ECE 600 Advanced Device Fabrication Spring 2020 Syllabus

Instructor: Dr. C.K. Harnett, Shumaker 248
Contact: c0harn01@louisville.edu - Ask questions online at http://bit.ly/AdvDevFab
Teaching Assistants: N/A
Lecture: Tuesdays & Thursdays 2:30-3:45, W. S. Speed 106
Office Hours: TBA
Prerequisites: Graduate standing or permission from instructor
Textbooks:
1. PDF course notes free from instructor
2. *Plastic Fantastic*, Eugenie Samuel Reich. ISBN-13: 978-0230623842

Objectives: Students will use course notes to review the fundamental properties and processing methods for new, unconventional materials that make flexible and stretchable electronics possible. A major objective is for students to understand the influence of processing on materials' electrical, optical, and mechanical properties. Through homework assignments and case studies, the class will determine how to align, combine, and characterize soft materials for specific applications. Students will tour labs in ECE, ChE and BioE, and then do individual reports related to a current or their own possible future research topic. Based on these studies and assigned reading, students should develop a realistic understanding of the state of the art in soft, printable and stretchable devices.

Course Learning Outcomes - students who complete this course will be able to:
1. Evaluate the influence of processing on materials' electrical, optical, and mechanical properties.
2. Apply engineering principles to plot data points and compare them against a mathematical model (given in homework assignments)
3. Propose a realistic process to fabricate a device from soft and flexible materials.
4. Package an idea for intellectual property evaluation.
5. Conduct a literature review based on a research topic.
6. Demonstrate command of a topic in a research paper by making a brief presentation in class
7. Critically evaluate extraordinary claims in research papers and press releases.

Topics: See schedule below.
Overview:
Solar cells printed from electronic inks. Stretchable circuits and bendable displays. Wearable sensors. 3D printed biological tissues. Fibers that sense and actuate. Soft inflatable robots. These "extreme machines" show how printable, soft, and stretchable materials are taking us to the science fiction future. How can we make devices with them?
Compared to the 70+ year history of semiconductor electronics, these soft material systems are young. Advances in semiconductors gave us computers. Now, low-cost computers make it possible to 3D print, pattern, and assemble soft materials with new functions. New forms of materials include nanoparticle inks that conduct electricity and emit light. Tissue engineers now use soft 3D printable biocompatible materials to host biological cells and sculpt them into organs. Conventional semiconductors recently joined the soft materials family in ultrathin forms that are flexible and even stretchable.

Students will be guided through the research literature to explore how to identify the advantages of these new materials and put them to work in devices.

Coursework Policies:
Reports are to be written on a computer; *this includes text, calculations, and figures.*
Point Values: Point values will depend on the particular project and experiment, and will be specified along with the details of each assignment.
Late Work: A penalty of 5 percent of the assignment's point value will be applied to each day, or part thereof, that the report is late. Exceptions may be made, on an individual basis, if arranged in advance with the instructor, for certain documentable extraordinary circumstances.
Plagiarism: See "Academic Dishonesty" below. We will rely on others' writing to build research plans, and you will be trained on citing others work properly. If someone else said it better, quote directly with "quotation marks" and cite the book, journal article, website or other source using your citation manager.
Electronic Submission of Assignmentss: You'll send in reports, slides and other assignments electronically via BlackBoard. Formats for slides should be PowerPoint (.pptx) or Prezi. Reports should be Word (in *.docx* format). Make an effort to use vector graphics (.eps, .ps, .pdf, .svg, .ai, .dxf) for all graphs and drawn figures, while bitmaps (.jpg, .tif, .bmp, .gif) are acceptable for photos at 400dpi or higher. Exceptions are made for certain images (for example some electron microscope images) that only exist in low resolution format. You may zip your files for easier uploading to BlackBoard. The only items accepted on paper for course credit are in-class quizzes. *Credit will not be given for work that is illegibly scanned, papers that are pushed under an instructor's office door, and/or items that are sent to instructors by email.*

