Lahore University of Management Sciences

ENGG 2XX: Introduction to Nanotechnology

Summer-II 2021

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Course URL (if any)	LMS

Course Teaching Methodology
• Teaching methodology: First preference will be to teach in-person. However, if face-to-face teaching is not possible, then a blend of both synchronous and asynchronous mode of teaching will be employed. • Lecture details: In case of online teaching, the lectures will be live with recording. The recorded lectures will be accessible.

COURSE BASICS				
Credit Hours	3			
Lectures (s)	5	110 min each		
Lab				
Recitation/Lab (per week)				
Tutorial (per week)				

COURSE DISTRIBUTION	
Core	
Elective	
Open for Student Category	
Closed for Student Category	

COURSE DESCRIPTION
Nanotechnology is all about materials that are significantly smaller than a human eye can see. To put this into perspective, 1 nanometer is 1 billionth of a meter (1 nm = 10^{-9} m) and a human hair is typically 80,000 – 100,000 nm thick. Such small materials can be formed by scaling down from bulk/microscale to nanoscale dimensions or can be grown atom by atom. The characteristics of materials can potentially change when their dimensions are reduced to nanoscale and in this regime their properties can also be tuned. For example, color of the same material, e.g. gold, at nanoscale can be controlled by their size! Moreover, electrical, magnetic, mechanical and other properties can be altered and enhanced which opens up new avenues of their potential widespread use. This course will provide an overview of nanotechnology and demonstrate why nanoscale regime is different from microscale and bulk regime which results in unique properties. Applications of nanotechnology will be discussed including the very first known use of nanoscale gold and silver in the 4th century Lycurgus Cup, use of metallic nanoparticles in the medieval Islamic pottery, and stained-glass windows. Modern era applications in electronics, sports, medicine, textiles, energy and environment will also be discussed e.g. light-weight automobile bumpers, golf balls and tennis rackets, sunscreens, faster recharging batteries for handheld devices, and digital displays. The famous "Moore's law", predicted by the Intel co-founder Gordon Moore in 1965, will be discussed which is still valid but is it approaching the ultimate limit? These applications are driven by the discovery and synthesis of a diverse range of nanomaterials, development of fabrication technologies capable of producing such materials at small scale, development of tools which can see such small materials and manipulate them as seen in the World's Smallest Movie by IBM. The course is multidisciplinary in nature and will primarily attract science and engineering students and will include 2-3 short guest lectures from experts in a relevant field of nanoscience and nanotechnology.

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COURSE PREREQUISITE(S)	
	None

COURSE OBJECTIVES
• Overview of the broad field of nanotechnology as a multidisciplinary field. • Basic understanding of the underlying principles and effects in the nanoscale regime. • Provide insight into the host of top-down and bottom-up technologies for fabricating nanomaterials and devices. • Understand different types of nanomaterials based on their material class or morphology. • Emphasize the applications of nanotechnology from medieval ages to modern era and how it can shape the future. • Introduce the experimental tools which can see and manipulate nanomaterials down to atomic scale.

LEARNING OUTCOMES
At the end of this course, students should be able to: • Define nanotechnology as a multi-disciplinary field and list some historical, current and emerging applications of nanotechnology. • Explain the length scale of nanometer and relate it to different length scales from atoms to planets. • Explain why the properties of materials can change at nanoscale. • Classify different fabrication approaches for nanomaterials and devices with some examples. • Develop an understanding of advanced experimental techniques to observe nanomaterials with their capabilities and limitations.

GRADING POLICY		
Quizzes	20 %	8-10 short quizzes
Assignments	15 %	3 Assignments
Attendance and class participation	15 %	
Case study presentations	15 %	
Final Exam	35 %	

EXAMINATION DETAIL	
Midterm Exam	No
Final Exam	Yes

Harassment Policy
Harassment of any kind is unacceptable, whether it be sexual harassment, online harassment, bullying, coercion, stalking, verbal or physical abuse of any kind. Harassment is a very broad term; it includes both direct and indirect behaviour, it may be physical or psychological in nature, it may be perpetrated online or offline, on campus and off campus. It may be one offense, or it may comprise of several incidents which together amount to sexual harassment. It may include overt requests for sexual favours but can also constitute verbal or written communication of a loaded nature. Further details of what may constitute harassment may be found in the LUMS Sexual Harassment Policy, which is available as part of the university code of conduct. LUMS has a Sexual Harassment Policy and a Sexual Harassment Inquiry Committee (SHIC). Any member of the LUMS community can file a formal or informal complaint with the SHIC. If you are unsure about the process of filing a complaint, wish to discuss your options or have any questions, concerns, or complaints, please write to the Office of Accessibility and Inclusion (OAI, oai@lums.edu.pk) and SHIC (shic@lums.edu.pk) —both of them exist to help and support you and they will do their best to assist you in whatever way they can. **To file a complaint, please write to** harassment@lums.edu.pk.
SSE Council of Equity and Belonging
In addition to LUMS resources, SSE's **Council on Belonging and Equity** is committed to devising ways to provide a safe, inclusive and respectful learning environment for students, faculty and staff. To seek counsel related to any issues, please feel free to approach either a member of the council or email at cbe.sse@lums.edu.pk

