UNIVERSITY OF CALIFORNIA, MERCED

Nanodevice Fabrication (MSE 126, BIOE 126, BEST 226)
Spring, 2017

5 modules (8-9 hrs per session on average) and 11 lectures (1 hr per session on average)

Instructor: Jennifer Lu, SE2-285 jlu5@ucmerced.edu
Lecturer: Muharrem Acerce, SE2-080
Lecture: Monday 3:00 pm ~ 3:50 pm, KOLLIG 296
Lab: Tuesday 8:30 am ~ 6:30 pm SE2-080
Office Hours: Wednesday 4:00 pm - 5:00 pm (JL)
Friday 4:00 pm - 5:00 pm (MA) or by appointment

I. Course Description: The fundamentals of nanomaterial chemical synthesis and associated physical properties will be taught. Nanomaterial-enabled platforms for energy conversion such as electrochemical energy storage, fuel cells and water splitting etc. will be introduced. Students will synthesize nanostructures and characterize their properties for energy storage and electrocatalysis. *Graduate students will receive additional reading and lab assignments. Graduate students will be asked to propose their own 3D structure fabrication for effective and efficient energy conversion as a part of the final report. Furthermore additional questions that require solid understanding will be posted to them during exams.*

II. Course Goals and Outcomes:

a. ***Course Goals:***

1. Teach synthetic principles of bottom-up nanomaterial formation. Through interactive and hands-on education (lectures, lab sessions and demonstrations), students will learn how to synthesize nanoparticles (nanocatalysts) and to grow zinc oxide nanowires and carbon nanofibers using both solution-based and vapor deposition techniques;
2. Review up-to-date 3D nanostructure fabrication strategies and introduce 3D surface functionalization via polymer grafting;
3. Introduce basic concepts for energy conversion based on electrochemical reactions with the emphasis on electrochemical reactions for energy storage and for oxygen reduction for fuel cells and metal-air batteries. Student will learn how to characterize as-synthesized nanomaterial platforms. *Graduate students will be asked to develop their own 3D nanostructures with enhanced electrochemical or electrocatalytically active performances*;
4. Teach and demonstrate unique optical and electronic properties of nanomaterials;
5. Teach conventional semiconductor device fabrication techniques. Students will learn how to use photolithography to generate patterned arrays;
6. Apply fundamental knowledge in chemistry, physics and engineering for better understanding of literature.
   a. Undergraduate students will be asked to cite literature in their lab reports.
   b. *Graduate students will be required to present their critical readings of a recent paper published in Science/Nature related to energy conversion* at the end of the semester.

b. ***Learning Outcomes:*** Students will gain multi-disciplinary knowledge from chemistry, physics, materials science and engineering and electrical engineering. They will:

1. Be able to describe the mechanisms of energy conversion, *e.g.,* storage and

conversion; and be able to explain advantages of nanomaterials and possible issues related to the use of nanomaterials for these applications;

2. Be able to describe the mechanism for 1D nanomaterials growth via seed-assisted growth. Be able to explain key experimental variables and how they can affect the growth results.
3. Be able to synthesize functional nanoparticles via the polymer template approach and to be able to grow 1D nanomaterials via the solution and vapor deposition techniques;
4. Be able to employ cyclic voltammeter (mainly), *ring-rotation disk electrode and rotation disk electrode (graduate students)* for characterization;
5. Independently perform wafer cleaning and photolithography patterning;
6. Gain hands-on experience using atomic force microscopy to characterize nanostructures and scanning electron microscopy to inspect 1D nanomaterials;
7. Be ale to understand and explain some unique properties offered by nanomaterials;
8. Develop enhanced critical thinking and communication skills through solving experimental issues encountered in the lab sessions, both independently and in a team environment.
9. *Acquire protocols for obtaining precision and accuracy of measurement tools (graduate students only).*

Undergraduate Students

This course is also conceived as an opportunity for students to demonstrate a developing proficiency in the program learning outcomes that have been adopted by both MSE and BIOE programs as a whole. They relate to the following PLOs:

(a) An ability to apply knowledge of mathematics, science, and engineering.
(b) An ability to design and conduct experiments, as well as to analyze and interpret data.
(c) An ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability.
(d) An ability to function on multidisciplinary teams.
(e) An ability to identify, formulate, and solve engineering problems.
(f) An understanding of professional and ethical responsibility.
(g) An ability to communicate effectively.
(h) The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context.
(i) A recognition of the need for, and an ability to engage in life-long learning.
(j) A knowledge of contemporary issues.
(k) An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.

