ISE 718
Micro/Nano-scale Fabrication and Manufacturing
Spring 2024

INSTRUCTORS:

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Class Time: 3:00 – 4:15 PM, Tuesday and Thursday

Classroom: 136 Monteith Engineering Research Center (MERC)

Office hours: 1:00 – 2:00 pm Tuesday (for on campus students), and by individual appointment

2:00 – 3:00 pm Tuesday (for distance students), and by individual appointment

Text Book: Marc Madou, *Fundamentals of Microfabrication*, 2nd Edition, CRC Press, 2002

Course website: https://moodle-courses2324.wolfware.ncsu.edu/course/view.php?id=5620

COURSE OBJECTIVES

This is an introductory course on the physical theory, design, analysis, fabrication, and characterization of micro/nano scale fabrication and manufacturing. The main focus of the course is on the fabrication/manufacturing of important types of microstructures used in micro/nano devices and the techniques and tools used to fabricate and characterize them. The course includes lithography, additive and subtractive processes, bulk and surface micromachining techniques. LIGA, precision and tolerance issues, packaging, scaling, actuators, and sensors.

COURSE ORGANIZATION:

This course consists of the following:

1. Lectures: Slides will be posted after each class.

   Attendance is required for on campus students, will be checked on random dates in class

2. Homework: homework will be given from time to time.

   The purpose of homework assignments is to give you a chance to practice what you learned from the class. Try to solve the homework problems by yourself first. You may discuss homework with your classmate, but have to work out and submit your own copy of solution. Solutions with similarity beyond reasonable level may trigger the concern of plagiarism.

   Homework problems will be assigned on Moodle, generally due in ten days to two weeks before class through Moodle submission links. No late homework or other assignments will be accepted.

3. Term Project: The project is an in-depth study on any topic that is related to this course, which could be a literature survey, a micro-device design, or a related topic from your own research.
4. Exams - Two take-home tests (midterm and final) will be given.

GRADING:

Attendance	10%
Homework	20%
Project Reports	20%
Midterm Exam	25%
Final Exam	25%
Up to -20% for improper classwork manners	
Total	100%

ADMINISTRATIVE POLICIES

1. No late homework or other assignments will be accepted. Homework is due before the class hour.
2. **No after-fact excuse** on missing assignment or test will be accepted. After-fact excuse is not acceptable.
3. You must show all calculations or procedures in your test paper/report in order to get full score.
4. This is an engineering course. You are expected to act as a responsible engineer. Every document handed-in must be neatly prepared. Sloppy work may cost you points.
5. **Academic Integrity:** Exams are to be solved individually including the take-home ones (if any), without any help other than that provided directly by the Instructor. Any observed violation will result in a ZERO grade for that exam, and possibly further action. You may discuss over home work questions and project. But the submitted documents have to be done by yourself. Duplicated homework and reports will result in a ZERO grade.

   Using illegally posted previous assignment solutions is a violation of academic integrity, and can result in zero point of the related assignments and even fail grade of the course.

   It is understood and expected that all work turned in under your name is your own work or, if a group assignment, the work of you and your group members, and that you have neither given nor received unauthorized aid. The University policy on academic integrity can be found in the Code of Student Conduct (see Appendix L of the Handbook for Advising and Teaching: www.fis.ncsu.edu/ncsulegal/41.03-codeof.htm).

   Using the help from AI (e.g. ChatGPT) for the project report is prohibited.

6. **Incomplete Grades:** If requested by a student, the grade of Incomplete will be given for work not completed because of a serious, documented interruption in the student's work not caused by their own negligence.
7. **Absences and Scheduling Make-up Work**: Missed exams need to be justified by the student with a written corroboration (Doctor's note or similar), see http://www.ncsu.edu/provost/academic_regulations/attend/reg.htm for NC State's policy on excused absences. Non-justified missed exams will be assigned a grade of ZERO.

TOPICS TO BE COVERED

- **History and Fundamentals of Micro/Nanotechnology**
  Micro/Nano World, length scales
  Devices, Sensors and Actuators
  Topical applications

- **Scaling, Actuators and Power in Miniaturized Systems**
  Scaling rates for common physical characteristics
  MEMS actuation forces and scaling rates

- **Visualization of the Micro/Nano-Scale**
  Electron Microscopy
    - Scanning Electron Microscopy
    - Transmission Electron Microscopy

  Atomic Force Microscopy/Lateral Force Microscopy

- **Lithography**
  Fundamentals and definitions
  Photolithography: types, profiles, resolution calculations, side profiles, etc.
  Other types of lithography (X-ray, e-beam, laser, charged particle)

- **Unconventional fabrication approaches**
  Softlithography
  Tip based lithography
  Imprint lithography
  Micro-contact printing

- **Additive Processes**
  Resistive thermal evaporation, E-beam evaporation, and sputtering deposition methods
  Vapor pressure, alloy evaporation, and mean-free-path calculations
  Cosine law of depositions
  Doping
  Oxidation

- **Subtractive (Etching) Processes (Dry)**
  - Plasma physics (DC, RF)
  - Reactive Ion Etching (RIE)
  - Diode and Triode systems
  - Etch mechanisms and rules
  - Paschen curves

- **Subtractive (Etching) Processes (Wet)**
  - Unit Cell and Miller Indices
  - Isotropic and Anisotropic etching
  - Chemical etch models
  - Corner compensation

- **Surface Micromachining Techniques**
  - Sacrificial layers
  - Film stress and strain
  - Hinged MEMS fabrication
  - Drying and Stiction

- **Precision & Tolerance**
  - Definitions and calculations

- **Packaging**
  - Bonding techniques (Anodic, Fusion, Eutectic, Adhesive)