

New Course Spring 2002

Introduction to Nanomaterials Science and Engineering

Special Problems 14:150:491:01

Registration Index# 74294

Tuesday/Friday 8:10-9:30AM

ARC 206

Coordinator: Lisa C. Klein, x5-2096,

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Prerequisite: Completion of 60 credits in Engineering,
Chemistry or Physics Programs

Nanotechnology involves behavior and control of materials and processes at the atomic and molecular levels. This interdisciplinary course introduces the student to the theoretical basis, synthetic processes and experimental techniques for nanomaterials. This course is the introduction to 3 advanced courses in (1) Photonic, Electronic and Magnetic Applications of Nanomaterials and Nanostructures, (2) Structural, Mechanical and Chemical Applications, and (3) Biological Applications. The advanced courses, along with an accompanying laboratory, will be offered in subsequent semesters (Fall, 2002 or Spring 2003). Students interested in nanomaterials science and engineering should take this Introduction first, and then choose 1 or more of the advanced courses.

Topics:

1. Synthesis of nanomaterials, clusters, particles, fullerenes.
2. Synthesis methods, vapor phase, liquid phase, aerosols, laser methods.
3. Nanofabrication, lithography, thin film, e-beam deposition.
4. Consolidation
5. Characterization, scattering, diffraction, atomic force microscopy.
6. Properties and Applications.

Grading:

Group project/presentation 20%; in-class tests 40%;
homeworks 20%; final exam 20%.

Text:

Nanomaterials: Synthesis, Properties and Applications, ed.
A. S. Edelstein and R. C. Cammarata, IoP (UK), 1996.

OUTLINE

Date	T/F	Topic	Assigned Reading	Lecturer
January				
22	T	Philosophy, History, Motivation	3-10	LK
25	F	Survey of Materials and Scaling 1. Metals, ceramics, semiconductors, polymers 2. Structural materials and functional materials 3. Rate-controlling mechanisms and diffusion	13-54	LK
29	T	Nucleation 1. Classical nucleation theory 2. Clusters 3. Nucleation rates	55-71	LK
February				
1	F	Ultrafine Powders and Comminution 1. Classification 2. Monodispersity 3. Mechanochemical activation	89-110	LK
5	T	Nanocomposites		LK
8	F	Thin Films and Coatings	113-144	TT
12	T	Sol-Gel Processing 1. Precursors 2. Hydrolysis and condensation 3. Gel formation 4. Drying and consolidation	147-164	LK
15	F	Sol-Gel Applications: Monoliths, films and membranes		LK
19	T	Gas Phase Synthesis 1. Introduction a. Why form nanomaterials from the gas phase? b. Types of nanomaterials produced from the gas phase c. Introduction to transport and chemical kinetics 2. Current gas-phase synthesis processes a. Thermal evaporation, sputtering, laser ablation, spark erosion b. Chemical vapor deposition c. Flame synthesis d. Plasma/rapid quenching synthesis of non equilibrium states 3. Demonstrations a. Laser ablation b. Flame synthesis		STse
22	F	Self Assembly 1. Definition of surfactants 2. Micelles 3. Ligands and chelates		LK
26	T	Consolidation 1. Sintering		LK

		2. Hot pressing		
		3. Infiltration		
March				
1	F	Photolithography for Nanofabrication	497-539	YL
		1. Introduction		
		2. The photolithographic process		
		3. Photoresist materials		
		4. Photoresist coating, exposure and development		
		5. Pattern transfer for nanostructure formation		
		6. Photomask fabrication		
		7. Photolithography exposure systems		
		a. optical		
		b. e-beam		
		c. x-ray		
		8. Lab tour: Photolithography facility in the MERL clean room		
5	T	Atomistics and Simulations		ST
		1. Methods for simulating matter.		
		a. Molecular Dynamics.		
		b. Monte Carlo.		
		c. Brownian Dynamics.		
		2. Overview of Molecular Dynamics.		
		a. Intermolecular Potentials.		
		b. Time Step, Algorithm, Initializations.		
		c. Periodic Boundary Conditions.		
		3. Additional Details and Calculation of Properties.		
		a. Static Properties: Temperature, Internal Energy, Pressure, Mean Square Forces, Heat Capacity.		
		b. Other Thermodynamic Properties.		
		4. Simulation of Fluid Experiments		
		a. Basic Program for MD.		
		b. Sample Output for MD for 108 atoms.		
		5. Phase Equilibria and Interfaces.		
8	F	MIDTERM		
12	T	Characterization, Atomic Probe Microscopies: Structural Characterization		JH
		1. Powder diffraction, Xray.		
		2. Scanning probe microscopies (SPM),		
		a. Tunneling (STM)		
		b. Force (AFM)		
		c. Other operational modes.		
15	F	Microstructure-Nanostructure	201-218	TT
Spring Break				
26	T	Mechanical Properties	323-345	TT
29	F	Fullerenes in structural applications	477-494	TT
April				
2	T	Chemical, Electrochemical, Catalyst Properties	305-321	JX
		1. Nanostructured transition metal oxides electrodes for high-energy, high-performance		
		2. Intercalation electrodes for rechargeable batteries		

		3. Nanocomposites to reduce diffusion length for the electrochemical intercalation reaction		
		4. Increased rate and power		
		5. Reducing agglomeration		
5	F	Quantum Effects		MG
		1. Wave functions, quantum confinement energy spectra		
		2. 2-D systems: Quantum well, semiconductor heterostructures		
		3. 1.D systems: Quantum wires, carbon nanotubes		
		4. 0-D systems: Quantum dots (electrons in artificial atoms)		
		5. Electronic properties of macromolecules (DNA, etc.)		
9	T	Electronic Properties: Quantum nanodevices	347-373	MG
		1. Quantum limits of the modern MOS technology, what's next?		
		2. Single-electron transistors, Coulomb blockade		
		3. Coherence effects: Aharonov-Bohm, universal conductance fluctuations, etc.		
12	F	Magnetic Properties, GMR, SET	375-394	TT
16	T	Photonics	395-436	MG
		1. Confinement of light in microcavities		
		2. Photonic-bandgap materials		
19	F	In-Class Test		
23	T	MEMS Devices		LK
26	F	Bio-MEMS	459-476	LK
30	T	Presentations		
May				
3	F	Presentations		
10	F	EXAM, 8:00-11:00 AM		

Lecturers:

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