Syllabus
Spring Semester 2023
Fundamentals of Microfabrication
ECE 5221, ECE 6221, ME EN 5050, ME EN 6050, BME 6421, MSE 6421 (3 Units)
MoWe / 11:50AM-12:40PM WEB L104

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Course webpage: Canvas,

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Course TAs: Chayanjit Gosh (Grader) u1014842@utah.edu
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The objective of this course is to teach the attending students the fundamentals of microfabrication. Topics are fundamental definitions, application fields of microfabricated devices, general overview over microfabrication processes, technologies and relevant microfabrication materials. Further topics include an introduction to clean room and vacuum technology as well as various microfabrication technologies such as substrate fabrication, oxidation, chemical vapor deposition, physical vapor deposition, lithography, ion implantation, lithography, wet and dry etching, and more advanced techniques as well as packaging of microfabricated structures. Extra work required of graduate students.

Canvas will be used to administer the class. Important announcements will be posted there and students need to ensure they can access these announcements.

The classes will be taught in person unless COVID related circumstances requires a partial or full transition to an online format.

Please note that the class includes a compulsory laboratory section, that constitutes significant value for your educational experience and your resume. We are in the unique position at the University of Utah to be able to provide access to a world class micro and nanofabrication cleanroom facility that supports solid state, sensors, MEMS and biomedical device fabrication, testing and characterization. As confirmed by alumni and employers, having practical experience in cleanroom microfabrication constitutes a key

competitive advantage for students applying for their first jobs in relevant areas that make use of these technologies.

As part of the Microfabrication Lab, you will be designing, fabricating and testing a simple microfabricated sensor device, that you will be able to take home upon completion of your class. Lab sessions are reserved as 3h time slots that will be offered from Tuesday to Friday (8am-11am, 11am-2pm, 2pm-5pm). This will allow for sufficient preparation time, gowning/de-gowning and debriefing. How many and what exact time slots are offered will depend on the number of students in the class and decided in the first week of the semester. Before each lab a set of short questions will be posted in Canvas. The students will need to work on these questions to prepare themselves for the lab session. Before entering the lab, the TA will discuss the questions with the students to ensure that these questions have been completed. If students demonstrate insufficient preparation they may be banned from the corresponding lab and will be required to talk to the main instructor for a make up assignment. After each lab section, the students will write a small protocol to discuss the initial questions, the experiments and the results. This protocol needs to be submitted prior to the next lab section and will be part of the grade. Failure to comply with individual lab entrance requirements more than once throughout the course will lead to exclusion from the course (incomplete course).

Work is done in teams of 3 people, with two teams (6 people total) constituting one lab session that is supported by one TA and members of the Nanofab technical staff. Since the lecture part of the class is taught only twice per week (50 min each), the additional lab hours justify the credit hours of the class. The homework assignments will ask the students to answer questions related to the previous week to consolidate knowledge, gives a task to support the current weeks lecture and will ask the students for a limited literature research / other assignment to prepare for the following week. Please schedule sufficient time in your weekly schedule for these assignments.

Course slides serve as framework and “textbook” for the course, only. Examples and supplemental information that may be relevant for exam preparation will be given throughout the class. Additional reading suggestions will be also given on the course slides.

The University of Utah seeks to provide equal access to its programs, services, and activities for people with disabilities. If you will need accommodations in this class, reasonable prior notice needs to be given to the Center for Disability Services, 162 Olpin Union Building, 801-581-5020. CDS will work with you and the instructor to make arrangements for accommodations. All written information in this course can be made available in an alternative format with prior notification to the Center for Disability Services.

No.	Lecture	Session	Date
1.	**Overview and Introduction** Instructor introduction, first example: cantilever-based microsensors, objectives and structure of lecture, overview, definitions, application fields, microfabrication technologies and processes, introduction to photolithography	1-3	01/09 - 01/18
2.	**Cleanroom Technology** Contamination sources, cleanroom classes, cleanroom concepts, Particle measurement (purpose, methods), DI water (properties, fabrication, control)	4-5	01/23 - 01/25
3.	**Materials** Properties of solid-state materials, crystal structure (Si, GaAs), semiconductor effects, comparison of materials	6-9	01/30 - 02/08
4.	**Substrate Fabrication** Si ingot fabrication, Floating Zone, dicing, polishing, wafer geometry	10	02/13
6.	**Oxidation** Dry oxidation, wet oxidation, oxidation kinetics (deal grove model), oxide properties	11	02/15
7.	**Chemical Vapor Deposition** LPCVD, PECVD, processes (SiO2, Si3N4, LTO,), reactors	12	02/22
	Mid-term exam preparation	13	03/27

No.	Lecture	Session	Date
	Mid-term exam		03/01
8.	**Physical Vapor Deposition** E-beam evaporation, sputtering, HF, magnetron sputtering, equipment	14	03/13
9.	**Lithography** Process steps, resists**,** coating, developing, removing, contact and proximity exposure, alignment and marks, light sources	15-16	03/15 - 03/20
10.	**Layer Structuring** Structuring fabrication principles, dry/wet etch, isotropic etching, anisotropic etching, lift-off process, anisotropic etching	18-21	03/22 - 03/29
11.	**Layer Modification** Doping, diffusion and diffusion barriers, ion implantation, annealing	22	04/03
12.	**Packaging** Wire bonding (ball-wedge, wedge-wedge, Au, Al), Flip Chip Bonding, thick film / thin film technology	23	04/10
13.	**Introduction to Vacuum Technology** Partial pressure, mean free path, absorption, desorption, pumps (turbo, cryo, etc.), leakage, pressure ranges for processes	24	04/12
14.	**Advanced Topics / Buffer**	25	04/17
15.	**Final Exam preparation**	26-27	04/19 - 04/24
	Final Exam		04/27

Please note that given dates for the classes are an estimate only. Exams, however will take place on the given date unless otherwise announced in the class and on Canvas.

