

Electronic Materials Processing EMA 4614/6616

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

Locations: CSE E122 (in-person) and Zoom (remote), links are posted in Canvas

Academic Term: Fall 2021

Instructor:

Ryan F. Need (they/them)
150 Rhines Hall
rneed@ufl.edu
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. Finally, we will discuss emerging technologies and research areas in low-dimensional and magnetic materials for flexible, low-energy electronics.

Course Pre-Requisites / Co-Requisites

None, but some knowledge of the electronic properties of materials is assumed.

Course Objectives

To provide the student with an up-to-date picture 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

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 be 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	Broad Topic	Subtopics*
	1	Course Introduction	Historical perspective, course overview, syllabus
1	2	Metals	Drude conduction model, key metals for ICs
	3	Semiconductors I	Key semiconductors, intrinsic vs. extrinsic semis
	4	Semiconductors II	Band theory, direct vs. indirect gaps, effective mass
	5	Dielectrics	Key dielectrics, polarization, capacitance
2	6	Bulk Crystal Growth I	Czocharlaski growth
	7	Bulk Crystal Growth II	Float Zone and Bridgman growth
3	8	Thin Film Growth I	PVD overview, thermal evaporation, MBE
	9	Thin Film Growth II	Sputtering, e-beam deposition, PLD
	10	Thin Film Growth III	CVD overview, MOCVD, CBE
4	11	Characterization I	Electrical transport: conductivity, carrier mobility
	12	Characterization II	XRD/XRR: crystal characterization
	13	Characterization III	Ellipsometry: dielectric constants
	14	Exam I: Electronic Materials Growth and Characterization	
5	15	Lithography I	Photolithography, proximity and contact methods
	16	Lithography II	Projection, immersion, e-beam, and X-ray lithography

	17	Lithography III	Masks and photoresists
6	18	Etching I	Wet etching, chemical mechanical polishing
	19	Etching II	Plasma etching, high-density plasma etching
	20	Etching III	Ion milling, reactive ion etching
7	21	Implantation I	Ion implantation, ion sources, Coulomb scattering
	22	Implantation II	Channeling, shallow junctions, implantation damage
8	23	Diffusion	Fick's law, dopant diffusion
	24	Thermal Oxidation	Deal-Grove model, oxidation regimes, SiO ₂ vs. GeO ₂
	25	Rapid Thermal Processing	Radiative heat transfer, RTP uses
	26	Exam II: Nanofabrication Processes	
9	27	Diodes I	Contact fabrication and geometries
	28	Diodes II	Ohmic vs. Schottkey transport
	29	Diodes III	pn junction physics and transport
	30	Diodes IV	Applications: solar cells, LEDs, laser diodes
10	31	Logic Devices I	MOSFET
	32	Logic Devices II	High-k gate dielectrics
	33	Logic Devices III	MESFETs, HBTs
	34	Logic Devices IV	HEMTs, FinFETs, TunnelFets
11	35	Memory Devices I	DRAM, SRAM
	36	Memory Devices II	Flash, ReRAM, MRAM
12	37	Oxide electronics I	TMOs, correlated electron physics
	38	Oxide electronics II	Spintronics, processing challenges
	39	2D electronics I	vdW prototypes, exfoliation processing
	40	2D electronics II	Valleytronics, processing challenges
	41	Course Review	Review: Practice problems, Q&A
	42	Exam III: Devices and Emerging Technologies	

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 Monday, 8/23. The first lecture will be posted roughly Saturday, 8/21, which is also when the course's Canvas will become open. The next class is Wednesday, 8/25, and the corresponding lecture will be available on Monday, 8/23, and so on throughout the semester.

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

Students are to watch the lecture before the live MWF class times. These live class sessions will serve to reinforce the recorded lectures through group discussion and practice problems. Live classes can be attended in person but will also be accessible via Zoom for remote learners. These live class sessions will not be recorded, in general, but discussion prompts or problems and solutions will be posted to Canvas for those unable to attend.

Office hours will be held virtually this term, from 3-4pm on Thursdays. Reoccurring Zoom links for office hours and the live class sessions are at the top of the syllabus.

Recording Notification

In general, live classes will not be recorded. In the event that I decide to record a class, I will notify the class in writing in Canvas prior to the class and verbally at the beginning of class before recording begins. 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 the live class sessions (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, 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	Due Date
Module Wrap-Up	5%	End of every module	Three days after the last class of the module
Homework	15%	Almost every module (~10/term)	
Quizzes	20%		
Exam I	15%	Once	~9/24
Exam II	15%	Once	~10/25
Exam III	15%	Once	12/8
Term Paper	15%	Once	12/8
Total	100%		

Term Paper: This assignment is designed to develop critical reading and writing skills by performing a concise literature review on any subtopic listed in the course schedule. Each student will select a topic and submit a one-paragraph abstract of their topic for me to review and approve by the date of the first exam. The student will then have the remainder of the semester to write a five-page report summarizing that topic. This must include resources external to those provided in class and properly formatted references. A full list of requirements and grading rubric for the assignment will be provided via Canvas.

Exams: There will be three exams in this course. Exams will be given through Canvas on or about the dates listed in the tables above. Once students begin the exam, they will have a finite time window with which to complete the exam. Exams are open note *must* be completed individually with no collaboration.

Quizzes: Most modules will have quizzes associated with them. Quizzes are due by 11:59PM three days after the last class of the module. That way students can ask any final questions about the module's content before taking the quiz. Quizzes are open note but *must* be completed individually with no collaboration.

Homework: The first ten modules module will be accompanied by *either* a small problem set homework or a discussion post assignment. These assignments will be accessed and submitted through Canvas. Email and physical copies are not acceptable for submission methods. Homework is due by 11:59PM three days after the last class of the module.

Module Wrap-Up: Each module, there will be a wrap-up activity that is part reflection for you, part feedback for me. They consist of short open answer discussion post prompts on Canvas that ask you: (1) what was the most useful thing you learned, (2) what were the clearest and muddiest points, and (3) what were you interested to know more about. Feedback is graded for completion and due by 11:59PM three days after the last class of the module.

All unexcused missed assignments will be accepted within the first 24 hrs after the deadline for maximum 50% credit. After 24 hrs the assignment will receive a zero.

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."

If you have a family member whose financial situation was affected by the COVID-19 crisis, especially loss of work hours or job, you may submit a revision petition for consideration of having their income reevaluated. UF is encouraging these students to complete the [2019-20 Financial Aid Revision](#) Petition and the [2020-2021 Revision](#) Petition.

Health and Wellness

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

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)

While faculty and staff in our department are also resources for you, please keep in mind some of us (including me) are [Title IX mandatory reporters](#).

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

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 support, 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>.