# EE143 – Fall 2016
# Microfabrication Technologies

**Prof. Ming C. Wu**

**wu@eecs.berkeley.edu**

**511 Sutardja Dai Hall (SDH)**




## Course Information (1)

- **Lecture**
  - **11:10 to 12:30 pm Tuesday, Thursday**
  - **Room: Cory 241**
- **Instructor:**
  - **Professor Ming C. Wu**
  - **511 Sutardja Dai Hall (SDH), wu@eecs.berkeley.edu**
  - **Office hours: tba**
  - **Best way to communicate: Email**
- **GSIs:**
  - **Mark Hettick, Head GSI**
  - **Korok Chatterjee**
  - **Dominic E. Labanowski (10 hour GSI)**
  - **Thomas Rembert**



## Course Information (2)

- **Prerequisites:**
  - **EE16A/B and Physics 7B or equivalent**
- **Course Description**
  - **EE143 teaches the fundamentals of integrated-circuit (IC) fabrication, giving the student a basic understanding of IC processes and the effect of processing choices on device performance.**
  - **Students learn to use process simulation tools and also fabricate and characterize devices in the laboratory.**
  - **This lecture part will cover the processing techniques and design methodologies of microfabrication.**





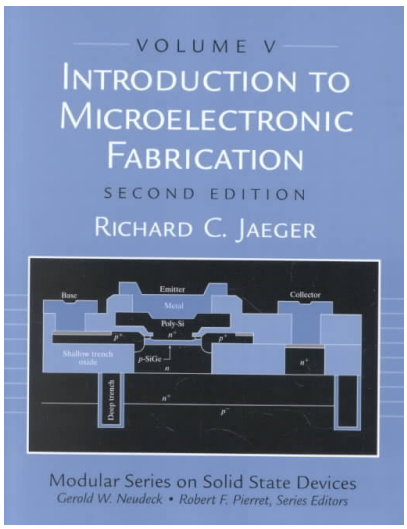


## Course Information (3)

- **In addition to transistors and IC's, you will fabricate simple MEMS (micro-electro-mechanical systems) structures**
- **The second part of the course will cover process simulation, layout design rules, MOS, IC, and MEMS process integration.**
- **The laboratory part of the course will provide students opportunities to have hands-on experience to fabricate and characterize a NMOS chip with simple MEMS components.**



# Textbook




- Introduction To Microelectronic Fabrication (2nd edition)
  - R. C. Jaeger
  - Prentice Hall
- Minimum reading
  - Assigned sections in syllabus
- Best to read the relevant sections before lecture
  - Enables meaningful in class discussions

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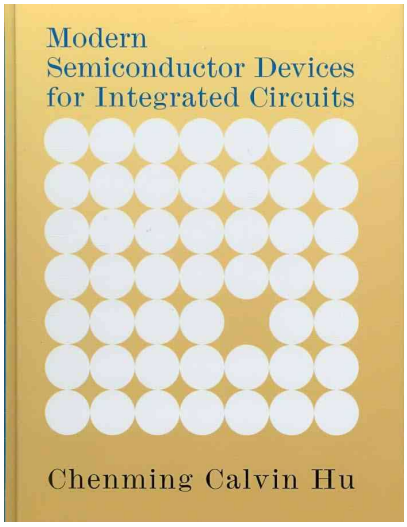
# Reference Book for MOS Devices




- Modern Semiconductor Devices for Integrated Circuits
  - Prof. Chenming Hu
  - Prentice Hall, 2010
- Available online
  - https://people.eecs.berkeley.edu/~hu/Book-Chapters-and-Lecture-Slides-download.html

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## Course Web Sites

- Open website
  - General course info, lecture notes, Labs, HW problems
  - http://www-inst.eecs.berkeley.edu/~ee143/fa16/
- bcourses
  - https://bcourses.berkeley.edu/
  - Grades (check frequently, and inform your GSI if you find any discrepancy)
  - HW solutions
  - Exam solutions
- Piazza
  - Discussions




## Grades

- Laboratory: 35%
  - Includes quizzes, lab work, and reports
  - You must complete all labs to pass the course!
- Homework: 5%
  - Lowest score will be dropped from grade calculation
  - (You can miss one HW without impacting your grade)
- Midterms: 15% x 2 = 30%
  - Closed book. One sheet of notes allowed.
- Final Exam: 30%
  - Closed book. 3 sheets of notes allowed.
- Cheating will result in automatic Fail



