Course Syllabus

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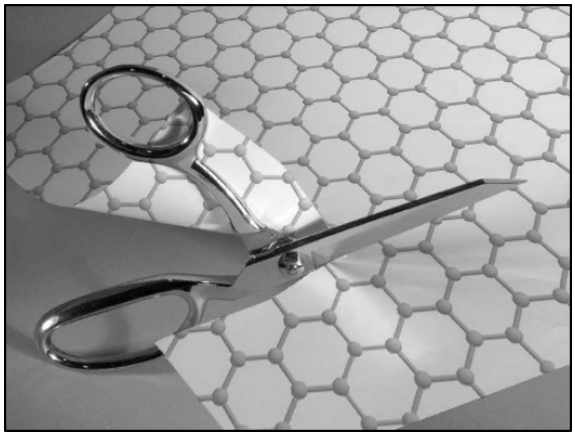
ME588: Nanoscale Fabrication & Characterization



“If a craftsman wants to do good work, he must first sharpen his tools.”

- **Confucius (https://www.goodreads.com/quotes/7244563-if-a-craftsman-wants-to-do-good-work-he-must)**

“New directions in science are launched by new tools much more often than by new concepts. The effect of a concept-driven revolution is to explain old things in new ways. The effect of a tool-driven revolution is to discover new things that have to be explained.”

— **Freeman Dyson (https://quotefancy.com/freeman-dyson-quotes)**

Course Description

Nanoscale systems are important to a host of future technologies in energy, information, health, and environment, impacting nearly every aspect of our modern lives. This course will provide a practical understanding of state-of-the-art nanoscale fabrication and characterization approaches, and the fundamental principles behind these advanced techniques needed for research or industry careers in nanotechnology. Lectures will introduce students to topics including top-down and bottom-up paradigms of nanofabrication, characterization of structures smaller than can be resolved with light. Lectures also provide the theoretical underpinnings of the quantum properties of nanomaterials that these technique probe and engineer, and how to leverage these properties to realize select applications at the forefront of nano-research. The focus will be on two dimensional materials, which will be used as a case study to understand the broader challenges and opportunities of making and using nanoscale systems.

There will be three concurrent sections of ME588, for 3 credits and 4 credits.

ME588 GR3: The 3 credit in persion option will include lectures, homework, and a final project exploring emerging techniques, and will serve as an introductory course for students interested in nanotechnology. This course will be available to graduate students, and Undergradaute Seniors (special dispensation will be required).

ME588 GR4: The 4 credit option in person will add a hands-on lab where students will apply course concepts to synthesize monolayer graphene, characterize nanoscale structure and properties, and engineer devices like graphene field effect transistors, as well as postlab assignments learning to analyze and interpret data produced during the labs. This course will be available to graduate students, and Undergradaute Seniors (special dispensation will be required). The lab may not be taken separately for credit.

ME588 ONL: The 3 credit online secton is for online-only remote students, and will include lectures, homework, and a final project exploring emerging techniques. For the online section, lectures from the in-person section will be streamed and recorded, and instructor will be available for questions via zoom during office hours.

For more detail, see the list of planned **Lecture and Lab topics (https://canvas.illinois.edu/courses/48249/files/13291196?wrap=1)** **(https://canvas.illinois.edu/courses/48249/files/13291196/download?download_frd=1)** .

Prerequisites

Any of ME 330, CEE 300, PHYS 460, MSE 304, ECE 340, CHEM442, or equivalent;

Any of Physics 212, Math 285, ME330, or equivalent;

Recommended: PHYS 214 or equivalent.

Basic Information:

- **Lecture:** MW, 10 am –11:20 pm
- **Location:** 3100 Sidney Lu Mechanical Engineering Building (LuMEB)
- **ME 588 GR3 -** 3 credit lecture, **CRN:** 79416
- **ME 588 GR4 -** 3 credit online lecture section, **CRN:** 79811
- **ME 588 ONL** - 4 credit lecture & lab, **CRN:** 79417
  - **Lab Section AB1:** Th 12 pm – 2:30 pm, CRN: 79802
  - **Lab Section AB2:** F 11 am -1:30 pm, CRN: 79802

Instructor Information

- **Instructor:** Prof. Arend van der Zande

- **Office:** MRL 214
- **In Person office hours:** Monday 3-4 pm, or by appointment, will log in to zoom for online students
- **Teaching assistants:** Siyuan Huang and Dong Young Yoon
- **TA office hours:** Friday, 2:00-3:00 PM, via ZOOM.