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COURSE OVERVIEW			
Lec.	Topics	Recommended Readings	Objectives/ Application
Topic 1: History and General Concepts in Nanotechnology			
1-2	– Nanometer as a length scale – Limitations of what can be seen by naked eye and introduction to a light microscope – Timeline of nanotechnology and important discoveries and developments	Lecture notes	– To understand the length scale of 1 nanometer and relate it to different scales ranging from sub-atomic particles to planets. Understand the energy and wavelength relation of electromagnetic spectrum including the visible range. – Earliest examples of nanomaterials when the term "nano" was unknown, important discoveries and milestones in modern era, current status and potential market for nanotechnology.
2-3	– Why properties change at nanoscale? – Size effects – Role of surfaces and interfaces	Lecture notes	To understand classical and quantum effects in materials, significantly increase surface area to volume ratio in nanomaterials and, thus, the importance of surfaces and interfaces in determining the overall material properties and behavior.
Topic 2: Seeing is believing			
4-5	Development of techniques which enabled to see small-sized materials at resolutions down to atomic scale (electron microscopy).	lecture notes	– To understand the wave-particle dual nature and how electrons can be used to image things leading to the development of electron microscopy. – Applications including in-situ techniques.
5-6	Development of techniques which enabled to see as well as manipulate atoms and molecules (scanning probe microscopy).	lecture notes	– To understand forces between atomically sharp tips and how they can be used to image surfaces and manipulate atoms and molecules leading to the development of scanning probe microscopy. – Scanning tunneling microscopy and atomic force microscopy. – Applications including in-situ techniques.
Topic 3: Examples of Nanomaterials			
7	Carbon based nanomaterials (nanotubes, fullerenes, graphene)	lecture notes	To understand the sizes, shapes and properties of these nanomaterials and the potential they offer for different applications.
8	Nanoparticles including quantum dots	lecture notes	
9	Nanowires, nanofibers, nanotubes	lecture notes	
10	Nanocomposites	lecture notes	
11	Thin films and coatings **+ Guest lecture**	lecture notes	
Topic 4: How to make such small-sized materials?			
12	Top-down fabrication methods (starting from bulk and microscale materials) – Milling – Lithography – Etching techniques – Deposition techniques	lecture notes	Overview of fabrication methods and their capabilities. Relevant examples will be discussed such as nanostructured alloys, MEMS-based nanotechnology, functional surfaces, and microfluidic devices (example: Lab-on-a-chip).
13	Bottom-up fabrication methods (starting from atoms and molecules) – Nanochemistry – Self-assembly – Sol-gel synthesis	lecture notes	Overview of synthesis methods and their underlying principles. Relevant examples of nanomaterials (gold, oxides, and polymers) will be discussed with emphasis on size and shape control. Fabrication of quantum dots with tunable colors will be discussed as well.
Topic 5: Current and Potential Applications of Nanotechnology			
14	Nanotechnology in everyday use	lecture notes	– To realize how nanomaterials are already in use in everyday consumer products such as sporting goods, sunscreens, antireflective coatings to name a few. – Some advanced applications will also be discussed such as personal body armor, smart fabrics, smart surfaces, wear-resistance coatings, etc.
15	Faster and smarter electronics	lecture notes	– To study how transistors evolved in size from approx. 200 nm in the

	+ Guest lecture		year 2000 to just a few nm in 2020 in context of the famous Moore's law. – Use of quantum dots in ultra-high definition displays, stretchable electronics. – Nanoparticle suspensions as alternative to hazardous lead-based solders, etc.
16-17	Energy generation and storage	lecture notes	– Use of nanoparticles to boost chemical reactions (i.e. catalysis) to save cost and reduce pollutants e.g. petroleum refining and catalytic converters in automobiles. – Rechargeable batteries and thin-film solar panels. – Lightweight epoxy nanocomposites for windmill blades. – Nanoscale additives in polymers for lightweight automobiles, tires, air vehicles, etc.
18-19	Environmental remediation **+ Guest lecture**	lecture notes	– Clean and affordable drinking water, water desalination, wastewater treatment (e.g. dyes from textile industries). – Mitigating air pollution through use of nanopores in filters. – Sensors to detect contaminants in air, water and soil. – Mitigating carbon dioxide emission (global warming) through nanotechnology.
20	**Final Examination**		

Textbook(s)/Supplementary Readings

Many books are available on nanotechnology but there is no single book which is preferred for an introductory undergraduate course suitable for students from diverse backgrounds. The primary source of reading will be lecture notes which will be uploaded before each lecture. Additional reading material will also be provided in form of book chapters, research articles and other online resources.

These two books are good for supplementary reading.
[Ashby] NANOMATERIALS, NANOTECHNOLOGIES AND DESIGN: An Introduction for Engineers and Architects, *Michael F. Ashby*, Butterworth-Heinemann. 2009.
[Ratner] Nanotechnology: A Gentle Introduction to the Next Big Idea, *Mark Ratner*, Prentice Hall. 2002