# Laboratory Requirements (35% of the total grade)

- Lab attendance: 10 pts (5% of the total grade).
  - Each absence results in -2 pts. Each lateness results in -1 pt.
  - Students receiving a lab attendance grade of 0 pts or less will automatically fail the course.
  - Make-up lab sections are allowed (student will be attending a different lab section for that week), however, prior written request must be submitted to Professor Wu. Students attending pre-approved make-up sections will not lose points.
  - Note that being unprepared, unwilling to participate in the lab activities, and/or not following the safety procedures will result in losing lab attendance points.
- Lab Quizzes: (5% of the total grade).
  - They will be given often (unannounced) at the beginning of each lab.
- Lab Report 1: 100 pts (15% of the total grade).
- Lab Report 2: 100 pts (10% of the total grade).
  - Note for both Lab Reports: For every day that it is turned in late, you will lose 20 pts. We will not collect after 4 days past the deadline.



# Midterm & Final Dates

- Midterm 1:
  - 10/4/16 (Tue) in class
- Midterm 2:
  - 11/1/2015 (Tue) in class
- Final Exam:
  - 12/14/16 (Wed), 8-11 am
- General rule: no early or late exams
  - Rare exceptions, e.g., presenting a paper in a conference
  - Need to inform the instructor well in advance

## Course Structure – Lab and Lecture

- You learn the theories in class; you practice them in lab
- You are going to make:
  - Resistors, diodes, MOS-cap
  - Bipolar transistor, MOS-transistor, …
  - Some MEMS structures, like beams, …
- By the end of the semester, you should have learned
  - Basic lab techniques
  - How to operate some fabrication equipment
  - How to characterize the devices you made

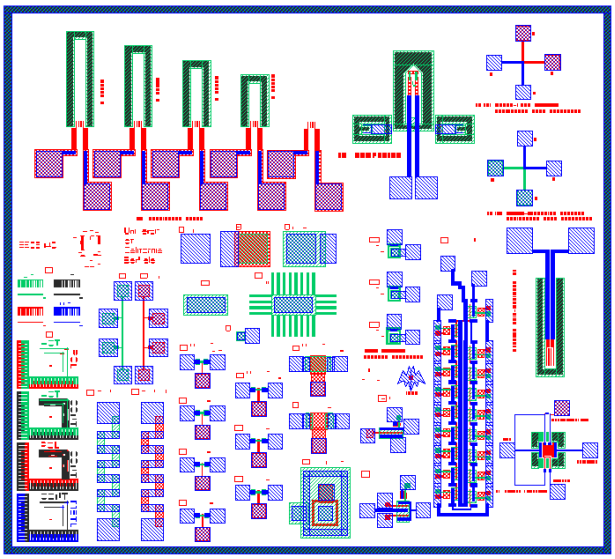



## Lecture Schedule

- Introduction to Materials and Processing (1-2 weeks)
- Photolithography (2 weeks)
- Etching (1 week)
- Oxidation (1 week)
- Deposition (1 week)
- Diffusion (1 week)
- Ion Implantation (1 week)
- Metallization/CMP (1 week)
- Simulation/Layout
- Process Integration (throughout)
- Introduction to Devices (2 weeks)