Graduate Students

(a) Core Knowledge – Graduates will possess the fundamental knowledge needed to understand and critically evaluate current research literature in their chosen field of materials science and engineering, and micro/nanotechnology.
(b) Research Competency – Graduates will hone their knowledge to:
(Ph.D. graduates) Independently identify new research opportunities, plan effective strategies for pursuing these opportunities, and conduct research that makes a new contribution to knowledge in their chosen field.
(c) Communication Skills - Graduates will be adept at oral and written communication of

research results in their field to expert and non-expert audiences.

(d) Ethics - Graduates will understand and promulgate the importance of research and professional ethics, and maintaining the trust of governmental and non-governmental scientific organizations, professional colleagues, and the public.

III. Format and Procedures: Lectures, demonstration and hands-on labs will be mixed with discussions, team projects and presentations.

IV. My Assumptions: Nanotechnology is a unified discipline, where many fields converge. Therefore, it can only thrive through multi-, trans and inter- disciplinary cross-fertilization. This course will clearly show students the connection of nanotechnology with several traditional fields. The proposed course teaches integrated knowledge from chemistry, physics, materials science, and electrical engineering that is not covered by any existing course. Hands-on education will not only de-mystify nanotechnology but also stimulate the students' interest in nanotechnology. The team-oriented hands-on project will provide the opportunity for students to gain much needed practical knowledge in nanoscale material synthesis and device fabrication. This will also enlist students in taking an active role in learning, thinking and problem solving through sharing and integrating knowledge from different fields.

I. Course Requirements:

a. Students are required to attend lab and discussion sessions.

b. Course readings and handouts will be distributed before the classes start. Students are encouraged to read journal articles and review fundamental knowledge.

c. Course assignments and projects: Homework including lab reports, mid-term and final paper presentation (graduate student only).

II. Grading Procedures:

For undergraduate students: The final grade will be based on lab performance and reports (65%), mid-term (15%), final (20%).

For graduate students*: The final grade will be based on reports including device performance (55%), mid-term (15%), literature reading outcome (10%) and final presentation (20%)*

III. Academic Integrity:

Course Requirements:

a. Students are required to attend lab and discussion sessions.

b. Course readings and handouts will be distributed before the classes start. Students are encouraged to read journal articles and review fundamental knowledge's.

c. Course assignments and projects: Homework including lab reports, mid-term and final paper presentation.

a. Each student in this course is expected to abide by the University of California, Merced's Academic Honesty Policy.

b. Students are encouraged to study together with other students. However, they are required to do their homework and lab work independently unless it involves the team project. Any unauthorized collaborative behavior may lead to failure of the course and University disciplinary action.

IV. Accommodations for Students with Disabilities:

The University of California Merced is committed to ensuring equal academic opportunities and inclusion for students with disabilities based on the principles of independent living, accessible universal design and diversity. I am available to discuss appropriate academic accommodations that may be required for student with disabilities. Requests for academic accommodations are to be made during the first three weeks of the semester, except for unusual circumstances. Students are required to register with the Disability Services Center to verify their eligibility for appropriate accommodations.

V. Tentative Weekly Schedule:

(Note: The schedule below is subject to revision as circumstances dictate.)

	Lecture	Lab
1		Syllabus, lab report and chemical safety
Week 2-6	Lit search, Lab report, nanocatalysis for vapor-based 1D growth	KOH etch and plating and carbon nanotube growth
	Vapor-based 1D growth	KOH etch and plating and carbon nanotube growth
	Battery and fuel cells	Acid or air annealing and cyclic voltammetry (Pt/C, microporous C, CNFs on C)
	Electrochemical Conversion- energy storage	Lab report, Battery assembly and make up sessions
	Electrochemcial Conversion - fuel cells	Electrografting N doped polymer and pyrolysis and characterization
Week 7	Polymer templates-electropolymerization for surface decoration	Lab report, Electrografting N doped polymer and pyrolysis and characterization
Week 8	Polymer templates-electropolymerization for surface decoration and review	ZnO hydrothermal
Week 9	Mid-term	ZnO hydrothermal and SEM (option: MOF)
Week 10	Review and solution-based 1D growth	Lab report, ZnO hydrothermal and SEM (option: MOF)
Week 12	Solution-based 1D growth	Block copolymer formation and AFM
13	Block copolymer templates and AFM characterization	Lab report, Nanoparticles via polymer (AFM) and block copolymer formation
14	Top-down: Lithography	2D formation, Resistance measurement before and after Gox
15	3D synthesis and applications	Cleanroom
16	Review	Lab report, MOF on ZnO fim on ITO or carbon cloth