EngrMSE 160: Advanced Laboratory in Synthesis and Characterization of Materials

Course Syllabus (2020)

Department of Materials Science and Engineering
University of California, Irvine

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Course Syllabus

Course EngrMSE 160: Advanced Laboratory in Synthesis and Characterization of Materials

Description Synthesis and characterization of ceramic, polymer, and electronic materials. Connect the process, structure, properties, and performance of materials science knowledge to a hands-on laboratory setting

Pre-requisites: ENGR 54 or Chem 130 A-B or Chem 156

Lecture Tu/Th, 9:30 - 10:50 AM in SSTR 101

Laboratory
M/W Section: 1:00-4:50pm ET 649/637
Tu/Th Section: 1:00-4:50pm ET 649/637

Instructor
Professor William Bowman
UCI Email: will.bowman
Available by appointment

Teaching Assistants
Hasti Vahidi, UCI email: vahidih
Caroline Qian, UCI email: cyqian

Lab Manager
Steve Weinstock
UCI email: steve.weinstock

Grading

Lab Reports (3)	50%
Final Presentations	20%
Pre-lab quizzes	15%
Team work	10%
Instructor discretion	5%

Campus Resources
Academics
Academic Honesty Policies
Center for Excellence in Writing and Communication

Libraries
Research Resources

Computing
Computing Laboratories

Student Expectations Outcomes

1. Apply basic and advanced fundamentals of science, mathematics, and engineering in the context of materials science and engineering to understanding synthesis, processing, characterization and properties of materials.

2. Design and conduct experiments in materials science as well as analyze and interpret data.

3. Function in teams, with students from Chemical Engineering and Materials Science and Engineering.

4. Communicate effectively, both orally and in writing as evidenced by written reports and oral presentations.

5. Understand that materials are continually evolving, requiring continuing education to learn about advances in characterization of materials.

6. Develop an ability to apply and integrate knowledge from each of the four primary elements of Materials Science and Engineering (structure, properties, processing and performance) to solve problems related to materials selection and design.

Lectures

- Week 1 – How to write a lab report
- Week 2 – Polymer synthesis
- Week 3 – Polymer characterization
- Week 4 – None
- Week 5 – Ceramic synthesis
- Week 6 – Ceramic characterization
- Week 7 – None
- Week 8 – Semiconductor synthesis
- Week 9 – Semiconductor characterization
- Week 10 – None

Lab Calendar

M/W Group 1 – 14 students (section 19432)
M/W Group 2 – 14 students (section 19433)
T/Th Group 1 – 7 students (half of section 19431)
T/Th Group 2 – 7 students (half of section 19431)

	Monday	Tuesday	Wednesday	Thursday
Week 1 **1/6 – 1/9**	No Lab	No Lab	No Lab	No Lab
		Lecture topic: How to write a lab report		No Lecture
Week 2 **1/13 – 1/16**	No Lab	No Lab	**QUIZ ON POLYMER LAB MANUAL** Polymers - Crosslinking - DSC - Hot-stage OM	**QUIZ ON POLYMER LAB MANUAL** Polymers - Crosslinking - DSC - Hot-stage OM
		Lecture topic: Polymer synthesis		No Lecture
Week 3 **1/20 – 1/23**	No Lab	No Lab	**QUIZ ON POLYMER LAB MANUAL** Polymers - Crosslinking - DSC - Hot-stage OM	**QUIZ ON POLYMER LAB MANUAL** Polymers - Crosslinking - DSC - Hot-stage OM
		Lecture topic: Polymer characterization		No Lecture
Week 4 **1/27 – 1/30**	Lab report writing workshop (optional)	Lab report writing workshop (optional)	**M/W Groups polymer lab reports due by 1 PM PST** No Lab	**T/Th Groups polymer lab reports due by 1 PM PST** No Lab
		No lecture		No Lecture
Week 5 **2/3 – 2/6**	**QUIZ ON CERAMICS LAB MANUAL** Ceramics - Si NP synthesis - ORMOSIL synthesis	**QUIZ ON CERAMICS LAB MANUAL** Ceramics - Si NP synthesis - ORMOSIL synthesis	Ceramics characterization - DLS - XRD/SEM - FTIR	Ceramics characterization - DLS - XRD/SEM - FTIR
		Lecture topic: Ceramic synthesis		No Lecture
Week 6 **2/10 – 2/13**	**QUIZ ON CERAMICS LAB MANUAL** Ceramics - Si NP synthesis - ORMOSIL synthesis	**QUIZ ON CERAMICS LAB MANUAL** Ceramics - Si NP synthesis - ORMOSIL synthesis	Ceramics characterization - DLS - XRD/SEM - FTIR	Ceramics characterization - DLS - XRD/SEM - FTIR
		Lecture topic: Ceramic characterization		No Lecture
Week 7 **2/17 – 2/20**	Lab report writing workshop (optional)	Lab report writing workshop (optional)	**M/W Groups ceramic lab reports due by 1 PM PST** No Lab	**T/Th Groups ceramic lab reports due by 1 PM PST** **No Lab**
		No lecture		No Lecture

