Syllabus: MATSE 404, Thin Film Mechanical Properties

(Fall Semester, 2021)

COURSE DESCRIPTION:

Introduces seniors and new graduate students to fabrication, analysis, and mechanical properties of thin film materials through hands-on experiments. Covers both the principles and practice of (a) deposition of thin film materials by vacuum evaporation, sputtering and plasma assisted processes; (b) modification of mechanical properties by thermal reaction, surface treatment, etc.; (c) measurement 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. *Prerequisite:* MSE 307 and MSE 308 or permission of instructor. Senior standing.

References (Available online through UIUC library)
R. V. Stuart, "Vacuum Technology, Thin Films, and Sputtering, An Introduction", Elservier, 1983.
G.L.Weissler & R.W. Carlson editors, Methods of Experimental Physics – Volume 14: Vacuum Physics and Technology, Academic Press, 1979 (https://vufind.carli.illinois.edu/vf-uiu/Record/uiu_7047826).
J. L. Vossen and W. Kern, "Thin Film Processes II," Academic Press, 1991.
M. Ohring, "The Materials Science of Thin Films," 2nd Edition, Academic, 2002.

GOALS:

The objective of this course is to provide lab experience to students in the area of Thin Film Processing and Characterization. The course is organized using a set of experiments performed in laboratory sessions, problem solving and student presentation. Students are encouraged to read background materials before each experimental module. Students are also encouraged perform the experiments with minimal help from the lab's technical specialist.

COURSE TOPICS:

1. Thin films and vacuum
2. Deposition Principles and processes
   - Formation from the vapor state
   - Thermal evaporation
   - Sputtering
3. Thermal Reactions
   - Annealing
4. Properties
   - Microstructure
   - Stress
   - Optical

LABORATORY WORK:

Part I Thin-film related techniques

1. Vacuum

a. Construct and describe pumping sequence diagram for the thermal evaporator

b. Measure high vacuum pumping rate

c. Submit the mini-report

2. Ellipsometry

a. Construct a schematic diagram for the ellipsometor, 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

b. Measure film thicknesses and optical refractive index of provided samples

c. Refinement of the optical model

d. Submit the mini-report

3. Thin-film stress measurement (wafer curvature)

a. Construct a schematic/geometric configuration of system, explain the principle of stress measurement and its sensitivity

b. Determine the instrument measurement accuracy using penny experiment

c. Temperature scan of SiO_2/Si wafer, explain the results

d. Submit the mini-report

4. X-ray diffraction

a. Construct a schematic diagram for the diffractometer and describe the principle of X-ray diffraction, what is measured and how the measurement can be related to materials microstructure

b. Calibrate the diffractometer using Silicon powders by indexing the experimental pattern and compare with powder diffraction database

c. Obtain diffraction pattern from the silicon wafer, index measured diffraction peaks and determine its orientation

d. Submit the mini-report

5. Deposition of thin metal films by sputtering

a. Deposit Au films of specified thicknesses with help of quartz thickness monitor, record key parameters, including base pressure, deposition pressure, deposition rate

b. Calibrate deposition rate using ellipsometry

c. Determine the film thicknesses and uniformity using Ellipsometry

d. Submit group video presentation

Part II Thin-film stress

7. Thin film stress and microstructure

a. Deposit Al film of specified thickness by sputtering on a silicon wafer (Discuss with TA)

b. Measure thin-film stress as function of temperature

c. Characterize annealed film structure using X-ray diffraction

d. Share your experimental data with class

e. Prepare and submit your final report

LABORATORY GROUP:

The class will organized in groups of two students for instrument sign-up and the laboratory work. Student will be responsible for his/her own report

LABORATORY INSTRUMENT SCHEDULE

Instrument	2-3 pm*	3-4 pm*	4-5 pm*
X-ray diffractometer			
Ellipsometor			
Denton sputter coater			
Wafer curvature			
Thermal evaporator			

* Must sign up as a group, with TA's approval

Time and workload: 2x3=6 hours/week/student
Session-1 (2pm to 4:30pm) Monday
Session-2 (2pm to 4:30pm) Tuesday
Session-3 (2pm to 4:30pm) Wednesday
Session-4 (2pm to 4:30pm) Thursday

MINI-REPORTS (4 IN TOTAL):

At end of assignments 1-4 in **Part I**, hand in mini-report, before moving on to next assignment. The mini-report contains solution to thinking questions and a summary of measurement results. The members of group are encouraged to discuss the solutions, but each member should hand-in his/her own mini-report.

GROUP VIDEO PRESENTATION:

Each group will select 4 or 5 of PART I and prepare an instruction style video on the selected topic, incorporating your experimental results. The video will be uploaded and graded by the class during 2nd half of the lab session.

FINAL REPORT:

Each student will provide a final report on "Thin film stress and microstructure". Instructions for written report will be given separately. Only electronic submission through Compass2g will be accepted.

CLASS MANAGEMENT:

The class meets from 08/24/20 to 10/16/20, which provides 6 weeks for finishing the lab modules and 1 week for final report.

INSTRUCTOR

Jian-Min (Jim) Zuo, 1006 MRL, 244-6504, jianzuo@illinois.edu

TEACHING ASSISTANTS

Zhao, Ziqi <ziqiz7@illinois.edu>

OFFICE HOURS:

Anytime during Lab sessions or by individual appointment

GRADING:

Final grade = 10% lab performance and class participation
+ 30% group presentation video
+ 30% on mini-reports
+ 30% final report, graded by instructor