As with all of these lecture slides, I am indebted to Dr. Dieter Schroder from Arizona State University for his generous contributions and freely given resources. Most of (>80%) the figures/slides in this lecture came from Dieter. Some of these figures are copyrighted and can be found within the class text, *Semiconductor Device and Materials Characterization*. Every serious microelectronics student should have a copy of this book!
Welcome

- **Welcome to ECE4813 Semiconductor Device and Material Characterization.** This is a most useful course if:
  - You are working with semiconductor materials or devices
  - You are involved with measurements
  - You are looking for a job (answer interview questions)

- It will give you a good overview of most of the characterization techniques in the semiconductor industry:
  - Electrical measurements
  - Optical measurements
  - Electron and ion beam measurements
  - X-ray and probe measurements

- The prerequisite for this course is a previous course in semiconductor device physics, e.g., ECE3040, 3080, or 4751
  - You should be familiar with the basic semiconductor devices: pn junctions, metal-semiconductor devices, and MOS devices
Learning Objectives

- The objective of this course is an understanding of most of the characterization techniques used in the semiconductor industry.
- The major emphasis will be on electrical characterization, since these characterization techniques are most frequently used.
- However, optical techniques, as well as electron beam, ion beam, and X-ray methods will also be discussed.
- Where necessary, device physics will be outlined to understand certain techniques.
Your Responsibility

- It is your responsibility to master the material
- I will assign homework so that you have to apply the course material and reinforce learning
- The textbook is one of the best reference books available, Dr. Dieter Schroder’s text “Semiconductor Device and Materials Characterization”. Every Serious Microelectronics Person should keep a copy of this book. An excellent complement to this book is:
- Occasionally I will provide a paper to read
References

Course Outline

- Electrical Characterization
  - 0. Basic Electrical Measurement Theory, Probe and Instrumentation
  - 1. Resistivity
  - 2. Carrier/Doping Densities
  - 3. Contact Resistance
  - 4. Series Resistance
  - 5. Schottky Barriers
  - 6. MOSFET Channel Length
  - 7. Threshold Voltage
  - 8. Defects, Impurities
  - 9. MOS Capacitors
  - 10. Oxide Charges
  - 11. Interface States
  - 12. Carrier Lifetime
  - 13. Mobility
  - 14. Charge-based Measurements
  - 15. Probe Microscopy
  - 16. Reliability
  - 17. Failure Analysis
Course Outline

Optical Characterization

1. Optical Microscopy
2. Ellipsometry
3. Transmission, Reflection
4. Photoluminescence
5. Emission Microscopy
Course Outline

Physical/Chemical Characterization

- 1. Scanning Electron Microscopy
- 2. Auger Electron Spectroscopy
- 3. Transmission Electron Microscopy
- 4. Voltage Contrast
- 5. Secondary Ion Mass Spectrometry
- 6. Rutherford Backscattering
- 7. X-Ray Fluorescence
- 8. X-Ray Photoelectron Spectroscopy
Approximate Course Schedule

- **Week 1**
  - Introduction, Resistivity

- **Week 2**
  - Sheet Resistance

- **Week 3**
  - Doping Profiling

- **Week 4**
  - Series, Contact Resistance

- **Week 5**
  - Diodes

- **Week 6**
  - Threshold Voltage
  - Channel Length

- **Week 7**
  - Defects

- **Week 8**
  - MOS Charges

- **Week 9**
  - Recombination
  - Mobility

- **Week 10**
  - Charge-based
  - Probes

- **Week 11**
  - Optical
  - Electron Beam

- **Week 12**
  - Ion Beam
  - X-Rays

- **Week 13**
  - Reliability (time permitting or presentations)

- **Week 14**
  - Failure Analysis (time permitting or presentations)
Material/Device Parameters

- Gate Length/Width
- Threshold Voltage
- Contact/Series Resistance
- Oxide Thickness
- Oxide Charges
- Junction Depth
- Doping Profile
- Resistivity
- Impurities
- Defects
- Mobility
- Generation/Recombination
- Lifetime

IBM's POWER 6
7.9x10^8 transistors
4.7 GHz, 2007