Week 8 **2/24 – 2/27**	**QUIZ ON SEMICONDUCTOR LAB MANUAL** Semiconductors - Resistivity measurements OR - Au NP synthesis	**QUIZ ON SEMICONDUCTOR LAB MANUAL** Semiconductors - Resistivity measurements OR - Au NP synthesis	Semiconductors - Resistivity measurements OR - Au NP synthesis	Semiconductors - Resistivity measurements OR - Au NP synthesis
		Lecture topic: Semiconductor synthesis		No Lecture
Week 9 **3/2 – 3/5**	**QUIZ ON SEMICONDUCTOR LAB MANUAL** Semiconductors - Resistivity measurements OR - Au NP synthesis	**QUIZ ON SEMICONDUCTOR LAB MANUAL** Semiconductors - Resistivity measurements OR - Au NP synthesis	Semiconductors - Resistivity measurements OR - Au NP synthesis	Semiconductors - Resistivity measurements OR - Au NP synthesis
		Lecture topic: Semiconductor characterization		No Lecture
Week 10 **3/9 – 3/12**	**M/W Group 1 final presentations**	**T/Th Groups 1 & 2 final presentations**	**M/W Group 2 final presentations**	**No Lab**
		No Lecture		No Lecture
Week 11 **3/14 – 3/20**			**M/W Groups semiconductor lab reports due by 1 PM PST**	**T/Th Groups semiconductor lab reports due by 1 PM PST**

Lab Notebook A lab notebook is required for this course. It must have carbon copy pages to turn in with your lab report.

Lab Reports Lab reports should provide a complete record of the experiment and are to be written individually. Group data collection is expected and collaborative problem-solving is encouraged, but NOT collaborative writing. The required sections of a complete report are briefly described below. Any further expectations for lab reports will be discussed by your instructor. Late reports will be penalized per day late.

Lab Report Sections

Abstract: 300 words or less, summary of each key results and significance. Every experiment and corresponding result should be addressed succinctly. This section lets your reader know what he/she can find out more about if he/she continues reading the report. It is the "spoiler" of your report, but this is very useful when there are many possible papers to read on a topic, but only a few that address exactly what the reader wants learn about.

Introduction: Explain relevance of project to the field. This includes background on the topic, motivation for the work and experiments to be conducted as well as potential significance and added knowledge to the current research and understanding on the topic.

Objective/Hypothesis: Clearly state the hypothesis of the work or the goal of your project. This is the message of what you plan to do in order to investigate further on a specific topic. It includes predictions and reasoning for your plan based on prior knowledge/research.

Materials and Experimental Methods: A key part of this report is to write up experimental protocols for other scientists to follow. Describe all materials that were used. Describe all experimental procedures that are used and detail the experimental protocol. This includes sample volumes, incubation times, specialized procedures, flow rates, solvents, chemical recipes, etc. Be sure to include any variation from expected protocol and justification for any changes.

Results: Graphs and tables showing results must be provided. Graphs must be properly labeled and constructed showing error bars and statistical analysis if available. Raw data must be appended in the appendix. Provide a textual description of the results and any calculations that were done. All graphs, tables, calculations, etc. must be accompanied by a description of what is shown so that the audience knows what it is looking at. This does not include interpretation and significance of results. This is saved for the discussion section. Include observations in this section as well.

Discussion: Interpret and explain all results including observations. Refer to figures of the Results section and relay their significance. Try to see how one set of results can relate to another. Compare and contrast to find trends and significance. Answer questions such as: Did the results confirm your hypothesis? Were the objectives of the lab met? Why (if applicable) were results different from the initial expectations? What are the implications of these results for future work in the lab? What future work do

you recommend? What could the implications be to a real-world problem or product? Could your findings improve a product or help solve a real-world problem?

Conclusion: State the overall outcome(s) of the experiment and the overall significance of your data and findings. How have you helped a "big picture" become clearer with your work?

Works Cited: Give a full bibliography in which you acknowledge all of the references that helped you to understand and critically analyze your data. This section also includes any papers that helped you to write your report including the introduction, methods or materials and discussion sections, all of which should have references for writing a proper report.

