Syllabus Nanomaterials – Chem/MtSE 748

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This **3 credit** course [3 hrs/week of class] on Nanomaterials is designed to introduce advanced undergraduates and graduate students in chemistry, materials science, physics, electrical engineering and bio-engineering to the emerging area of nanotechnology that has the potential to revolutionize techniques by which materials and products will be created in the future with new and superior properties and functionalities. Nanotechnology refers to the world as it works on the nanometer scale from **below a nanometer to a few hundred nanometers**. The synthesis and control of nanomaterials will involve so-called **"bottom up"** strategies of self-assembly starting with the smallest possible entities, such as atoms and molecules, much in the same way as synthesis is conducted in natural biological systems. Some **"top down"** mechanical methods will also be discussed. The goal of the course will be to prepare and train students in this evolving technology which lies at the interfaces of chemistry, physics and biology. The course will start with fundamental concepts and then proceed to nanoscale phenomena and properties. This will be followed by discussions on the synthesis and self-assembly of nanomaterials and methods for their characterization. Emerging and potential applications of nanomaterials will be considered in the final segment of the course.

Weeks 1-4

I. Introduction
1. Definitions and course organization
2. Historical development of nanomaterials
3. Classification of nanomaterials

II. Fundamentals
1. Size & Scale
    - Units
    - Scaling
    - Atoms, Molecules, Clusters and Supramolecules
2. Structure and Bonding in Nanomaterials
    - Chemical Bonds (types and strength)
    - Intermolecular Forces
    - Molecular and Crystalline Structures
    - Hierarchical Structures
    - Bulk to Surface transition, surface reconstruction

Self assembly and thermodynamics

Weeks 5-8

III. Properties and Size dependence of properties

- Chemical
- Optical, vibrational, thermal
- Electrical
- Magnetic
- Mechanical
- Theoretical Aspects-e.g. density functional theory

Week 8: Mid-term exam

Weeks 8 - 14

IV. Nanomaterial Synthesis

- Chemical routes
- Electrochemical methods
- Vapor growth
- Thin films methods: chemical vapor deposition, physical vapor deposition (sputtering, laser ablation), Langmuir-Blodgett growth
- Mechanical methods: ball milling, mechanical attrition
- Sol-gel methods
- Special nanomaterials: *carbon nanotubes, fullerenes, nanowires, porous silicon*
- Bio-inspired synthesis
- Nanocomposite fabrication
- Nanolithography

V. Nanomaterial characterization techniques

- Scanning and Transmission Electron Microscopy
- Scanning Probe Microscopies: Atomic Force, scanning tunneling microscopy
- Diffraction and scattering techniques
- Vibrational spectroscopy
- Surface techniques

VI. Applications

- Nano-electronics
- Nano optics
- Nanoscale chemical- and bio-sensing
- Biological/bio-medical applications
- Photovoltaic, fuel cells, batteries and energy-related applications
- High strength nanocomposites
- Nanoenergetic materials

Final exam

Textbook

The Physics and Chemistry of NanoSolids by Frank J. Owens and Charles P. Poole Jr, Wiley-Interscience, 2008.

Reference Books

Nanomaterials- Synthesis, Properties and Applications, Edited by A.S. Edelstein and R.C. Cammarata, Institute of Physics Publishing, London, 1998 (paper back edition)

Nanochemistry: A Chemical Approach to Nanomaterials, by G. Ozin and A. Arsenault, RSC Publishing, 2005

Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience, Edward L. Wolf, Wiley-VCH, 2nd Reprint (2005)