Lahore University of Management Sciences

CHEM 516 – Characterization Techniques for Materials

Fall 2023

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Course URL (if any)	LMS
Support Services	LUMS offers a range of academic and other services to support students. These are mentioned below, and you are encouraged to use these in addition to in-class assistance from course staff. For a complete list of campus support services available for you click here (https://advising.lums.edu.pk/#supportservices)

Course Basics				
Credit Hours	3			
Lecture(s)	Nbr of Lec(s) Per Week	2	Duration	75 min
Recitation/Lab (per week)	Nbr of Lec(s) Per Week		Duration	
Tutorial (per week)	Nbr of Lec(s) Per Week		Duration	

Course Distribution	
Core	
Elective	Yes
Open for Student Category	SBASSE (senior, graduate)
Close for Student Category	Freshmen, sophomore, junior

COURSE DESCRIPTION
Development of new materials and their applications is driven by understanding their structure-property relationship which is at the core of any materials related research. A host of experimental techniques are available which yield information about materials at scales ranging from macro down to atomic level. This interdisciplinary course introduces the basic principles and techniques used in structural, morphological, chemical, thermal, and mechanical characterization of materials. Emphasis will be on the fundamental theory and principles, instrumentation, data analysis and interpretation. Recent research literature and case studies will also be discussed and, if possible, there will be lab demos of relevant techniques.

COURSE PREREQUISITE(S)	
•	None

COURSE OBJECTIVES	
1. 2. 3.	To provide a broad overview of the fundamental principles of materials characterization techniques. To discuss the instrumentation, capabilities, and limitations of each technique. To understand the type of information from each technique and apply it to characterize physical and chemical properties of materials.

Learning Outcomes	
CLO1	**Explain** the fundamental principles behind different materials characterization techniques.
CLO2	**Analyze** the data acquired from each technique and interpret it.
CLO3	**Evaluate** the data acquired considering the capabilities and limitations of each technique.

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Grading Breakup and Policy
Assignment(s): 10% (3-4 Assignments) Quiz(s): 15% (6-7 quizzes) Project: 10% Midterm Examination: 25% Final Examination: 40%

Examination Detail	
Midterm Exam	Yes/No: Yes Combine Separate: Combine Duration: 75 min Preferred Date: 8th week of semester Exam Specifications:
Final Exam	Yes/No: Yes Combine Separate: Combine Duration: 150 min Exam Specifications:

Campus supports & Key university policies

Campus Supports

Students are strongly encouraged to meet course instructors and TA's during office hours for assistance in course-content, understand the course's expectations from enrolled students, etc. Beyond the course, students are also encouraged to use a variety of other resources. (Instructors are also encouraged to refer students to these resources when needed.) These resources include Counseling and Psychological Services/CAPS (for mental health), LUMS Medical Center/LMC (for physical health), Office of Accessibility & Inclusion/ OAI (for long-term disabilities), advising staff dedicated to supporting and guiding students in each school, online resources (https://advising.lums.edu.pk/advising-resources), etc. To view all support services, their specific role as well as contact information click here (https://advising.lums.edu.pk/#supportservices).

Academic Honesty/Plagiarism

LUMS has zero tolerance for academic dishonesty. Students are responsible for upholding academic integrity. If unsure, refer to the student handbook and consult with instructors/teaching assistants. To check for plagiarism before essay submission, use similarity@lums.edu.pk. Consult the following resources: 1) Academic and Intellectual Integrity (http://surl.li/gpvwb), and 2) Understanding and Avoiding Plagiarism (http://surl.li/gpvwo).

LUMS Academic Accommodations/ Petitions policy

Long-term medical conditions are accommodated through the Office of Accessibility & Inclusion (OAI). Short-term emergencies that impact studies are either handled by the course instructor or Student Support Services (SSS). For more information, please see Missed Instrument or 'Petition' FAQs for students and faculty (https://rb.gy/8sj1h)

LUMS Sexual Harassment Policy

LUMS and this class are a harassment-free zone. No behavior that makes someone uncomfortable or negatively impacts the class or individual's potential will be tolerated.

To report sexual harassment experienced or observed in class, please contact me. For further support or to file a complaint, contact OAI at oai@lums.edu.pk or harassment@lums.edu.pk. You may choose to file an informal or formal complaint to put an end to the offending behavior. You can also call their Anti-Harassment helpline at 042-35608877 for advice or concerns. *For more information: Harassment, Bullying & Other Interpersonal Misconduct: Presentation (http://surl.li/gpvwt)*

