MSE MSE4330: Fundamentals of Nanomaterials and Nanostructures
School of Materials Science and Engineering
G021 Molecular Science & Engineering Building
Tuesdays and Thursdays 4:30–5:45 pm

Office Hours: 1:00–2:00 pm (Tuesdays and Thursdays) or appointment by emails
3100N Molecular Science & Engineering Building

Prerequisites: MSE 2001 or instructor consensus

Course Overview: This course covers the fundamentals of nanomaterials and nanostructures, as well as their unique properties for a broad spectrum of applications in science and technology. It emphasizes the interplay of engineering, chemistry, surface science, and physics to elucidate the multi-disciplinary nature of nanoscale science and engineering. The selected topics are appropriate for students in materials science and engineering, chemistry, physics, chemical engineering, mechanical engineering, environmental engineering, biomedical engineering, and electrical engineering.

Course Description: This course will *i*) start with physical chemistry and surface science to elucidate the fundamental concepts and unique properties of solid materials emerging at the nanoscale; *ii*) introduce both "top-down" and "bottom-up" approaches to the fabrication of nanostructures and nanomaterials and discuss advanced tools for characterizing the physical and chemical properties of nanomaterials; *iii*) observe the synthesis and characterization of nanomaterials and develop further understanding of module *ii* ; *iv*) review recent developments of nanomaterials for applications in catalysis, electronics, optoelectronics, energy, and nanomedicine; and discuss the environmental, health and safety (EHS) issues of nanomaterials for understanding the societal impact of nanotechnology.

Instructor: Professor Dong Qin, School of Materials Science and Engineering
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Teaching Method: In-class lectures and lab demonstrations

Teaching Modules:
Module I: Physical and Chemical Concepts in Nanoscience; Homework #1, Midterm Exam #1
Module II: Synthesis, Fabrication, and Characterization of Nanomaterials and Nanostructures
Module III: Lab Time; Homework #2 and Midterm Exam #2
Module IV: Case Studies of Advanced Nanomaterials; Term papers

Requirements 4330:

Midterm exam#1	15%
Midterm exam #2	15%
Homework	30% (15% for each homework)
Lab sessions+class participation	10%+10%
Term paper	20%

Textbooks:
Introductory Nanoscience: Physical and Chemical Concepts*, Masaru Kuno, Garland Science; the first edition (August 19, 2011) (Optional, Module I)*
Nanostructures and Nanomaterials: Synthesis, Properties, and Applications*, Guozhong Cao and Ying Wang, World Scientific, the 2nd edition (2011) (Optional, Modules II)*
Recent reports and review articles will also be given during the lecture *(Optional, Module IV)*
No Small Matter: Science on the Nanoscale*, Felice C. Frankel and George M. Whitesides, The Belknap Press of Harvard University Press, 2009 (Optional, Final project)*

Module I: Introduction of Nanoscience – Physical and Chemical Concepts

Aug. 21	**Lecture 1**	Introduction and course overview
Aug. 23	**2**	Structure and property – 2D and 3D system
Aug. 28	**3**	Bonding and inorganic solids
Aug. 30	**4**	Homogenous and heterogeneous nucleation of a phase
Sept. 4	**5**	The gas-solid interface: adsorption; catalysis
Sept. 6	**6**	Nanomaterials – surface energy
Sept. 11	**7**	Length scales – semiconductors
Sept. 13	**8**	Length scales – metals
Sept. 18		Class review of module #1

Module II: Synthesis, Fabrication, and Characterization of Nanomaterials and Nanostructures

Sept. 20	**9**	Top-down approach: Fabrication of nanostructures **(HW#1 due)**
Sept. 25	**10**	Bottom-up approach: Synthesis of 0-D and 1D nanomaterials
Sept. 27	**11**	Light Microscopy
Oct. 2		**Exam #1**
Oct. 4	**12**	Electron microscopy
Oct. 9		Fall break
Oct. 11	**13**	Scanning probe microscopy
Oct. 16	**14**	Raman spectroscopy and surface-enhanced Raman spectroscopy
Oct. 18		Class review of module #2 and prep of lab time

Module III: Lab Time: Synthesis, Characterization, and Application of Noble-Metal Nanomaterials

Oct. 23	**Lab #1**	Synthesis of nanomaterials and soft lithography **(HW #2 due)**
Oct. 25	**Lab #2**	Light characterization of nanomaterials
Oct. 30	**Lab #3**	SEM, TEM, and EDS
Nov. 1	**Lab #4**	XPS and AFM
Nov. 6	**15**	Quantum dots

Module IV: Recent Development of Nanomaterials for Emerging Applications

Nov. 8		**Exam #2**
Nov. 13	**16**	Metal nanoparticles
Nov. 15	**17**	Graphene and carbon nanotubes
Nov. 20	**18**	Self-assembly and photonic crystals
Nov. 22		**Thanksgiving break**
Nov. 27	**19**	Magnetic nanoparticles
Nov. 29	**20**	Perovskite solar cells
Dec. 4	**21**	Safe nanotechnology
		Term paper due at 6:00 pm by email

Term paper: Students are encouraged to select a topic from case studies and the book **"No Small Matter: Science on the Nanoscale" by Felice C. Frankel and George M. Whitesides** for a term paper and presentation that should *i*) describe a phenomenon and its fundamental science on the nanoscale; *ii*) envision a potential application in nanotechnology; and *iii*) identify a critical, unresolved scientific or technological issue. Recommended subjects include *i*) metal nanostructures; *ii*) quantum dots; *iii*) magnetic nanoparticles; *iv*) graphene and carbon nanotubes; perovskite solar cells; and *v*) safe nanotechnology. The term paper should be 5-6 pages (Times New Roman, 12 pt, single space), including text and figures and excluding references.