Chemistry 185 - Chemistry of Nanomaterials, Spring 2007

Tuesdays and Thursdays, 9:35 am to 10:50 am (1/16/2007 - 5/11/2007). Location: Seaver North Laboratory, classroom 111. Prerequisite: 110A,B; MATH 31; PHYS 51A,B.

Office hours: Monday, Tuesday, Wednesday 1:00 pm to 3:00 pm.

Chemistry of Nanomaterials (CHEM 185) is a full semester course covering increasingly important topics such as soft matter, biophotonics, nanotechnology, and self-assembly. Although the field of nanomaterials is strictly interdisciplinary, this course will have a chemical perspective on the subject. Therefore a decent grasp of organic chemistry and physical chemistry is expected. There is no required textbook for this course but up to date developments from the chemical literature will be underscored whenever possible. Links to the journals used in this course can be found on my website.

The course is taught in four units and the schedule of topics to be covered is shown below. Unit 1 of the course will begin with fundamental material, namely the physical chemistry of phenomena manifested at the nanoscale where surface effects become important. The introductory material will also cover self-assembly and adsorption. This will provide a sound background to discuss nanomaterials and their applications (unit 2). Unit 3 will focus on specialized techniques that are routinely used to characterize nanomaterials. The final unit will focus on biophotonics. Evaluation of the student's performance in this course is based on one mid-term examination and a presentation. The 15 minute presentation will be on any topic relating to this course. The presentation will describe the findings of a recent journal article of choice. The comprehension of the paper, the quality of the presentation, and ability to answer questions will be used to evaluate the student's performance in this course.

SYLLABUS

Unit 1: Fundamentals of Molecular Self-Assembly, Interfacial Phenomena, and Supramolecular Chemistry

Tuesday, January 16: Introduction to the course and discussion of the syllabus. The scope of nanomaterial chemistry. The nanoscale and colloidal systems. Fundamentals of surface and interfacial chemistry. Surface tension and wettability. Insoluble monolayers.

Thursday, January 18: Surface chemistry and monolayers. Electrostatic interactions in self-assembling systems. Self-assembly of amphiphiles. Monolayers, micelles, and microemulaions. The structure and properties of micelles.

Tuesday, January 23: Adsorption phenomena. Adsorption of surfactants at solid surfaces. Langmuir adsorption and models describing multilayer adsorption.

Thursday, January 25: Field trip: Nanotechnology: Small World – Big Issues. A speakers program exploring challenging science issues at the forefront of public concern. This special program will actually take place on Saturday, January 27, 1:20 – 3:30 pm at the California

Science Center IMAX Theater, Los Angeles. For more information visit: http://goto.californiasciencecenter.org/sciencematters.

Tuesday, January 30: Liquid crystals, bilayer systems, and lipid membranes. Macromolecular systems. Molecules assembled at the air-water and solid-air interface. Langmuir-Blodgett films. Two-dimensional adsorption isotherms.

Thursday, February 1: Discussion session covering some recent literature based on Unit 1 material and the field trip to the California Science Center.

Tuesday, February 6: Unit 1 Examination. This will be the only examination in this course.

Unit 2: Nanomaterials and their Applications

Thursday, February 8: Defining nanodimensional materials. Size effects in nanomaterials. Application and technology development. General methods available for the synthesis of nanodimensional materials. Manipulation of nanoparticles.

Tuesday, February 13: Nanofabrication methods: Bottom-up methods, photolithography, scanning probe methods, soft lithography.

Thursday, February 15: Supramolecular machines. Fundamentals of energy transfer and photon motion manipulation. Solar energy harvesting. Fundamentals of electron motion manipulation. Electron pumping and molecular wires.

Tuesday, February 20: The interaction of polymers with surfaces. Polyelectrolyte multilayer assemblies. The application of electrostatic self-assembly to construct multilayers in a layer-by-layer fashion. This lecture will cover fabrication methods, including spin-assembly, and a detailed description of film structure and morphology.

Thursday, February 22: Chemical functionalization. Recent advances in thiol-Au and silane chemistry. Layer-by-layer synthesis of multilayer assemblies. Applications.