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COURSE OVERVIEW			
Lecture	**Topics**	**Recommended Readings**	**Objectives/ Application**
1	Introduction to materials science, development of advanced materials including nanomaterials, properties and applications, characterization techniques.	Lecture notes	Understanding of various types of materials, their applications, and the need to characterize their structural, chemical, and physical properties at macro-, micro- and nano- scale.
Module 1: Light and Electron Microscopy			
2	**Optical Microscopy (OM)** Resolution, magnification, depth of field, optical microscopy techniques (reflected, transmitted, fluorescence, confocal), applications.	Lecture notes	To learn the capabilities, applications, and limitations of various techniques of optical microscopy.
3-5	**Scanning Electron Microscopy (SEM)** Principle, instrumentation, electron-sample interaction, imaging modes, detectors, compositional and topographical contrast, Energy-dispersive X-ray spectroscopy (EDS or EDX) and Scanning Transmission Electron Microscopy (STEM) mode in SEM.	**[Goldstein]** & Lecture notes	Difference between light and electron microscopy, construction of electron microscopes, types of signals and image formation in SEM, compositional analysis, capabilities and applications of SEM.
6-7	**Transmission electron microscopy (TEM)** Principle, specimen preparation, image formation, diffraction contrast, selected area electron diffraction (SAED) of single & poly crystals, indexing, high resolution TEM (HR-TEM), Scanning Transmission Electron Microscopy (STEM) and High-Angle Annular Darfield Field mode in STEM (HAADF-STEM).	**[Carter]** & Lecture notes	Difference between SEM and TEM, various modes of imaging in TEM, capabilities, and applications of TEM.
8	**Data analysis and interpretation**	Lecture notes	To learn data analysis and interpretation by discussing examples, recent research articles and case studies.
Module 2: Surface Analysis			
9	**Introduction** Surface science and analysis	**[Gilmore]** & Lecture notes	Role of surfaces in various applications and analysis techniques available to characterize their physical and chemical properties.
10-12	**X-ray photoelectron spectroscopy (XPS)** Principles, photoelectric effect, binding energies, instrumentation, qualitative and quantitative analysis, core levels, chemical shifts, applications.	**[Gilmore]** & Lecture notes	Understanding fundamentals of XPS and its applications in characterizing composition and surface chemical states.
13	**Scanning probe microscopy (SPM)** Principle, imaging modes, instrumentation, probe tips. Applications of (i) ***Atomic force microscopy*** (AFM) and (ii) ***Scanning tunneling microscopy*** (STM) will be discussed.	**[Gilmore]** & Lecture notes	SPM basics, applications of SPM in imaging and forces spectroscopy.
14	**BET surface area and pore size analyzer** Basic principles, instrumentation, and data analysis	Lecture notes	Micro-, meso- and macro-porous materials and their characterization using BET surface area and pore size analyzer, types of isotherms, applications
15	**Data analysis and interpretation**	Lecture notes	To learn data analysis and interpretation by discussing examples, recent research articles and case studies.
Module 3: X-ray Diffraction			
16-17	**Introduction** Structural order, Bravais lattices, miller indices, crystal structures, symmetries.	**[Cullity]** & Lecture notes	Understand the crystal structure of materials.
18-21	**X-ray diffraction (XRD)** Generation of X-rays, diffraction, Bragg's law, diffraction intensities, indexing, crystal structure determination, phase identification, determination of structural properties (crystallite size, strain, epitaxy, texture, mixing), single crystal and powder (polycrystalline) methods, instrumentation.	**[Cullity]** & Lecture notes	Use of X-rays to accurately determine crystal structure and other structural properties.

22	**Data analysis and interpretation**	Lecture notes	To learn data analysis and interpretation by discussing examples, recent research articles and case studies.
Module 4: Thermal Analysis			
23	**Differential Scanning calorimetry (DSC)** Principle, instrumentation, determination of glass transition, crystallization, and melting temperatures, heat of crystallization, heat of fusion, heat capacity.	Lecture notes	Use of DSC to qualitatively and quantitatively understand amorphous and crystalline behavior, polymorph and other transitions, curing and curing kinetics, etc.
24	**Thermogravimetric Analysis (TGA)** Principle, instrumentation, monitoring weight changes during desorption, absorption, sublimation, vaporization, oxidation, reduction, decomposition, and any other chemical reaction. Determination of degradation temperature, filler percentage, thermal stability.	Lecture notes	Use of TGA to characterize changes in physical and chemical nature of materials by monitoring weight changes as a function of temperature and/or time.
25	**Data analysis and interpretation**		To learn data analysis and interpretation by discussing examples, recent research articles and case studies.
Module 5: Static and Dynamic Mechanical Analysis			
26-27	Stress, strain, stress-strain properties (tensile, shear, compressive), yield strength, Young's modulus, toughness, compressive strength, impact strength, hardness, fracture toughness, creep, fatigue. Mechanical properties of metals, ceramics, polymers and composites. Dynamic mechanical analysis and nanoscale mechanical testing.	Lecture notes	Basic understanding of mechanical properties of materials with focus on characterization of viscoelastic materials and nanoscale materials.
28	**Data analysis and interpretation**	Lecture notes	To learn data analysis and interpretation by discussing examples, recent research articles and case studies.

Textbook(s)/Supplementary Readings
[Weller] Inorganic Materials Chemistry, M.T. Weller. **[Goldstein]** Scanning Electron Microscopy and X-Ray Microanalysis, J. Goldstein, 3rd edition. **[Carter]** Transmission Electron Microscopy: a Textbook for Materials Science, D.B. Williams and C.B. Carter, 2nd edition. **[Gilmore]** Surface Analysis: The Principal Techniques, J.C. Vickermann and I. Gilmore, 2nd edition. **[Cullity]** Elements of X-Ray Diffraction, B.D. Cullity and S.R. Stock, 3rd edition. **[Hammond]** The Basics of Crystallography and Diffraction, C. Hammond, 4th edition.