Lab topics
Week 1: Sign-up for laboratory sections
Week 2: Introduction to device design and planned process flow
Week 3: FEA/numerical simulation of device design: build FEA model
Week 4: FEA/numerical simulation of device design: meshing and current application
Week 5: FEA/numerical simulation of device design: generate and plot simulation data, analysis
Week 6: Nanofab lab safety training and test
Week 7: Buffer for delays / make up week
Week 8: Chemical Vapor Deposition of Nitride Layer
Week 9: Heater photolithography and metal deposition
Week 10: Heater lift-off
Week 11: Backside photolithography
Week 12: Backside nitride and oxide etch, Potassium hydroxide etch
Week 13: Testing and characterization
Week 14: Buffer for delays / make up week

Exams and Grading
The quizzes after each class are a series of easy questions to solidify knowledge and ensure that the students participated in the class. A quiz may be retaken 2 times and >75% correctness level is necessary to pass. If students fail a quiz, they need to get in contact with the instructor to discuss this and receive a pass at the discretion of the instructor (in such a case the quiz will still be counted as 0 points). Students need to pass all but one of the previous quizzes to be eligible to participate in the midterm or final exam. All passed quizzes contribute points towards the final grade depending on correctness level.

The final grade consists of:

1. Canvas Quizzes (10% of final grade)
2. Lab reports (10% of final grade)
3. Homework assignments (20% of final grade)
4. Midterm exam (25% of final grade)
5. Final Exam (35% of final grade)

All assignments and reports are due on the time that is stated when given the assignments. Late assignments will be accepted only at the discretion of the instructor if sufficient reason is given, but not after the content was already discussed in the class.

Due to the ongoing pandemic the exact nature of midterm and final exams will be decided based at a later time base upon recommendations by the college. Currently they are planned as in-person closed book exams with one (Mid-term) or two pages (Final) letter size **handwritten** notes allowed.

Typical approach towards grading: Curved (may be adjusted, depending on distribution and situation):

A range	better than: average "+" standard deviation
B range	in the range: average "+/-" standard deviation (between A and C range)
C range	below: average "–" standard deviation
E range	less than half of the highest mark

Comment: B range means there may be a shift to B- or B+ depending on grade distribution (lower third: B-, intermediate third: B, upper third B+)

College of Engineering policies for students on adding/dropping/withdrawing/repeating classes at: https://www.ece.utah.edu/ugpolicies

Difference between 5000 and 6000 level

6000 level students will be required to answer additional advanced questions in mid-term and final exam. In addition, a small literature review project will be required in the second half of the semester (pass/no pass). Voluntary collaboration or contribution of 6000 level students is permissible but will not lead to additional credit.

Office hours
Tue 1:30-3:30, virtual

Feedback on course and lab content as well as general MEMS questions are always encouraged.

Note: This syllabus is not a contract. It is meant to serve as an outline and guide for our course. Please note that the instructor may modify it and the course schedule to accommodate different situations and the needs of the class. Any changes will be announced in class and posted on Canvas under Announcements.

Personal concerns such as stress, anxiety, relationship difficulties, depression, cross-cultural differences, etc., can interfere with a student's ability to succeed and thrive at the University of Utah. For helpful resources contact the Center for Student Wellness at www.wellness.utah.edu or 801-581-7776.

Class rosters are provided to the instructor with the student's legal name as well as "Preferred first name" (if previously entered by you in the Student Profile section of your CIS account). While CIS refers to this as merely a preference, I will honor you by referring to you with the name and pronoun that feels best for you in class, on papers, exams, group projects, etc. Please advise me of any name or pronoun changes (and update CIS) so I can help create a learning environment in which you, your name, and your pronoun will be respected. If you need assistance getting your preferred name on your UID card, please visit the LGBT Resource Center Room 409 in the Olpin Union Building, or email bpeacock@sa.utah.edu to schedule a time to drop by. The LGBT Resource Center hours are M-F 8am-5pm, and 8am-6pm on Tuesdays.

***Addressing Sexual Misconduct**. Title IX makes it clear that violence and harassment based on sex and gender (which Includes sexual orientation and gender identity/expression) is a civil rights offense subject to the same kinds of accountability and the same kinds of support applied to offenses against other protected categories such as race, national origin, color, religion, age, status as a person with a disability, veteran's status or genetic information. If you or someone you know has been harassed or assaulted, you are encouraged to report it to the Title IX Coordinator in the Office of Equal Opportunity and Affirmative Action, 135 Park Building, 801-581-8365, or the Office of the Dean of Students, 270 Union Building, 801-581-7066. For support and confidential consultation, contact the Center for Student Wellness, 426 SSB, 801-581-7776. To report to the police, contact the Department of Public Safety, 801-585-2677(COPS).*