Appendix: Include sketches, photographs, raw data, spectroscopy sheets, excel files of raw data and photocopies of any calculations that were done by hand as well as your carbon copy lab notebook pages.

Quizzes Quizzes will take 15 minutes and are meant to test your understanding of the relevant lab manual and supplemental materials posted by the instructor. Specifically, we want to make sure you understand the experiment's principles and procedures and can perform the lab safely. Reference material for the quizzes will be posted 1 week before the lab period.

Final Group Presentations The presentation will follow the same format as the final report. It is meant to display key background information, findings and recommendations on a particular topic for educational benefit of a scientific audience. You will work in groups of at least two. The format should be a PDF presentation (without animations) and should take 12 -15 minutes if there are no interruptions. Questions will be asked by the audience afterwards.

Teamwork Teamwork grade accounts for collaboration, communication and leadership skills during the experiments as well as during the final presentation.

Instructor Discretion This grade includes (but is not limited to) lab participation, attendance of both lectures and laboratory, final presentation performance and completion of the end of quarter evaluation.

Final Presentation

Important Dates:
Week 6 - Presentation abstracts due at lecture. See details below.
Week 10 - Presentations given during lab period. See description below.

Presentation Team:
You are to work in groups of two or three with another student in your lab period.

Presentation Guidelines:
Start with **your choice** of scientific topic developed from your own interest, influenced by this course or suggested from the list of categories below. Through research of the scientific literature, describe a **current and specific** challenge within this topic and what state-of-the-art science and engineering is doing to solve this problem. The scientific articles that you research must include analytical techniques, including those you have learned and utilized throughout this course. Within your presentation, be sure to discuss how the researchers use **up to three analytical techniques** taught in this class (listed below) to help study your research topic of interest. Be sure to briefly discuss the theory of each technique that you reference. Additionally, incorporate figures of the characterization or experimental data of your articles, citing at least one literature reference per technique, and discuss why the researchers might have chosen this method of analysis. Additionally, state your own ideas of what new/original work could be done to enhance this field in the future as well as the environmental impact of the this work from beginning to end. This includes the life-cycle of materials, how long the material will last for its given function, and what potential applications will result in the highest ratio of benefit-to-cost of the material.

We encourage you to take this opportunity to learn more about a topic you are interested in including the positive and negative aspects. This presentation should help prepare you for technical questions that may be asked in a job interview, questions you may not have thought to ask yourself, or jump-start your thinking about a research career you may pursue in a Masters or PhD program.

Additional Requirements:
The research articles that you cite in your presentation must be from 2015 to present to be considered current. Background and topics of theory may be from earlier than 2015.

Presentation Abstracts:
Each team must submit an abstract at the start of lecture in week 6. The abstract outlines your specific topic, what techniques you will focus on for your presentation and how it relates to this course. This is a typed summary (less than 300 words) of your topic written in a collaborative effort with you and your partner. The Professor and/or TAs will review your topic and discuss the outcome with you during the next lab period.

Teamwork:
Equal work is required and both students must be knowledgeable on all aspects of the presentation, meaning that you could present this work alone if need be with equal success.

Scientific topics (suggestions, non-exhaustive)

- LEDs/Solar Cells/Quantum Dots
- Water Splitting
- Metamaterials - ex. camouflage
- Biomaterials - ex. drug delivery/tissue engineering
- Biomimetics
- 3D printing
- Superhydrophobic materials/coatings - ex. protective clothing/water transport
- Metalworking – ex. forging
- Space technologies – ex. insulation, high-temp protection, antifouling
- Amorphous materials – ex. sol-gels, glass, metals
- Failure/Fatigue – ex. polymer part failure
- Adsorbent materials – BPS materials
- Functionalized Materials - ex. smart materials

Possible techniques used in this lab

- Scanning Electron Microscopy (SEM)
- Transmission Electron Microscopy (TEM)
- Dynamic Light Scattering (DLS)
- Zeta Potential
- Contact Angle Goniometry
- Small Angle X-ray scattering (SAXS)
- X-ray Photoelectron Spectroscopy (XPS)
- Electron Dispersive Spectroscopy (EDS)
- Fourier Transform Infrared Spectroscopy (FTIR)
- Spincasting/coating
- Nanoparticle Synthesis (Stöber method)
- Organic vs. Aqueous solvents/wettability
- Colloids/particle suspensions/aggregates
- Sintering
- Ultra-Violet Visible (UV-Vis) Spectroscopy
- Hot-Stage Optical Microscope
- Dynamic Mechanical Analysis (DM)
- 2-Point Resistance Measurement
- 4-Point Resistance Measurement
- Ultraviolet-Visible Spectroscopy (UV-Vis)
- Cyclic Voltammetry (CV)