Presentations: One midterm presentation on a material (5%) and one final presentation on a proposed device (10%).
Midterm Report: A report on an advanced material from a journal article (10%).
Technical Disclosure. Fill out the U of Louisville Research Disclosure form with your device idea based on an advanced material from one of a set of journal articles (5%).
Participation (Class discussions, attendance at lectures and all lab tours, a couple of quizzes) 5%
Homework: 40% (8 assignments each worth 5%)
Final Paper: Describe a problem your proposed device will solve (1-2 page), literature review of state of the art devices and background on the material you will use to make the device (4-5 pages), a process diagram and description of how it will be fabricated (1-2 pages), and methods for characterizing your results and evaluating success (2 pages). Combine into a **single final paper** worth 25% of your course grade.

ECE 600 Final Exam The final paper is due on the final exam date of April 24.

Grading: Your final grade will be based on the following:

Activity	Percentage Grade

Presentations (2)	15%
Midterm Report	10%
Technical Disclosure	5%
Participation	5%
Homework (8)	40%
Final Paper	25%
TOTAL	100%

Grade Scale: Grades will be assigned on a plus/minus scale.

A+	97-100
A	90 – 97
A-	88 – 90
B+	85 – 88
B	80 – 85
B-	78 – 80
C+	75 – 78
C	70 – 75
C-	68 – 70
D	60 – 68
F	< 60

Topics week-by-week
Week 1
Soft Materials Families:
Nanoparticle/Fiber/Polymer/Thin films —
Our course modules are organized in the order of this material family tree.
Scaling plots.

Week 2
Nanoparticles: Fundamentals and homework – Nanoparticle self assembly forces
Nanoparticle behavior in solutions, on surfaces and when drying
Silver colloid ink

Week 3
Nanoparticle processing:
Solution processing: Inkjetting, spraying. Optomec and Dimatix
Semiconductor nanoparticle ink/Solar cell lab

Week 4
Mechanics:
What does 'soft' mean: it stretches or bends a 'lot' for a 'small' force
Fluid flow (need this later when discussing hydrogel printing)
Capillary forces & other forces in soft materials: fundamentals and homework
Soft to hard interface problem

Week 5
Soft Robotics:

Elastomers, what are they
Sacrificial materials, what and why

Week 6
Fibers:
Mechanical properties of fibers
Extrusion
Liquid crystal elastomer actuator fibers, coiled polymer actuator fibers
Polymers + Fibers: a composite soft material
Fiber reinforced soft robots

Week 7
Optics:
Fiber optics
Optical properties of soft materials
Stretchable optical fibers: lab visit
Quantum dots revisited (because of their optical properties)

Week 8
Gels:
Hydrogels, micelles
3D printing micro and macro objects from gels–Resolution limits homework
Biological applications overview. Tissue printing requirements for biocompatibility.
Gel printing tour (lab hydrogel printer & enzymes)

Week 9
Electronics:
Review concepts: conductivity, LEDs, transistors
Review what is already happening: Flexible circuit industry, anisotropic conductive films are commercial. Some are intrinsically stretchable (zebra connectors) others just bendable. Liquid metals are still cutting-edge.
PEDOT, organic semiconductor inks (and other materials) for flexible displays
Plastic Fantastic: hype vs reality.
Commercial products with organic semiconductors: lightweight, yet giant TVs

Week 10
Thin Films:
Conventional semiconductors as flexible materials: stretchable electronics from thin films
What are thin films? What about graphene?
What makes a thin film “stretchable?”

Week 11
Case Studies:
Students present case studies on advanced materials from assigned journal papers.
Students can develop final presentations on this, or a different topic.

