Fabrication of Micro/Nano Devices and Systems

EEL 5934   Section 6

Class Periods: Tuesday 7 (1:55 – 2:45 PM), Thursday 7-8 (1:55 – 3:50 PM)
Location: Larsen 239
Academic Term: Fall 2022

Instructor:

Jack Judy
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M: 352-672-1787
Office Hours: TBD

Teaching Assistant/Peer Mentor/Supervised Teaching Student:

None

Course Description

(3 credits): Introduction to the fabrication of microsystems and nanosystems, such as micro-electro-mechanical systems (MEMS) and nano-electro-mechanical systems (NEMS), which are used for many different applications (IoT, biomedical, aerospace, automotive, environmental, defense, biometric cyber security, etc.). Topics include scaling laws, many micro-/nano-machining processes used to produce MEMS/NEMS, process integration, packaging, and other manufacturing issues.

Course Pre-Requisites / Co-Requisites

Elementary Differential Equations, College Physics, and General Chemistry 1, or permission of the instructor.

Course Objectives

Since microsystems and nanosystems are used in a wide variety of applications (e.g., sensing and actuation for electronic, mechanical, biomedical, environmental, etc.), this course seeks to teach students from many different backgrounds how to manufacture microsystems and nanosystems through the integration of a wide variety of different micro-/nano-machining methods. Many different micro-/nano-fabrication steps, unique to the production of microsystems and nanosystems, will be described in detail.

Materials and Supply Fees

None.

Required Textbooks and Software

1. M. Madou, Fundamentals of Microfabrication and Nanotechnology, Vol. II (1st Edition), CRC Press, 2011.
2. Readings to be handed out in class.

Recommended Materials

1. Books:
   - R.C. Jaeger, *Introduction to Microelectronic Fabrication*, Prentice Hall, 2002.
   - S. Wolf and R.N. Tauber, *Silicon Processing for the VLSI Era, Volume 1 – Process Technology, 2nd Edition*, 2000.
   - S. Senturia, *Microsystem Design, 2nd Edition*, Kluwer Academic Publishers, 2004

- N. Maluf, *An Introduction to Microelectromechanical Systems Engineering*, Artech House, 2000.
- G. Kovacs, *Micromachined Transducers Sourcebook*, McGraw-Hill,1998
- W. Trimmer, Editor, *Micromechanics and MEMS*, IEEE Press, 1997

2. Primary Journals:
   - J. Microelectromechanical Systems (IEEE/ASME)
   - J. Micromechanics and Microengineering (IoP)
   - Sensors and Actuators (Elsevier)
   - IEEE Sensors Journal (IEEE)

Course Schedule

Week	Topics	Due (estimated)
Week 1:	Admin, Introduction to Micro/Nano Devices and Systems	
Week 2:	Applications and Markets for Micro/Nano Systems	
	Scaling Laws, Contamination, Cleaning, and Yield	
Week 3:	Fabrication Geometries, Process Flows	HW 1
Week 4:	Photolithography: Layout, Design Rules, Basics	HW 2
Week 5:	Photolithography: Exposure Systems & DOE	HW 3
Week 6:	DOE and Additive Micro/Nano Manufacturing	HW 4
Week 7:	Subtractive Micro/Nano Fabrication, Substrates	
	Midterm I (Scaling through DOE)	
Week 8:	Deposition: Oxidation, Diffusion	HW 5
Week 9:	Deposition: Ion Implantation, Vacuum Systems, PVD	HW 6
Week 10:	Deposition: PVD, CVD, ALD, Plating	
Week 11:	Etching: Wet and Dry	HW 7
Week 12:	Etching: Dry, Laser, and Other Processes	HW 8
Week 13:	Packaging: Bonding	
	Midterm II (Deposition through Etching)	
Week 14:	Process Integration: Soft Lithography	HW 9
Week 15:	Process Integration: Examples	
Week 16:	Process Integration: Examples, Modules, Travelers	HW 10

HW 1 - Apps, Markets, Scaling+
HW 2- Processes
HW 3- Photolithography
HW 4 – DOE
Midterm I (Scaling through DOE)
HW 5 - Additive
HW 6 - Oxidation, Diff., Imp.
HW 7 - Vac. PVD, CVD, ALD
HW 8 - Wet & Dry Etching
Midterm II (Deposition through Etching)
HW 9 - Other Etching, Packaging
HW 10 - Process Integration
Final – All above topics but strong emphasis on process integration.

