MSE 404 TM1: Thin Film Mechanical Properties, Fall 2026

Lab Times: Monday and Wednsday 2:00 pm – 4:50 pm,
113 Ceramics Building
Course information will be made available online via Canvas.

Instructor: Prof. Axel Hoffmann
Office: Materials Research Laboratory 1021 **Email:** axelh@illinois.edu

Office Hours: Anytime during lab hours or via prior appointment.

Teaching Assistants:
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Office Hours: Anytime during lab hours or via prior appointment.

Course Description:
The course introduces seniors and new graduate students to fabrication, analysis, and mechanical properties of thin film materials through hands-on experiments. The course covers both the principles and practice of:

- Deposition of thin film materials by vacuum evaporation, sputtering and plasma assisted processes;
- Modification of mechanical properties by thermal reaction, surface treatment, etc.;
- Measurements of key properties including film thickness, microstructure, optical refractive indices, and thin-film stress. Methods to optimize the film microstructure and engineering properties via the growth technique are emphasized.

Prerequisites:
MSE 307 and MSE 308; senior or graduate standing. *If you have not passed a prerequisite course, please see the instructor before continuing*.

Course Objectives:
The objective of this course is to provide lab experience to students in Thin Film Processing and Characterization while applying lessons from previous courses on good experimental practices, data analysis, and professional presentation. The course is organized around a set of experimental modules performed in laboratory sessions, problem-solving, and student presentation/report. Students should read relevant background materials before starting each experimental module. Instructors are available for guidance, but students are encouraged to proactively problem solve and accomplish the tasks.

Course Topics:

1. Deposition Principles and processes
    - Creating vacuum
    - Formation from the vapor state
    - Thermal evaporation
    - Sputtering
    - Thermal reactions and annealing
2. Structure & properties
    - Film thickness
    - Crystal microstructure
    - Stress
    - Optical refraction and absorption

Course Structure:

In the first part of the course, there will be short labs where students will have to learn about different tools used in thin film science, including vacuum systems, sputter deposition, Xray diffraction (XRD), ellipsometry, and Wafer stress measurement. These labs can be accomplished in any order and overlap as tool availability allows. There will be a deadline every 2 weeks to maintain progress through the semester. The last part of the course, there will be a longer final lab where students have to use multiple tools to understand how thermal annealing affects material properties.

At the start of the course, students will be organized into groups of 2 or 3 within their own session for instrument sign up and laboratory work. Students are encouraged to self-select their own group on the first day of class. Instructor will assign remaining students to teams. You will stay with the same team for the entire semester. You should notify Prof. Hoffmann immediately if you decide to drop the course.

Attendance: Teams should only attend lab days during their assigned sessions (i.e., MW). Teams are only required to attend the lab if they have a tool booked. Every member of a team is expected to be present during measurements or when using reserved tools unless they have specific exemption ahead of time from the instructor. If one team member is more than 10 minutes late from the start of experiments of the rest of the team, it will be marked as an absence. Teams are not required to attend lab if they are performing analysis or working on reports, but they are encouraged to use the lab time for group work or as office hours to get help from the instructors. Every student will be responsible for their own reports and analysis.

Laboratory Instrument Schedule:
Every day, there will be a signup where teams can reserve instruments in 1:30 to 3 hour increments. Teams must reserve instruments as a full group. TAs have the right to reorganize based on progress.

Instrument	2:00–3:30 pm	3:30–5:00 pm
Vacuum system		
X-ray Diffractometer		
Ellipsometer		
Denton Sputter coater		
Wafer Curvature		

Assignments:
All assignments will be submitted and graded on GradeScope. For the group presentation, students will also upload a video to Canvas.

Part 1: Mini-labs on thin film techniques
Pre-lab thinking questions
At the start of each lab activity, students will need to individually submit pre-lab report addressing concept questions needed for understanding the operation of the tool. The group members are encouraged to discuss the solutions, but each member should hand-in their own pre-lab written in their own words.

Post-lab report
At the end of each lab activity, students will individually need to turn in a post-lab report analyzing and interpreting the data. The report should be submitted before moving on to the next lab module. The post-lab report should include answers to the thinking questions and a summary of your measurement results and be written as a coherent document rather than a set of separate questions and answers. The group members are encouraged to discuss the solutions, but each member should hand-in their own post-lab report written in their own words.

