

“Advanced Electronic Materials” Syllabus

EMA 4615: Compound Semiconductor Materials

EMA 6412: Synthesis and Characterization of Electronic Materials

Class Period: MWF 10:40am – 11:30am (Period 4)

Office Hours: TBD – will poll at start of course

Locations: NEB 0102

Academic Term: Spring 2023

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 co-listed undergraduate/graduate class (4615/6412). The course builds on a basic understanding of electronic properties of materials (EMA 3413) and nanofabrication processing techniques (EMA 4614) and provides an overview of electronic materials that have emerged over the last few decades. These “beyond silicon” electronic materials enabled more flexible, energy-efficient, and better light-emitting electronics and led to the development of many familiar technologies including flat screens, wearable devices, and infrared detectors.

Course Pre-Requisites / Co-Requisites

Suggested: EMA 4614/6616, and either EMA 3413 or EEE 3396C

Course Objectives

The course begins with a recap of reciprocal space and electronic band structures, which lay the foundation for understanding the properties of electronic materials. From there, we discuss III-V and II-VI compound semiconductors, like GaAs and ZnSe, how they can be grown as multi-layer thin films to design unique electronic behavior at the heterointerfaces between two different electronic materials, and how these materials have been utilized for better transistors and optoelectronics. In the second half of the course, we consider three other categories of electronic materials including: (1) organic electronics, (2) low-dimensional electronics, and (3) correlated oxide electronics. For each of these, we will consider the common structures found in these material classes, how that structure gives rise to electronic behavior different than silicon or compound semiconductors, and how that unique behavior has been leveraged to create new technologies.

Materials and Supply Fees: None

Required Textbooks and Software: None

Recommended Course Materials

- Helpful texts:
 - **For Background/Foundation:** *Principles of Electronic Materials and Devices*, S. O. Kasap, third edition, McGraw-Hill, 2006, ISBN-10: 0072957913.
 - **Module 1:** *Introduction to Solid State Physics*, C. Kittel, eighth edition, Wiley, 2004, ISBN-10: 047141526X
 - **Module 2:** *Semiconductor Device Physics and Design*, U. K. Mishra and J. Singh, first edition, Springer, 2008, ISBN: 9781402064807
 - **Module 3:** *Organometallic Vapor Phase Epitaxy*, G. B. Stringfellow, second edition, Associated Press, 1998, ISBN-10: 0126738424
- [Nanohub.org](https://nanohub.org) account – will be used for device simulations occasionally

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	Subtopics*
0: Course Introduction	1	Course and syllabus overview
1: Reciprocal Space & Electronic Band Structures	2	Revisit: Crystal structures, compound semiconductors
	3	Phonon and phonon E-k spectra
	4	Fourier transforms to reciprocal space
	5	Brillouin zones
	6	Fermi's free electron gas model
	7	Nearly free electron gases & E-k band structures
2: Compound Semiconductor Electronics	8	Heterojunction types and terminology
	9	Ideal and non-ideal single heterojunctions
	10	HBTs vs. BJTs
	11	MESFETs and MODFETs
	12	Multi-junctions for optoelectronics
	13	LEDs and lasers
	14	Band gap tuning in compound semiconductors

3: Epitaxial Film Growth	15	Defining epitaxy
	16	Epitaxial growth modes
	17	MBE1: Vacuum technology
	18	MBE2: Evaporation, flux transport, and growth rates
	19	Pulsed laser deposition (PLD)
	20	Metal-organic chemical vapor deposition (MOCVD)
Exam I	21	<Buffer for extra time on any Exam I topic>
	22	Exam I Review
4: Organic Electronics	23	Exam I Questions
	24	Intro to organic semiconductors
	25	Charge transfer and light absorption in organics
	26	Synthesis methods
--- Spring Break ---		
4: Organic Electronics	27	Organic LEDs (OLEDs)
	28	Organic photovoltaics
5: Low-dimensional Electronics	29	Effect of dimensionality on band structure
	30	0D – Quantum dots
	31	1D – Carbon nanotubes, nanowires for QC
	32	2D – Flexible devices, graphene
6: Strongly Correlated Electronics	33	2D – Transition metal dichalcogenides (TMDCs)
	34	Electron correlations, and oxide crystal structures
	35	Mott metal-insulator transition, MottFETs
	36	Interfacial spin-orbit coupling devices (MESO)
	37	Magnetic oxides for spintronics
	38	Magneto-ionic switches
Exam II	39	<Buffer for extra time on any Exam II topic>
	40	Exam II Review
	41	Exam II Questions
B (Buffer or Bonus): Topological Electronics	42	Spin-orbit coupling and band topology 101
	43	Example: HgTe/CdTe infrared detectors

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, 1/9. The first lecture will be posted Saturday, 1/7, which is also when the course's Canvas will become open. The next class is Wednesday, 1/7, and the corresponding lecture will be available on Wednesday, 1/5, and so on throughout the semester.

	Sat.	Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat. + 1
Synchro. Class			Class 1		Class2		Class 3	
Lecture Posted	Lecture 1		Lecture 2		Lecture 3			Lecture 4

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 via Zoom. A time or times will be selected at the start of the course via Canvas polls. Reoccurring Zoom links for office hours and the live class sessions are at the top of the syllabus.

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	Due Date
Module Wrap-Up	5%	End of every module	Three days after the last class of the module
Homework	20%		
Exam I	25%	Once	~3/1
Exam II	25%		~4/19
Final Project	25%		First Draft: 3/10 Final Draft: 4/26
Total	100%		

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.

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.

Exams: There will be two 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.

Final Project: You will record a 5-8 minute mini-lecture video with slides to teach your peers more about one of the subtopics from the course schedule, or a closely related topic to be approved by me. Your first-drafts will be uploaded to Canvas mid-semester, and you will receive peer and my feedback. You will then have the option to incorporate that feedback, refine your video, and turn it in at the end of the semester for a final round of peer and professor grading, or keep your initial grade and skip the final submission. More details can be found on Canvas on the assignment page.

All unexcused missed assignments will be accepted between 0-24 hrs after the deadline for a maximum 50% credit. Between 24-48 hrs, max. credit drops to 25%. After 48 hrs, the assignment receives 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>.