MTSE 719 - PHYSICAL PRINCIPLES OF CHARACTERIZATION OF SOLIDS

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Section #	Call #	Days / Times
001 – 96175 -View Book Info - F:100PM - 355PM - TIER114		

Preamble:

Core course for students in Material Science and Engineering, Nano-scale characterization of materials. Basic science of solid state characterization. Elements of modern physics. Optical microscope. Neutron scattering. Infrared and Raman spectroscopy. Rutherford backscattering spectroscopy. NMR. X-ray diffraction. X-ray photoelectron spectroscopy and Auger Electron Spectroscopy. SEM, TEM, STEM and STM.

Emphasis:

Material = Device ?

General Information

Course Meetings: Fridays 1-4 pm; Tiernan Bldg # 114

Prerequisites: Undergraduate Background in Physical Sciences

Office Hours: Tiernan – 414; Generally Open-Door – 9.30 AM to 5.30 PM

Mondays through Wednesdays

Contact: 973.596.3278/6453; nmravindra@gmail.com;

Cell: 908.477.1722 – Only for emergencies please!

Preferred way of Communication: In Person or By Email

References - Texts and Suplementary Materials

James D. Livingston
Electronic Properties of Engineering Materials
ISBN: 978-0-471-31627-5
336 pages
December 1998, ©1999
Wiley

Rolf E. Hummel
Electronic Properties of Materials
Springer – Any Edition

Materials Characterization: Introduction to Microscopic and Spectroscopic Methods
Yang Leng
ISBN: 978-0-470-82299-9
384 pages
March 2009
Wiley

Microstructural Characterization of Materials, DAVID BRANDON AND WAYNE D. KAPLAN, 2nd Edition, Wiley, 2008.

Surface Analysis: The Principal Techniques John C. Vickerman (Editor), Ian Gilmore (Editor), 2nd Edition, Wiley, 2011.

Classroom Notes – Classroom Attendance Mandatory

Course

Supplementary Materials will be sent to you each week, on Tuesdays, in preparation for the class.

Description

Materials Research is constantly evolving and correlations between process, structure, properties and performance which are application specific require expert understanding at the macro-, micro- and nano-scale. The ability to intelligently manipulate material properties and tailor them for desired applications are of constant interest and challenge within universities, national labs and industry.

A fundamental premise in materials science is that properties and performance are the consequence of structure, and that structure is the consequence of the processes. Characterization has the task of revealing structure.

Materials Characterization is now a sub-discipline within materials science and engineering.

Learning Objectives and Outcomes:

This course presents materials characterization, emphasizing on surface, interface and microanalysis, using the underlying analytical techniques as a unifying framework, carrying through to illustrative applications. Its objective is to provide students with the knowledge level needed for them to:

- define a characterization strategy appropriate to the problem/situation

- select the most appropriate/promising techniques

- analyze and interpret the results – utilizing interpretation/simulation tools

- use mathematical models to simulate the results of experiments

- develop state of the art expertise – hardware, software, systems integration

- understand new techniques as they emerge.

The course provides some knowledge that is state-of-the-art. It is intended for graduate students.

A further benefit of the course is to provide students a fundamental and practical understanding of the interaction of particle radiation with condensed matter. Such knowledge finds applications in optoelectronics, microelectronics and, in general, all aspects of materials processing and characterization.

Responsibilities

Attendance at all classes is mandatory. There will be at least two exams and a quiz during the semester. All examinations will be closed notes and closed book.

Grading

Course grades will be determined on the basis of: two exams (40%) and homework (20%).

Outline of the Material –

The course will cover all aspects of materials characterization including techniques to determine chemical, electrical, electronic, magnetic, mechanical, optical, structural and thermal properties.

The materials to be covered include the following:

Electrical Techniques – 2-Probe, 4-Probe, I-V, C-V, DLTS, Hall Measurements

Optical Techniques – IR, UV, VIS Spectroscopy, Raman, Micro-Raman, SERS, FTIR

Analytical Techniques –

X-RAY TECHNIQUES - Techniques based on measuring the energy or angular distribution of scattered X-rays

X-ray fluorescence spectroscopy - Basics- core hole formation, fluorescence yield, transport ("ZAF"); Experimental realization - Bulk analysis; lab and synchrotron x-ray sources; Surface analysis – TXRF; Microscopy – x-ray beam manipulation

Inelastic scattering- X-ray absorption spectroscopy; Basics- edges and extended fine structure; XANES and EXAFS quantitation; Surface sensitivity; Experimental methods

Wide angle elastic scattering (XRD); atomistic -form factors; unit cell – structure factors, Bragg equation, reciprocal lattice, Laue equations; Experimental methods- transmission, reflection, thin film, in-situ; Other information- particle size distributions, etc.

