MSE 460: Electronic Materials, Devices and Processing

Course Description: This class introduces students to materials used in modern electronic and optoelectronic devices. The progress of microelectronic industry is largely driven by the development and introduction of new materials. The structure, chemistry, and processing of materials are closely related to their electronic and optical properties and therefore the device characteristics. This course will cover the processing of electronic materials, the materials science and engineering of semiconductors, the physics behind the operations of various electronic and optoelectronic devices, and the adoption of different materials as well as bulk and nanoscale semiconductor processing techniques to deliver the desired device performances.

Course Objectives: Students will be able to understand the operational mechanism of various electronic and optoelectronic devices, and how their performances are limited by material properties. Students will develop the technical insight into the choice of the most appropriate materials and processing techniques for different applications, and obtain a grasp of the most important challenges. The goal is to help students develop a background in semiconductor materials and semiconductor processing for related jobs, and more importantly to prepare them for future research in this field in graduate school if they would like to seek a career in the Research and Development sector of the semiconductor industry.

Prerequisites: MSE 304 or PHYCS 460

Lectures: 10:00-10:50 am, Monday/Wednesday/Friday, @ 305 MSEB

Instructor:

Prof. Qing Cao (Email: qingcao2@illinois.edu)

Office hour: Friday 2-3 pm @ 106 Materials Research Lab or by email appointment

Teaching Assistant:

Logan Keating (Email: logank3@illinois.edu)

Office hour: Thursday 12:30-1:30pm @ MEB 205A
Grading:
Homework: 21% (3% * 7)
Midterm Exam: 37%
Final Exam: 42%

Homework Protocol
Homework will due in class after one week. Please submit a stapled hardcopy with your name. Clear handwriting or print please.

References


Syllabus:
Lecture 1 (01/14): Introduction and Orientation

Semiconductor Processing Technologies
Lecture 2 (01/16): Lithography I: Basics
Lecture 3 (01/18): Lithography II: New Developments
Lecture 4 (01/23): Silicon Materials and Oxidation
Lecture 5 (01/25): Doping
Lecture 6 (01/28): Materials Deposition I
Homework 1: Due on 02/04
Lecture 7 (01/30): Materials Deposition II
Lecture 8 (02/01): Electrodeposition
Lecture 9 (02/04): Growth and Transfer Printing of Nanomaterials
Lecture 10 (02/06): Wet Etching Chemistry
Lecture 11 (02/08): Dry etching
Homework 2: Due on 02/15
Materials Science of Electronic Materials

Lecture 12 (02/11): Crystal structure and Phase Diagram
Lecture 13 (02/13): Free electron Fermi gas and energy bands
Lecture 14 (02/15): Energy Bands
Lecture 15 (02/18): Carrier Concentration in Semiconductors and Point Defects
Lecture 16 (02/20): Electronic States due to Point Defects and Line Defects
Homework 3: Due on 02/27
Lecture 17 (02/22): Planar and Volume Defects
Lecture 18 (02/25): Midterm Review

Lecture 19 (02/27): Midterm Exam

Lecture 20 (03/01): Carrier Transport in Semiconductors

p-n Junctions
Lecture 21 (03/04): p-n junctions
Lecture 22 (03/06): Current Voltage Characteristics of p-n Junctions
Lecture 23 (03/08): Schottky Diode and Heterojunctions
Homework 4: Due on 03/15
Lecture 24 (03/11): Light Emitting Diodes
Lecture 25 (03/13): Physics of Solar Cells
Lecture 26 (03/15): Solar cell-Materials
Lecture 27 (03/25): Transparent Conductive Oxide

Field-Effect Transistors
Lecture 28 (03/27): Electrostatics of MOS Capacitor
Lecture 29 (03/29): C-V Characteristics of MOS Capacitor And Operation of MOSFET
Lecture 30 (04/01): Subthreshold Region of MOSFET And Velocity Saturation
Lecture 31 (04/03): Device Scaling and Short-Channel effects
Homework 6: Due on 04/10
Lecture 32 (04/05): Non-ideal semiconductor-gate dielectric interface and High-k/metal gate
Lecture 33 (04/08): High-k/metal gate (II)
Lecture 34 (04/10): 3D Channel and New Channel Materials for MOSFETs
Lecture 35 (04/12): Thin-film Transistors and Flexible Electronics

**Memory Technologies**

Lecture 36 (04/15): Overview and SRAM
Lecture 37 (04/17): DRAM
Lecture 38 (04/19): Flash memory
Homework 7: Due on 04/26
Lecture 39 (04/22): PCM: device and materials
Lecture 40 (04/24): PCM: system and integration
Lecture 41 (04/26): RRAM
Lecture 42 (04/29): Non-volatile Memory for Neural Networks
Lecture 43 (05/01): Final Review

**Final Exam**