu/, 352-392- HELP (4357), or helpdesk.@ufl.edu. If you use email, write from your gatorlink@ufl.edu email address, or include your UFID and/or GatorLink username (NOT your password!) in the body of the email. Provide complete information regarding the course and content to which you are referring.

Financial and COVID Related Services

In case of emergency financial need, UF's Aid-a-Gator program provides students with emergency funding: https://www.sfa.ufl.edu/aidagator/. The program is intended to "help our students need to cover costs related to unanticipated travel, additional technology requirements, or other needs related to an emergency situation."

Health and Wellness

If you or someone you know is struggling with any crisis including but not limited to gender, sexual, racial, or domestic violence, there are many community and University of Florida resources available. Some of these include:

- *RESPECT – UF Division of Student Affairs* (respect.ufsa.ufl.edu)
- *Student Health Care Center* (352-392-1161, shcc.ufl.edu)
- *Multicultural & Diversity Affairs* (352-392-1217, multicultural.ufl.edu)
- *UF Health Shands Emergency Room / Trauma Center* (352-733-0111)
- *Gainesville Police Department* (non-emergency #: 352-955-1818, gainesvillepd.org)

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.

Hitchcock Field & Fork Pantry: https://pantry.fieldandfork.ufl.edu, assisting members of our campus community who experience food insecurity.

Counseling and Wellness Center: http://www.counseling.ufl.edu/cwc, 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. While faculty and staff in our department are also resources for you, please keep in mind that most are Title IX mandatory reporters.

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/.

Academic Resources

E-learning technical suppor*t*, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu. https://lss.at.ufl.edu/help.shtml.

Career Resource Center, Reitz Union, 392-1601. Career assistance and counseling. https://www.crc.ufl.edu/.

Library Support, 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/.

Writing Studio, 302 Tigert Hall, 846-1138. Help brainstorming, formatting, and writing papers. https://writing.ufl.edu/writing-studio/.

Student Complaints Campus*:* https://www.dso.ufl.edu/documents/UF_Complaints_policy.pdf.

On-Line Students Complaints*:* http://www.distance.ufl.edu/student-complaint-process.