MATERIALS SCIENCE (MSCI)

MSCI-200 Introduction to Semiconductors 4 Credits
Prerequisites: None
This course represents a broad technical survey of the semiconductors manufacturing ecosystem, from sand to wafers to integrated semiconductor chips and more. A brief history and overview of the global semiconductors industry sets the backdrop for the entire course material. The technical content begins with a general discussion of the energy-band structure of materials, which leads to the introduction and classification of semiconductors (intrinsic, extrinsic, n-type, p-type), and to a first basic discussion of semiconductor structures and devices (p-n junction, diodes, transistors). This foundational knowledge is then used as the backdrop for the introduction and discussion of the basic manufacturing processes (deposition, photolithography, etching, doping and packaging), followed by a more advanced discussion of the operation of diodes and transistors (BJTs and MOSFETs), and of actual, current practical architectures of devices (CMOS, FINFET, GAA Transistors, logic, and memories). Examples other than computer chip applications, like MEMS devices, optoelectronic devices (laser diodes, photodiodes), and photonic integrated chips (PICs) are also briefly addressed for a more rounded view of semiconductors beyond computing and beyond silicon. The course is taught in a studio-like format and consists of a blend of lectures and discussions, computer animations, simulations, and hands-on activities.
Lecture: 4, Lab 0, Other 0

MSCI-335 Computational Materials Science for Energy Applications 4 Credits
Prerequisites: MSCI-200
This course is designed for junior- and senior-level undergraduate students to introduce computational techniques in materials science with an emphasis on energy applications. It covers the theoretical foundations and practical use of materials modeling and simulation across multiple length scales, connecting atomic-level behavior to macroscopic properties. Students will learn a range of computational methods, including molecular dynamics, Monte Carlo techniques, and basic electronic structure concepts, and apply them in hands-on sessions to investigate materials relevant to energy technologies such as batteries, solar cells, and thermoelectric devices. The course also emphasizes the analysis, interpretation, and effective presentation of simulation results.
Lecture: 4, Lab 0, Other 0

MSCI-337 Material Synthesis 4 Credits
Prerequisites: CHEM-135 and CHEM-136
This course introduces the industrial and laboratory methods of synthesizing a variety of materials such as semiconductors, complex ionic solids, metal-organic frameworks, and nanomaterials. These materials have applications in the fields of electronics, energy, sustainability, and medicine. Topics include 1) Industrial preparation of silicon wafers and semiconductor alloys; 2) Chemistry in the fabrication of microelectronics 3) Laboratory synthesis of complex ionic solids, metal-organic frameworks and nanomaterials. A variety of synthesis techniques will be discussed, such as high temperature solid state reactions, hydrothermal and sol-gel methods, ultrasound-assisted and microwave-assisted methods, and thin- film deposition methods. A strong laboratory component will augment lectures.
Lecture: 4, Lab 0, Other 0

MSCI-465 Materials Characterization 4 Credits
Prerequisites: CHME-207 or MECH-207 or MSCI-200 or PHYS-366 or PHYS-376
This course is a broad survey course of properties and characterization techniques of materials, primarily at the microscopic level. The course begins with a review of material classification and properties in general, then quickly sets the focus on such microscopic properties as chemical (elemental and molecular) composition, crystal structure, energy band structure, charge carriers, electrical and optical properties and surface morphology and chemistry. The wave-particle behavior of light and electrons, critical for understanding the principle of operation of many of the techniques discussed, is also reviewed. The broad classes of techniques and associated instrumentation that are prevalent in industry and research materials characterization labs are then discussed. These include optical emission and absorption techniques for chemical composition (OES, OAS, UV-VIS, FTIR, Raman), X-ray fluorescence and ICP-MS; X-ray diffraction for crystal structure determination; optical microscopy and scanning-probe techniques (AFM, STM) for surface morphology characterization; surface chemistry techniques like X-Ray Photoelectron (XPS), Secondary-Ion Mass Spectroscopy (SIMS) and Scanning Electron Microscopy (SEM) with Energy-Dispersive X-Ray Spectroscopy (SEM EDS or EDX); techniques and instrumentation for optical properties, like UV-VIS absorption, fluorescence and photoluminescence and ellipsometry of thin films; and techniques for electrical resistance measurements. The application of these techniques to a variety of materials (semiconductors, metals, oxides) is discussed through case studies.
Lecture: 4, Lab 0, Other 0