Contact:

- Use Canvas DM for personal requests
- Use Canvas discussion boards for any clarification or HW questions

Zoom Links (login required)

Arend van der Zande Office Hours:

https://illinois.zoom.us/j/87247990690?pwd=mKa7arlDjyxwRNu0g7LTTCLFGXU9nQ.1 (https://illinois.zoom.us/j/87247990690?pwd=mKa7arlDjyxwRNu0g7LTTCLFGXU9nQ.1)

Meeting ID: 872 4799 0690
Password: 690822

TA office hours:

https://illinois.zoom.us/j/87011778793?pwd=XQQaBwvQnOaQNy3tF9GTGi6kUQrtE3.1 (https://illinois.zoom.us/j/87011778793?pwd=XQQaBwvQnOaQNy3tF9GTGi6kUQrtE3.1)

Meeting ID: 870 1177 8793

Password: 123456

Online Synchronous labs:

https://illinois.zoom.us/j/83792299790?pwd=jXG24BZzoRTWnw7SwsI5DVKjvzk6CY.1 (https://illinois.zoom.us/j/83792299790?pwd=jXG24BZzoRTWnw7SwsI5DVKjvzk6CY.1)

Meeting ID: 837 9229 9790
Password: 220926

Note: The lab zoom link will only be used on labs explicitly listed as online on their respective canvas page. In-person labs will not be recorded.

Course Objectives

This course will provide a practical grounding of the experimental techniques and underlying theory of nanostructure fabrication and characterization,

By the end of the course you should be able to:

- Identify the relation of individual research projects to grand challenges and technological roadmaps in science and industry.
- Understand how common synthesis, nanocharacterization and nanofabrication methods work, the advantages and limitations of these techniques and how they can be applied to probe and manipulate the properties of nanomaterials.
- Have a firm grounding in the underlying theory of structural, mechanical, electronic, thermal and optical properties of nanoscale systems.
- Understand how these properties lead to the behavior of devices and how they can be leveraged for new applications.
- Be aware of the emerging techniques, devices and applications of this rapidly expanding research field.
- Interpret the methods and results of new papers in the field.
- Be familiar with the rich library of 2D building blocks and how to produce 2D micro/nano-structures and devices.

Course Materials

Canvas: Posting & organizing all course files, and all course interactions including

- Lecture notes & handouts: Available before lecture
- Annotated lecture notes: Posted every few lectures after completion of relevant topic.
- Recorded lectures or labs: Posted day after relevant lecture when available
- Required/recomended reading: There is no single required textbook. Instead, we will provide articles, reviews, online tutorials, and select chapters from ebooks for the course such as *"Nanocharacterization Techniques" by Da Raz, "Nanofabrication: Principles, Capabilities and Limits" by Cui*, and *"Introduction to Solid State Physics" by Kittel*. Later in the semester, students will search out and present new papers on emerging topics in the fields
- Homework & Lab Assignments

Gradescope: All course assignment submission, grading, course scores

Recommended Textbook: We will cover topics related to multiple chapters from **Kittel's "Introduction to Solid State Physics" (https://i-share-uiu.primo.exlibrisgroup.com/permalink/01CARLI_UIU/gpjosq/alma99520240112205899)** . The book will be put on reserve in Grainger engineering Library. Students should consider purchasing the book.

Course activities

Homework

Homework will be assigned most weeks on lecture topics, with the goal of giving students a working knowledge of the topic. In addition, some weeks there will be post-lab assignments for students

enrolled in the 4-credit section to analyze and interpret the data acquired in lab. Because not all topics are amenable to homeworks, some weeks there will be no or short assignments. We will use Gradescope to submit and grade assignments. Homeworks are not weighted the same. Different numbers of points indicate homeworks that are worth more because the instructor thinks they are more difficult or time consuming.

Labs

We will hold weekly hands-on demonstrations of the techniques discussed in class, and hands-on labs where students will fabricate and characterize their own graphene field effect transistors. Some labs, will be done via synchronous zoom instead. We found during the pandemic that the synchronous zoom actually allow students a closer look at operations than is possible when fitting a large group into a very small room.

For more detail of lab topics and which are planned to be in person or online, see the list of planned **Lecture and Lab topics (https://canvas.illinois.edu/courses/48249/files/13291196?wrap=1)** **(https://canvas.illinois.edu/courses/48249/files/13291196/download?download_frd=1)** .

Project

We will have an end of semester project where students can explore an advanced nanofabrication or nanocharacterization technique of their choice. The project will be broken up into stages to help students stay on track, and practice scientific communication skills. See the **Final Project page (https://canvas.illinois.edu/courses/48249/pages/final-project)** for a detailed outline of the final project, project ideas, deadlines and weighting.

Class Participation

Students are expected to participate regularly in class discussion, labs, and activities. Part of your lab grade will be applied to regular attendance.

- During lecture and lab, the instructors are giving you their full attention, and request your full attention in return. While in person, keep off your cell phones and be engaged in the discussion.
- While logged in to remote labs, leave your video screens on so we can see you, close your email/ social media, and silence your cell phone, etc.
- If you have a question, ask – someone else probably has the same question.
- We will provide recorded lectures after class for reference, but watching the videos does not count as attendance, except for the online section.
- During lecture and lab, expect quick survey, polls, questions and activities to check attendance, engagement and stimulate discussion.

No Exams

The final projects will be considered the comprehensive for the course. There will be no exams.