Required Presentation Format - Slide Breakdown (each slide is needed for full credit)

Slide Number	Content
1	**Title slide:** Names, date, class, professor, title of presentation
2	**Introduction slide:** What topic have you chosen? Give background on the topic (relevance to real-world and science) Why are people studying this? What is the motivation for this work? Why should your audience care? Transition from **broad** topic to introducing the **specific** research of this topic that you will be discussing in detail for the rest of your presentation.
3	**Objective slide:** State the current challenge that your specific research topic is going to address and try to solve. This should also be specific.
4	**Current state-of-the-art slide:** Introduce the experiments the researchers use to investigate this your topic. What is the current technology being used to solve the issue? Need to cite scientific literature from 2011-present. What analytical techniques are being used and how are they helpful in their investigation? This should transition into the focus of your next three slides.
5	**Technique (1) Introduction slide:** Show how the techniques we learned in class have helped to study the current issue in your application/field. On this slide, discuss the theory behind one of the analytical techniques utilized in class and in you research topic. Share what the general usefulness of the technique and why it was useful to your research topic. Include figure(s) of how the instrument works to aid in your explanation. Ex. If SEM was used in the literature to analyze your specific topic, then briefly discuss how SEM generally works (including figure of instrumental setup) and state why researchers choose to use this technique and specifically why the researchers in your literature references chose this method. (This will help you transition to the next slide of what your data shows using this method.)
6	**Technique (1) Research slide:** Display relevant figures/data of the technique cited in your research references. Ex. If SEM was used in the literature to analyze your specific topic and had important findings for the project, then include the SEM image(s) of the significant data in your presentation. Discuss what the literature figures/data show in terms of your research topic and the significance to solving the research objective you stated on slide 3. In other words, what are the results? Why do they matter?
7	**Technique (2) Introduction slide:** See slide 5
8	**Technique (2) Research slide**:

	See slide 6
9	**Technique (3) Introduction slide:** See slide 5
10	**Technique (3) Research slide:** See slide 6
11	**Environmental Impact/Life Cycle Impact:** Discuss the environmental impact of this research from start to finish. This includes the life cycle of materials, how long the material will last for its given function, and what potential applications will result in the highest ratio of benefit-to-cost of the material.
12	**Future work slide:** After all of your research on this research topic, give insight into what you think the next steps of the project could be and why this is the best avenue to direct the project? (Think: pitch a project idea or next step that someone would fund!)
13	**Conclusions:** State the main points of your research and significance of your research presentation.
14	**References:** Numbered and in bibliographic format, list ALL of the references you utilized to create your presentation.

Note: For each figure that you borrow from your references, you will need to include a citation with that figure on the same slide it appears. You may use the full citation or the reference number corresponding to its order on your final reference slide, but it MUST be present.

Final Presentations - Scoring Rubric

Category	Scoring Criteria	Total Points	Score	
Organization (10 points)	Slide Order - slides are presented in a logical sequence following guidelines and transition smoothly	5		
	Organization within each slide - slides are clear and easy to understand, ideas in slide flow easily - title/header fit with slide contents	5		
Content (45 points)	Introduction and objective slides are relevant, describes the problem well, and establishes a framework for the rest of the presentation	10		
	Technical terms are clearly and succinctly defined in language appropriate for the target audience.	2.5		
	Presentation contains accurate information from at least three state-of-the-art references dating from 2013 to present	5		
	Techniques discussed are relevant to the techniques learned in class and students discuss relevance of techniques to the research topic as well as interpret data	10		
	Description of theory behind each technique demonstrates appropriate level of understanding from the course	5		
	Students discuss relevant impact on environment and considers material life cycle	5		
	Future work is original and insightful	5		
	Conclusion clearly summarizes key points in presentation	2.5		
Presentation (45 points)	Presentation appropriately cites references on slides	5		
	Speaker is engaging with the audience and maintains good audience rapport	5		
	Speaker presents in a clear, audible voice.	5		
	Delivery is poised, controlled, and smooth.	5		
	Appropriate language skills, vocabulary, and pronunciation are exhibited.	5		
	Visual aids: • Figures are easy to read with labels that are at least 18 pt font • Information is represented visually whenever possible • Photo/picture use is relevant to key information on slide • Text use is minimal and relevant	10		
	Student shows capability to answer all questions and demonstrates full participation in project	10		
	Presentation is well-paced and length is 12-15 minutes	5		
Teamwork (15 points)	Decided by group members in separate survey	15		
Total Points		120		
Score	For Student A and Student B			