Group presentation
For the sputtering lab, rather than a post-lab report, students will upload an instruction style video, incorporating your experimental results. These presentations need to show input from all team members and will be graded as a group assignment.

Part 2: Final lab and report
Teams will perform a longer set of experiments using multiple tools to understand how the microstructure of thin films changes under annealing. Each student will have to prepare a final report analyzing the data.

Laboratory Projects:

Part I: Thin-film related techniques

1. Vacuum
    - Construct and describe pumping sequence diagram for the thermal evaporator
    - Measure high vacuum pumping and leaking rate
2. Ellipsometry
    - Construct a schematic diagram for the ellipsometer to illustrate its working principle, mark the key components and their functions, describe the principle of ellipsometry measurement and the measured quantities, how these quantities are related thin film properties
    - Measure film thicknesses and optical refractive index of provided samples
    - Refinement of the optical model
3. Thin-film stress measurement (wafer curvature)
    - Construct a schematic diagram to describe the system configuration, and explain the principle of stress measurement and its sensitivity using the instrument
    - Determine the instrument measurement accuracy using penny experiment
    - Temperature scan of SiO_2/Si wafer, explain the results
4. X-ray diffraction
    - Construct a schematic diagram for the diffractometer and describe the principle of X-ray diffraction, e.g., what is measured and how the measurement can be related to materials microstructure
    - Calibrate the diffractometer using Silicon powders by indexing the experimental pattern and compare with the powder diffraction database
    - Collect diffraction patterns from the silicon wafer, index the measured diffraction peaks and determine the wafer orientation
5. Deposition of thin metal films by sputtering
    - Deposit Au films of specified thicknesses with the help of quartz thickness monitor, record key parameters, including base pressure, deposition pressure, deposition rate
    - Calibrate deposition rate using ellipsometry
    - Determine the film thicknesses and uniformity using Ellipsometry
    - **Submit a group video presentation**

Part II: Thin-film stress and microstructure

- Deposit Al film of specified thickness by sputtering on a silicon wafer
- Measure thin-film stress as function of temperature
- Characterize annealed film structure using X-ray diffraction
- **Prepare and submit your final report**

Grading:

Lab 1: Vacuum:	12%
Lab 2: Ellipsometry:	12%
Lab 3: Thin film stress:	12%
Lab 4: XRD:	12%
Lab 5: Sputter Deposition and presentation:	12%
Final Lab: Microstructure and processing:	30%
Attendance and participation:	10%

All assessment scores will be stored in the gradebook in Canvas.

Numerical total score corresponds to the following final grades:

A+	(97–100)	B+	(87–89)	C+	(77–79)	D+	(67–69)		
A	(93–96)	B	(83–86)	C	(73–76)	D	(63–66)	F	(0–59)
A-	(90–92)	B-	(80–82)	C-	(70–72)	D-	(60–62)		

Grade Reporting:

All assessment scores are stored in the gradebook in Canvas. Any errors in grade reporting appearing in the gradebook must be reported within 2 weeks of the grade being posted in the gradebook or by the last day of class, whichever is earlier. If you have a missing grade, contact the instructor.

Late Submission:

You get one "free" late assignment submission on any pre/postlab except the team video presentation. This is an up to 48-hour extension with no penalty that can be used over the entire semester. We will automatically apply this to the first assignment submitted late by any amount of time on GradeScope. Any additional late assignments after this one will automatically get a 20% penalty for assignments between 1 second up to 1 day late, and 40% penalty for assignments between 24 and 48 hours late. You will not receive credit for late assignments over this time limit.

Absences:

Excused Absence Request Form: https://forms.illinois.edu/sec/128714727

1. Excuses from assessments will only be given in the following circumstances:
    a. Illness
    b. Personal crisis (*e.g.,* car accident, required court appearance, death of close relative)
    c. Required attendance at an official UIUC activity (*e.g.*, varsity athletics, band concert)
    d. Religious observances, see the following website for further information: https://odos.illinois.edu/community-of-care/resources/students/religious-observances/.
2. In all cases you must complete the online Excused Absence Request Form and upload a scan of the official written documentation explaining your absence.
3. In cases (a) or (b) an official excuse letter from the Dean on Duty must be submitted via the online form within 2 weeks of the due date of the missed assessment, but no later than the last day of instruction (October 15). In cases of extended or unusual illness, late submission of excuse documentation will be considered. See Student Assistance Center.