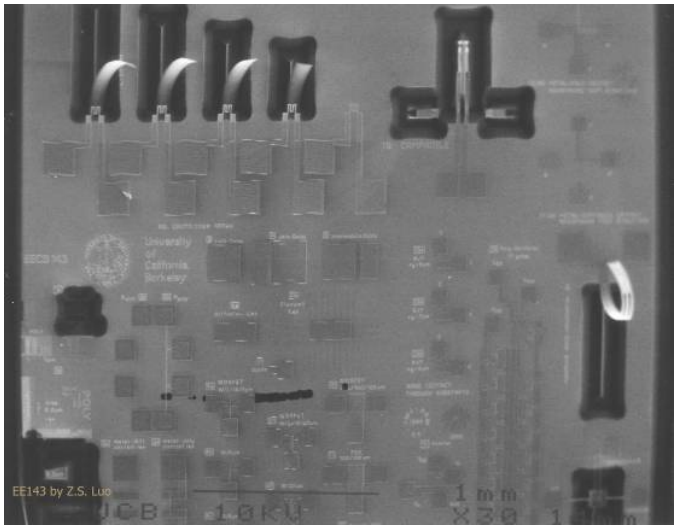


## The EE143 Chip





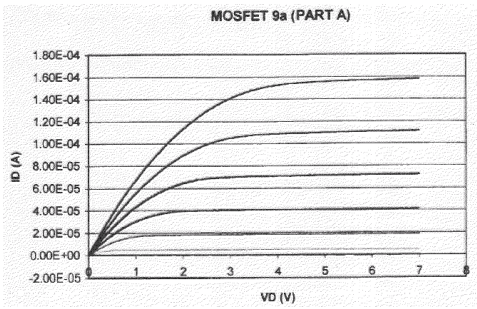
## This is How Your Chip Looks Like






# Measure Your Devices

- The resulting structures may be characterized electrically or mechanically




17-stage Ring Oscillator

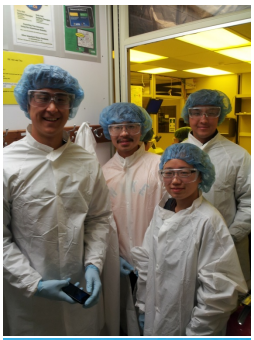


# Laboratory Information

- Lab starts in the week of Aug. 29
- We do our best to limit lab size to 6 students; as a result, your telebears enrollment is not a guarantee of being assigned to a lab.
- You MUST send an email to Professor Wu (wu@eecs.berkeley.edu) by this Friday 10am including the following information:
  - Email Subject: EE143 Lab
  - 1) Full Name
  - 2) Major
  - 3) Year (Jr., Sr., Grad student, etc.)
    4) Rank list of preferred lab sections in descending order of preference (i.e., 1st choice, 2nd choice…)
  - 5) List of any lab sections that you CANNOT attend
- Failure to send an email by this Friday may result in you being dropped from the course, even if you are registered on telebears.
- Final lab assignment will be sent to you via email. PLEASE ENSURE THAT YOUR EMAIL ADDRESS ON TELEBEARS IS CORRECT, SINCE THIS WILL BE USED FOR OFFICIAL CORRESPONDENCE!!!

## Lab Cleanliness

- Fully gowned before entering cleanroom
  - Hair net + lab coat + glove + shoe net + safety goggles
- Do NOT touch chemicals / equipment with bare hands
- Always handle wafers with tweezers and trays (unless told otherwise)
- Wash hands before and after entering the lab (why??)
  - Before: so as not to contaminate wafers or equipment
  - After: avoid chemicals being ingested
- 3rd week, GSIs will demonstrate how to clean masks
- 4th week, GSIs will demonstrate how to piranha-clean wafers





## Lab Safety

- First week is on Lab Safety (week of Aug. 29)
- Mandatory Lab attendance required
- You will have a lab orientation session, and will have to pass a safety quiz before you are officially enrolled in this course.
- You MUST attend the lab session to which you are assigned.

# Lab Safety

- Do NOT enter the lab when GSI aren't present
- Know all the emergency exits
  - Ask GSIs to show you
- Know where to find the MSDS
  - Under the whiteboard in characterization room
- Know where to find the closest water sources, shower, eye wash, sink
- Always ASK if you are not sure what to do!
  - Do NOT try things out without permission
- NO eating, drinking, playing, etc. inside the lab
- Things in the lab can be dangerous if not carefully handled. Be sure to respect the chemicals.



# Chemical Handling

- Wear protective gear when handling corrosive chemicals
  - Face shield, chemical apron, chemical gloves, respirator if necessary
- Check glove for holes
- Check pH of unknown spillage, label everything
- Corrosive chemicals: $H_2SO_4$, HF, aluminum etch, TMAH
- Wash and rinse the exposed body parts with water for > 15 mins
- Add acids to water, not the other way around
- Handle wet chemicals only at sinks, acid on right, others on left side

## Chemical Handling (cont'd)

- HF:
  - be very very careful
  - HF will penetrate your body and attack your skeletal system; once you feel it, it is already eating your bones!!!
  - apply calcium gluconate if exposure is suspected
  - use only plastic beakers for HF (why??)
- H2SO4:
  - very painful, severely burns
  - add $H_2O_2$ to $H_2SO_4$ to prepare piranha
  - do not carry the beaker around after mixing (HOT!!)
  - use only glass beakers for piranha (why??)
- Chemicals used in the lab are often harmful. Don't breathe and avoid exposure if possible.
- Use Teflon-ware when handling wafers in acids. Be careful, those Teflon tweezers do not hold the wafers very well!!

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## Chemical Disposal

- Organic chemicals are discarded in designated containers
- NOTE: in this lab, photoresist (PR) is also dumped down the drain.
- Do NOT mix organic wastes with acids (why??)
  - Can cause fire or even explosion
- Do NOT mix acids and bases

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# Lab Floor Plan

**Note: Not drawn to scale**