MSE 6405: Advanced Nanomaterials

School of Materials Science and Engineering
Tuesdays and Thursdays 5:00–6:15 pm through Canvas/Bluejeans

Office Hours: 1:00–2:00 pm (Tuesdays and Thursdays) or appointment by emails
Canvas/Bluejeans

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; and *iii*) 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.

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Teaching Method: Online Lectures through Bluejeans

Teaching Modules:
Module I: Physical and Chemical Concepts in Nanoscience; Midterm Exam #1
Module II: Synthesis, Fabrication, and Characterization of Nanomaterials and Nanostructures; Midterm Exam #2
Module III: Case Studies of Advanced Nanomaterials; Team presentation and term papers

Requirements 4330:

Midterm exam#1	25%
Midterm exam #2	25%
Team presentation	20%
Final term paper	30%

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, Module II)*
Recent reports and review articles will also be given during the lecture *(Optional, Module III)*
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. 18	**Lecture 1**	Introduction and course overview
Aug. 20	**2**	Structure and property – 2D and 3D system
Aug. 25	**3**	Bonding and inorganic solids
Aug. 27	**4**	Homogenous and heterogeneous nucleation of a phase
Sept. 1	**5**	The gas-solid interface: adsorption; catalysis
Sept. 3	**6**	Nanomaterials – surface energy
Sept. 8	**7**	Length scales – semiconductors
Sept. 11	**8**	Length scales – metals
Sept. 15	**9**	Class review of module #1 **Release of take-home exam #1**

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

Sept. 17	**10**	Top-down approach: Fabrication of nanostructures
Sept. 22	**11**	Bottom-up approach: Synthesis of 0-D and 1D nanomaterials
Sept. 24	**12**	Light Microscopy
Sept. 29		**Take-home exam #1 is DUE at 6:15 pm (no class)**
Oct. 1	**13**	Electron microscopy
Oct. 6	**14**	Scanning probe microscopy
Oct. 8	**15**	Chemical characterization
Oct. 13	**16**	Class review of module #2 **Release of take-home exam #2**

Module III: Recent Development of Nanomaterials for Emerging Applications

Oct. 15	**17**	Quantum dots
Oct. 20	**18**	Metal nanoparticles
Oct. 22	**19**	Graphene and carbon nanotubes
Oct. 27		**Take-home exam #2 is DUE at 6:15 pm (no class)**
Oct. 29	**20**	Magnetic nanoparticles
Nov. 3	**21**	Perovskite solar cells
Nov. 5	**22**	Self-assembly and photonic crystals
Nov. 10	**23**	Safe nanotechnology **(Team presentation due at 6:15 pm)**
Nov. 12		**Team presentation 1**
Nov. 17		**Team presentation 2**
Nov. 19		**Team presentation 3**
Nov. 24		**Team presentation 4**
Nov. 26		**Thanksgiving break**
Dec. 1		**Term paper due at 6:15 pm by email**

Four-person team presentation: Students are encouraged to select a topic from ***multifunctional nanomaterials***. The team presentation should be 35 minutes, including questions. Each team should cover the following four topics that include *i*) fundamental science on the nanoscale; *ii*) fabrication of nanomaterials; *iii*) characterization of nanomaterials; and *iv*) application of nanomaterials. **All the teams should send their copies of ppt files to the instructor at 6:15 pm on November 10, 2020**.

Final individual term paper: Students are encouraged to select a topic from multifunctional nanomaterials and the book "No Small Matter: Science on the Nanoscale" by Felice C. Frankel and George M. Whitesides. The term paper 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. The term paper should be 5-6 pages (Times New Roman, 12 pt, single space), including text and figures and excluding references. **The final paper is due by email at 6:15 pm on December 1, 2020.**