ECE 4813

Semiconductor Device and Material Characterization

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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:

  W.R. Runyan and T.J. Shaffner, *Semiconductor Measurements and Instrumentation*, McGraw-Hill, 1998.
- Occasionally I will provide a paper to read

References

- D.K. Schroder, *Semiconductor Material and Device Characterization*, 3rd ed., Wiley Interscience, 2006.
- W.R. Runyan and T.J. Shaffner, *Semiconductor Measurements and Instrumentation*, McGraw-Hill, 1998.
- T.J. Shaffner, "Semiconductor Characterization and Analytical Technology," *Proc. IEEE*, 88, 1416-1437, Sept. 2000.
- C.R. Brundle, C.A. Evans, Jr. and S. Wilson, Eds., *Encyclopedia of Materials Characterization*, John Wiley & Sons, 1992.
- R.E. Whan, K. Mills, J.R. Davis, J.D. Destefani, D.A. Dieterich, G.M. Crankovic, H.J. Frissell, D.M. Jenkins, W.H. Cubberly, R.L. Stedfeld, eds. *Materials Handbook Ninth Edition: Vol. 10 Materials Characterization*, American Society for Metals, 1986.
- A.C. Diebold, ed., *Handbook of Silicon Semiconductor Metrology,* Marcel Dekker, New York, 2001.
- S. Cristoloveanu and S. S. Li, *Electrical Characterization of Silicon-on-Insulator Materials and Devices*, Kluwer Academic, Boston, 1995.

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

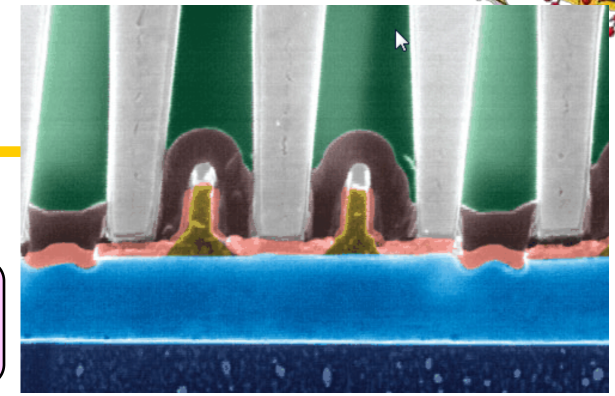
Course Outline

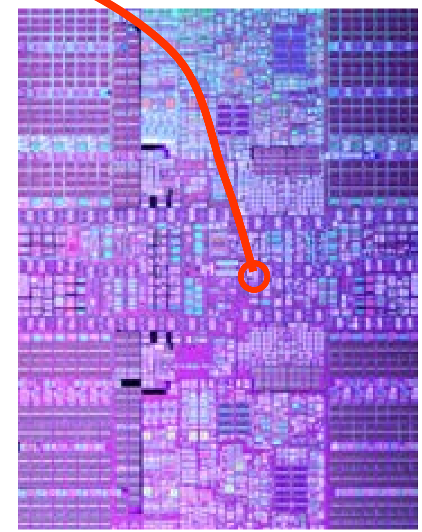
- Physical/Chemical Characterization
  - 1. Scanning Electron Microscopy
  - 2. Auger Electron Spectroscopy
  - 3. Transmission Electron Microscopy
  - 4. Voltage Contrast
  - 5. Secondary Ion Mass Spectrometry
  - 6. Rutherford Backscattering
  - 7. X-Ray Fluorescence
  - 8. X-Ray Photoelectron Spectroscopy

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





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