Week 12
Compliant microlectromechanical systems (MEMS):
MEMS as soft materials: Compliant MEMS membranes and structures
MEMS crash course, fundamentals and homework
MEMS lab tour: Compliant MEMS fabric grippers

Week 13 Review recent literature with an eye on applications and characterization
Advanced topics: soft flexible electrode arrays for brain/nerve/skin interaction
Advanced topics: soft paper and thread-based chemical sensors
Advanced topics: soft robotic skins

Week 14
Advanced topics: integrating soft materials into wearable systems
Advanced topics: wearability/washability/user acceptance
Advanced topics: soft materials for energy harvesting

Week 15
Individual presentations.

DISABILITIES: The University of Louisville is committed to providing access to programs and services for qualified students with disabilities. Students with disabilities, who need reasonable accommodation to complete assignments successfully and otherwise satisfy course criteria, are encouraged to meet with the instructor during the first week of the semester to identify and plan specific accommodations. Students are asked to supply a letter from the Disability Resource Center, certifying their eligibility, and other documentation, as needed, which will assist in planning of modifications. Students may also contact the Disability Resource Center for information, verification of eligibility and auxiliary aid.
PARTICIPATION in U*of*L-SANCTIONED EVENTS: Students who will be absent in order to participate in UofL-sanctioned events or activities, which are defined as "…event(s) in which a student represents the university to external constituencies in academic or extra-curricular activities," are required to notify the instructor in the first week of the semester, or on the same day that they are notified of participation, regarding the specific date(s) of their projected absence(s). Students will be responsible for all work and/or assignments missed.
RELIGIOUS HOLIDAYS: Students who will be absent in order to observe religious work-restricted holidays are asked to notify the instructor in the first week of the semester regarding the specific dates of their projected absences. Students will be responsible for all work and/or assignments missed.
ACADEMIC and PROFESSIONAL INTEGRITY: I expect you to act professionally and ethically, in accordance with the **Code of Student Rights and**

Responsibilities (*UofL Undergraduate Catalog*, Summer 2011 - Spring 2012, at http://louisville.edu/undergraduatecatalog/summer-spring/univpol/admitpolicies.html (see especially, **Non-Academic Student Policies** (a misnomer for some of the items therein), **Codes of Student Conduct, Rights, and Responsibilities, Section 5. Academic Dishonesty and Section 6. Discipline Procedures for Academic Dishonesty**), and relevant sections of the **Codes of Ethics** of the relevant professional societies: the *Association for Computing Machinery* (ACM), the *Institute of Electrical and Electronics Engineers* (IEEE) and the *National Society of Professional Engineers* (NSPE). Cheating of any form, including the use of homeworks from prior semesters and plagiarism (defined in the Code of Student Rights and Responsibilities, Section 5.E. as "*Representing the words or ideas of someone else as one's own in any academic exercise, ...*" [examples follow in the Catalog] can result in disciplinary action, including an F in the course and suspension/expulsion from the School and University. I will deal with cases involving cheating in accordance with the Speed School Procedures for Dealing with Breaches in Academic Integrity.
SAMPLES of WORK for ASSESSMENT: Copies of selected student work will be made and kept in departmental files for the purpose of accreditation-related assessment.

Title IX/Clery Act Notification
Sexual misconduct (including sexual harassment, sexual assault, and any other nonconsensual behavior of a sexual nature) and sex discrimination violate University policies. Students experiencing such behavior may obtain confidential support from the PEACC Program (852-2663), Counseling Center (852-6585), and Campus Health Services (852-6479). To report sexual misconduct or sex discrimination, contact the Dean of Students (852-5787) or University of Louisville Police (852-6111).

Disclosure to University faculty or instructors of sexual misconduct, domestic violence, dating violence, or sex discrimination occurring on campus, in a University-sponsored program, or involving a campus visitor or University student or employee (whether current or former) is not confidential under Title IX. Faculty and instructors must forward such reports, including names and circumstances, to the University's Title IX officer.

For more information, see the http://louisville.edu/hr/employeerelations/sexual-misconduct-brochure