

# **Electronic Materials Processing** EMA 4614/6616

**Class Period:** MWF, 1:55-2:45 PM (Period 7)

**Locations:** CSE E107 (in-person), and Zoom (remote) links posted in Canvas

**Academic Term:** Fall 2022

## **Instructor:**

Ryan F. Need (they/them)  
150 Rhines Hall  
[rneed@ufl.edu](mailto: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	Approx. Date	Broad Topic	Subtopics*
	1	8/24	Course Introduction	Topics overview and motivation, syllabus
1	2	8/26	Metals	Drude conduction model, key metals for ICs
	3	8/29	Semiconductors I	Key semiconductors, intrinsic vs. extrinsic semis
	4	8/31	Semiconductors II	Direct vs. indirect band gaps, effective mass
	5	9/2	Dielectrics	Key dielectrics, polarization, capacitance
2	6	9/7	Bulk Crystal Growth I	Czochralski growth
	7	9/9	Bulk Crystal Growth II	Float Zone and Bridgman growth
	8	9/12	Wafer Preparation	Dicing and chemical mechanical polishing
3	9	9/14	Thin Film Growth I	PVD overview, thermal evaporation, MBE
	10	9/16	Thin Film Growth II	Sputtering, e-beam deposition, PLD
	11	9/19	Thin Film Growth III	CVD overview, MOCVD, CBE
4	12	9/21	Characterization I	Electrical transport: conductivity, carrier mobility
	13	9/23	Characterization II	XRD/XRR: crystal characterization
	14	9/26	Characterization III	Microscopy: defect and device quality analysis
	15	9/28	<b>Exam I: Electronic Materials Growth and Characterization</b>	

	16	<b>9/30</b>		
5	17	10/3	Lithography I	Photolithography, proximity and contact methods
	18	10/5	Lithography II	Masks and photoresists
	19	10/7	Lithography III	Advanced lithography methods (projection, e-beam)
6	20	10/10	Etching I	Wet etching
	21	10/12	Etching II	Plasma etching, high-density plasma etching
	22	10/14	Etching III	Reactive ion etching
	23	10/17	Etching IV	Ion milling
7	24	10/19	Implantation I	Ion implantation, ion sources, Coulomb scattering
	25	10/21	Implantation II	Channeling, shallow junctions, implantation damage
8	26	10/24	Dopant Diffusion	Fick's law, dopant diffusion
	27	10/26	Rapid Thermal Processing	Radiative heat transfer, RTP designs and applications
	28	10/28	Thermal Oxidation	Deal-Grove model, oxidation regimes, SiO <sub>2</sub> vs. GeO <sub>2</sub>
	29	<b>10/31</b>	<b>Exam II: Nanofabrication Processes</b>	
	30	<b>11/2</b>		
9	31	11/4	Metal Contacts	Ohmic vs. Schottky contacts, transmission lines
	32	11/7	Diodes I	pn junction physics and transport
	33	11/9	Diodes II	Applications: Solar cells
	34	11/14	Diodes III	Applications: LEDs and lasers
10	35	11/16	Logic Devices I	Bipolar junction transistors (BJTs)
	36	11/18	Logic Devices II	MOSFETs
	37	11/21	Logic Devices III	CMOS Scaling: FinFETs, TunnelFets
	38	11/28	Logic Devices IV	Device biasing practice
11	39	11/30	Memory Devices I	DRAM, SRAM
	40	12/2	Memory Devices II	Flash, ReRAM, MRAM
	41	<b>12/5</b>	<b>Exam III: Device Technologies</b>	
	42	<b>12/7</b>		

### ***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	9/28 - 9/30
Exam II	15%	Once	10/31 - 11/2
Exam III	15%	Once	12/5 - 12/7
Term Paper	25%	Three checkpoints coincide with the starting date of each of the three Exams	
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. 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 roughly 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.

*Term Paper:* This assignment is to write a short literature review on any subtopic listed in the course schedule. Each student will select a topic and submit a one-paragraph abstract as a preview, which will be due by the start of Exam I. The student will then expand that abstract and feedback into a five-page draft report on their topic, due by the start of Exam II. Both the abstract and draft will be reviewed by myself and a group of peers, with your grade being an average of the reviewer scores. A full list of requirements for the abstract and report, as well as grading rubrics for the sub-assignments will be provided via Canvas.

**All unexcused missed assignments will be accepted within the first 24 hrs after the deadline for a maximum 50% credit. Between 24-48 hrs maximum credit drops to 25%. After 48 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](mailto:rbielling@eng.ufl.edu)
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, [taylor@eng.ufl.edu](mailto:taylor@eng.ufl.edu)
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, [nishida@eng.ufl.edu](mailto: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](mailto: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](mailto: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](https://respect.ufsa.ufl.edu))
- *Student Health Care Center* (352-392-1161, [shcc.ufl.edu](https://shcc.ufl.edu))
- *Multicultural & Diversity Affairs* (352-392-1217, [multicultural.ufl.edu](https://multicultural.ufl.edu))
- *UF Health Shands Emergency Room / Trauma Center* (352-733-0111)
- *Gainesville Police Department* (non-emergency #: 352-955-1818, [gainesvillepd.org](https://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](mailto: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](mailto: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](mailto: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](https://www.dso.ufl.edu/documents/UF_Complaints_policy.pdf).

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