Small angle scattering- SAXS; Basics- what SAXS sees; Mathematical modeling; **Experimental Methods**

ELECTRON MICROSCOPIES

Transmission electron microscopy (TEM/STEM) Electron interactions in solids- elastic and inelastic scattering, phase change; Contrast generation- bright field, dark field, "high-resolution"; Images- information and resolution; Diffraction; Beam damage; Experimental methods- hardware, specimen preparation; Inelastic scattering- electron energy loss; Emitted x- rays – elemental analysis, sensitivity, spatial resolution; STEM

Scanning electron microscopy Beam transport in bulk solids; Signals and images- backscattered and secondary electrons; Diffraction- channeling patterns – EBSD; X-ray generation and transport, detection and analysis; Other useful signals; Experimental methods; Electron probe micro-analyzer

ION BEAM TECHNIQUES- techniques using ions or neutrals made from them as the bombarding species

Ion beams - production- ion guns; manipulation- ion optics, filters

(Low Energy) Ion Scattering Spectroscopy- (LE)ISS Neutralization and scattering at low ion energy; Mathematical description - quantization; Experimental methods – energy spectroscopy

Rutherford (Nuclear) Backscattering Spectroscopy- (RBS) High energy ions in solids- electronic and nuclear (Rutherford) stopping; Quantitative description; Experimental methods – energy spectroscopy

Surface Mass Spectroscopy - SIMS Ejection of matter by bombardment: sputtering; Fate of ejected material- subsequent reaction, charge state; Mass detection – quad, magnetic sector, ToF; experimental issues

VIBRATIONAL SPECTROSCOPIES

Vibrations in molecules and solids – normal coordinates, group frequencies

Infrared spectroscopy: IR absorption – dipole scattering, selection rules; Optical arrangements- transmission, specular reflectance, diffuse reflectance, attenuated total reflectance, microscopy, in-situ; Signal collection and Fourier transform processing, data analysis

Raman: Energy transfer, selection rules; Normal, resonance, surface-enhanced, Fourier transform, UV

Non-linear: SFG Mechanism, selection rules, intensities; Experimental requirements and methods

RESONANCE ABSORPTION SPECTROSCOPIES

Nuclear Magnetic Resonance (NMR) Fundamentals; Experimental Techniques; Magnetic Resonance Imaging

Electron Paramagnetic Resonance (EPR) Fundamentals; Experimental Techniques

PROXIMAL PROBE MICROSCOPIES - Scanning Tunneling Microscopy (STM) and Atomic Force Microscopy (AFM) Basics; Experimental methods; Spectroscopy in Scanning Probe Microscopy

ELECTRON SPECTROSCOPIES- techniques based on measuring the energy distribution of emitted electrons

Photoelectron spectroscopy Basics- energy balance, element identification; Not-so-Basics- relaxation, chemical states, satellites; Surface sensitivity; Quantitation; UPS- the unfamiliar cousin.

Auger Electron Spectroscopy. Electron excitation; The Auger Spectrum - energy balance; Chemical effects; Quantization; Imaging- meaning and non-meaning of maps.

Experimental methods; Surfaces of real-world things; Below the surface- profiling, variable energy; Hardware and software. Samples and handling.

CHARACTERIZATION STRATEGY/GOALS –

What, How and why? Problem analysis Selection of Technique; Modeling the results; Data analysis

Learn at least one new technique each week; appreciate the correlations between process- property-performance.

Mid-Term – One; Final Exams – One; At least two surprise quiz

Lesson Plan:

Week 1	**Course Overview**
Week 2	**Electrical Properties**
Week 3	**Electrical Properties**
Week 4	**Optical Properties**
Week 5	**Optical Properties**
Week 6	**Electronic Properties**
Week 7	**Mid-Term**
Week 8	**Electronic Properties**
Week 9	**Magnetic Properties**
Week 10	**Mechanical Properties**
Week 11	**Structural Properties**
Week 12	**Structural Properties**
Week 13	**Thermal Properties**
Week 14	**Final Examination**

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