Attendance Policy, Class Expectations, and Make-Up Policy

Excused absences must be consistent with university policies in the undergraduate catalog (https://catalog.ufl.edu/ugrad/current/regulations/info/attendance.aspx) and require appropriate documentation.

Evaluation of Grades

Assignment	Percentage of Final Grade (Grad Section)
Homework Sets (10)	40%
Midterm Exams (2)	30%
Final Exam (1)	30%
Total:	100%

Homework: <u>DUE AT BEGINNING OF CLASS PERIOD</u>
-10% if turned in after lecture begins
-20% if turned in after lecture ends (up to 24 hours late)

Grading Policy

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

More information on UF grading policy may be found at:
http://gradcatalog.ufl.edu/content.php?catoid=10&navoid=2020#grades

Students Requiring Accommodations
Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting https://disability.ufl.edu/students/get-started/. It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

Course Evaluation
Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at https://gatorevals.aa.ufl.edu/students/. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via https://ufl.bluera.com/ufl/. Summaries of course evaluation results are available to students at https://gatorevals.aa.ufl.edu/public-results/.

In-Class Recording

Students are allowed to record video or audio of class lectures. However, the purposes for which these recordings may be used are strictly controlled. The only allowable purposes are (1) for personal educational use, (2) in connection with a complaint to the university, or (3) as evidence in, or in preparation for, a criminal or civil proceeding. All other purposes are prohibited. Specifically, students may not publish recorded lectures without the written consent of the instructor.

A "class lecture" is an educational presentation intended to inform or teach enrolled students about a particular subject, including any instructor-led discussions that form part of the presentation, and delivered by any instructor hired or appointed by the University, or by a guest instructor, as part of a University of Florida course. A class lecture does not include lab sessions, student presentations, clinical presentations such as patient history, academic exercises involving solely student participation, assessments (quizzes, tests, exams), field trips, private conversations between students in the class or between a student and the faculty or lecturer during a class session.

Publication without permission of the instructor is prohibited. To "publish" means to share, transmit, circulate, distribute, or provide access to a recording, regardless of format or medium, to another person (or persons), including but not limited to another student within the same class section. Additionally, a recording, or transcript of a recording, is considered published if it is posted on or uploaded to, in whole or in part, any media platform, including but not limited to social media, book, magazine, newspaper, leaflet, or third party note/tutoring services. A student who publishes a recording without written consent may be subject to a civil cause of action instituted by a person injured by the publication and/or discipline under UF Regulation 4.040 Student Honor Code and Student Conduct Code.

University Honesty Policy
UF students are bound by The Honor Pledge which states, "We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: "On my honor, I have neither given nor received unauthorized aid in doing this assignment." The Conduct Code (https://sccr.dso.ufl.edu/process/student-conduct-code/) specifies a number of behaviors that are in violation of this code and the possible sanctions. If you have any questions or concerns, please consult with the instructor 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
• Jennifer Nappo, Director of Human Resources, 352-392-0904, jpennacc@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:

Health and Wellness

Covid-19 Protocols:
- You are expected to wear approved face coverings at all times during class and within buildings even if you are vaccinated. Please continue to follow healthy habits, including best practices like frequent hand washing. Following these practices is our responsibility as Gators.

- 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. 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.

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

Counseling and Wellness Center: https://counseling.ufl.edu, 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 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://career.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://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/;https://care.dso.ufl.edu.

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