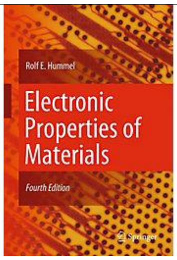
MTSE 719 - PHYSICAL PRINCIPLES OF CHARACTERIZATION OF SOLIDS

Course Information

Physical Principles of Characterization of Solids - MTSE 719 102

CRN: **14674**

Duration; Location; Hours: **January 16, 2024 - May 11, 2024; FMH 314; 6-8.50PM - Tuesdays**



RECOMMENDED

Electronic Properties of Materials
https://link.springer.com/book/10.1007/978-94-017-4914-5

1. **Edition:** 4th or alternate edition
2. **ISBN:** 9781441981639
3. **Author** Rolf Hummel
4. **Publisher:** Springer Nature
5. **Formats:** Hardcover
6. **Copyright Year:** 2011

Core course for students in Material Science and Engineering, Quantum Mechanics Fundamentals; Nano-scale characterization of materials. Basic science behind solid state characterization. Elements of modern physics. Optical microscopy. 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.

General Information

Course Meetings: Tuesdays 6-8.50 pm; FMH # 314

Prerequisites: Undergraduate Background in Physical Sciences

Office Hours: Tiernan–414; Generally Open-Door – Fridays: 10.00 AM to 5.00 PM

Contact:973.596.3278/6453; nmravindra@gmail.com

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

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

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

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

Classroom Notes – Classroom Attendance is Mandatory

Course

Supplementary Materials will be sent to you via email in support of the class notes.

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 two exams and a quiz during the semester. All examinations will be closed notes and closed book. Calculators are required during all classes and exams.

Grading

Course grades will be determined on the basis of: two exams (45% each) and homework (10%).

A - > 80%, B+ - 74-79%, B – 63-73%, C+ - 57-62%, C – 46-56%, D – 40-45, F - <40%.

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:

Quantum Mechanics Fundamentals – Electrons, Photons, Phonons

Fundamentals of Electronic & Electrical Properties

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

Fundamentals of Optical Properties

Optical Techniques – IR, UV, VIS Spectroscopy, Ellipsometry, 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; Basics- relaxation, chemical states, Surface sensitivity.

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 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.

Understand and appreciate State-of-the-art-Characterization Techniques, practiced in industry, in a class-room setting.

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	**EXAM - 1**
Week 8	**Electronic Properties**
Week 9	**Magnetic Properties**
Week 10	**Mechanical Properties**
Week 11	**Structural Properties**
Week 12	**Thermal Properties & Review**
Week 13	**Final Exams**

-

Spring 2024 Academic Calendar

January	15	Monday	Martin Luther King, Jr. Day
January	16	Tuesday	First Day of Classes
January	20	Saturday	Saturday Classes Begin
January	22	Monday	Last Day to Add/Drop a Class
January	22	Monday	Last Day for 100% Refund, Full or Partial Withdrawal
January	23	Tuesday	W Grades Posted for Course Withdrawals
January	29	Monday	Last Day for 90% Refund, Full or Partial Withdrawal, No Refund for Partial Withdrawal after this date
February	12	Monday	Last Day for 50% Refund, Full Withdrawal
March	4	Monday	Last Day for 25% Refund, Full Withdrawal
March	10	Sunday	Spring Recess Begins - No Classes Scheduled - University Open
March	16	Saturday	Spring Recess Ends
March	29	Friday	Good Friday - No Classes Scheduled - University Closed
March	31	Sunday	Easter Sunday - No Classes Scheduled - University Closed
April	1	Monday	Last Day to Withdraw
April	30	Tuesday	Friday Classes Meet
April	30	Tuesday	Last Day of Classes
May	1	Wednesday	Reading Day 1
May	2	Thursday	Reading Day 2
May	3	Friday	Final Exams Begin
May	9	Thursday	Final Exams End
May	11	Saturday	Final Grades Due
May	15	Wednesday	Commencement - MS and PHD Ceremonies
May	17	Friday	Commencement - Undergraduate Ceremonies