4. In case (c) an official letter from the designated university official must be submitted via the online form at least one week prior to the due date of the missed assessment.
5. If you will not be able to take an exam due to illness or any other reason, you must send email to your professor at the earliest possible opportunity. Excused exams will be replaced by a weighted average of the other exam scores at the end of semester.
6. Notwithstanding the above, at the professor's discretion you may be required to make up any excused work or attend substitute instruction or assessment.

Course Materials, Discussions and Announcements:
Course materials, including instructions for lab projects will be made available through our course Canvas website at https://canvas.illinois.edu.

Discussions and announcements related to course material will be facilitated by using the discussion boards of Canvas. This site will be used for all communication between the instructor, TAs, and students. If you desire, then you can post anonymously or make a private post just to the instructor (rather than sending an email). TAs are scheduled to be checking Canvas regularly during the week. *Note that* Canvas *should be used to communicate with your instructors, rather than email*.

Laboratory Safety Policy:
- All students and staff are REQUIRED to wear long pants, closed shoes, and safety glasses while working in the instructional labs. Any student not wearing correct attire will not be allowed to do lab work and will be marked as missing attendance for the day.
- No eating or drinking in the labs
- Students are responsible for cleaning up after themselves. The lab should be left in good condition before you are allowed to leave.

Obtaining help:
The main two ways to obtain help are online at Canvas or in person during the lab hours. Please do not send email directly to TAs or professors for routine help or absences. In cases of emergencies (*e.g.*, illness) you should email your professor at the earliest possible opportunity.

Accommodations:
To obtain disability-related academic adjustments and/or aids, students should contact the course instructor and the Disability Resources and Educational Services (DRES) as soon as possible. To contact DRES, you may visit 1207 S. Oak St., Champaign, e-mail disability@illinois.edu, or go to the DRES website: https://www.disability.illinois.edu. If you are concerned you have a disability related condition that is impacting your academic progress, academic screening appointments are available on campus that can help diagnose a disability.

For rare circumstances, such as extended illness and family emergencies that make it difficult for you to keep up with coursework, you should contact Professor Hoffmann via a Canvas private message as soon as possible to discuss options. In these cases, I encourage you to reach out to the Dean of Students office, which can help you contact and manage accommodations with all of your courses.

Academic Integrity:
The University of Illinois at Urbana-Champaign Student Code should also be considered as a part of this syllabus. Students should pay particular attention to Article 1, Part 4: Academic Integrity. Read the Code at the following URL: http://studentcode.illinois.edu/. Academic dishonesty will result in a sanction proportionate to the severity of the infraction, with possible sanctions described in 1-404 of the Student Code (https://studentcode.illinois.edu/article1/part4/1-404/). Every student is expected to review and abide by the Academic Integrity Policy as defined in the Student Code: https://studentcode.illinois.edu/article1/part4/1-401/. As a student, it is your responsibility to refrain from infractions of academic integrity and from conduct that aids others in such infractions. A short guide to academic integrity issues may be found at https://provost.illinois.edu/policies/policies/academic-integrity/students-quick-reference-guide-to-academic-integrity/. Ignorance of these policies is not an excuse for any academic dishonesty. It is your responsibility to read this policy to avoid any misunderstanding. Do not hesitate to ask the instructor(s) if you are ever in doubt about what constitutes plagiarism, cheating, or any other breach of academic integrity.

Individual Work:
You are welcome to use publicly available resources (library, faculty, academic literature, computers, etc.) to do your reports. This includes discussions with other students in the class. However, each student is expected to turn in their own work on every assignment. In addition, every student should refrain from using reports from previous semesters, regardless of whether these are obtained from a friend, or posted to an online source.

Changes to syllabus:
May occur as deemed necessary by the professor; they will be announced.

Calendar and Topics:
Changes to the schedule will be announced; see the MSE 404 TE website on Canvas for exact schedule, assignments, and to remain up to date.