Tuesday, February 27: Quantum dots, nanocores and applications. Detailed description of the fabrication of functionalized gold nanocores and their application in cancer therapy.

Thursday, March 1:. Nanoparticles and nanowires, carbon nanotubes. Detailed coverage on the fabrication and characterization of single- and multi-walled carbon nanotubes.

Tuesday, March 6: Discussion session covering some recent literature based on Unit 2 material.

Unit 3: Specialized Techniques for Characterizing Nanomaterials

Thursday, March 8: QCM, ellipsometry, and dual polarization interferometry (DPI) as methods used to obtain nano-gram masses, nano-scale thicknesses, and the optical properties of ultra-thin assemblies.

Tuesday, March 13: No Class (spring recess)
Thursday, March 15: No class (spring recess)

Tuesday, March 20: Infrared spectroscopy of nanoassemblies. Attenuated-total reflection (ATR) and grazing incidence angle techniques. Reflection-absorption IR spectroscopy (RAIRS). Surface enhanced Raman spectroscopy (SERS).

Thursday, March 22: Nonlinear spectroscopies: Second-harmonic generation (SHG) and sum-frequency spectroscopy (SFG). The use of nonlinear optical methods to obtain infrared spectra of ultra-thin assemblies confined to surfaces.

Tuesday, March 27: Imaging techniques: AFM, STM, imaging ellipsometry. The use of imaging ellipsometry to explore the photo-patterning of lipid membrane films.

Thursday, March 30: Optical microscopy. Fluorescence/phase contrast microscopy, confocal microscopy, total internal refection microscopy (TIRM), Brewster angle microscopy (BAM), phase measurement interference microscopy, second harmonic microscopy (SHM).

Tuesday, April 3: Nano-optics and local spectroscopy. Scanning near-field optical microscopy and photon scanning tunneling microscopy, scanning plasmon near-field optical spectroscopy (SPNM), near-field optical spectroscopy, fluorescence spectroscopy, Raman spectroscopy, near-field nonlinear optics.

Thursday, April 5: Discussion session covering some recent literature based on Unit 3 material.

Unit 4: Photonics and Biophotonics

Tuesday, April 10: Fundamentals of nanophotonics. Near field interactions. Quantum-confined materials.

Thursday, April 12: Applications of bioimaging. FRET and FLIM methods. Microarray technology for genomics and proteomics. Optical biosensors.

Tuesday, April 17: Laser tweezers and laser scissors: selected examples of applications in biology. Bionanophotonics and biomaterials for photonics.

Thursday, April 19: Review of the course. Additional material.

Tuesday, April 24: Group presentations/discussion. You will deliver a 15 minute presentation on any topic relating to this course. Your presentation will describe the findings of a recent journal article of your choice. Your comprehension of the paper, the quality of your presentation, and your ability to answer questions will be used to evaluate your performance in this course.

Thursday, April 26: Group presentations/discussion continued.

Useful References

Many different sources were used to compile the notes delivered in lecture. These notes in addition to any handouts should be sufficient for the course. Therefore, there is no required textbook. In fact most of the cutting edge work cannot be found in textbooks. The following references were used to compile the material used in this course. In addition to these books articles from the RSC journal *Soft Matter* and the ACS journals *Langmuir* and *Nanoletters* were used extensively. Most of the following books can be found in the College library. All of them can be found in my office.

- "Introduction to Biophotonics" by Paras N. Prasad; 2003 John-Wiley and Sons, Inc. (ISBN: 0-471-28770-9).

- "Nanophotonics" by Paras N. Prasad; 2004 John-Wiley and Sons, Inc. (ISBN: 0-471-64988-0).

- "The Colloidal Domain: Where Physics, Chemistry, Biology and Technology Meet" by D. Fennell Evans and Håkan Wennerström; 1999 John-Wiley and Sons, Inc. (ISBN: 0-471-24247-0).

- "Surfactants and Polymers in Aqueous Solution" by K. Holmberg, B. Jönsson, B. Kronberg, B. Lindman, 2003 John-Wiley and Sons, Inc., second edition (ISBN: 0-471-49883-1).

- "The Chemistry of Nanomaterials: Volume 1, Synthesis, Properties and Applications" Edited by C.N.R. Rao, A. Müller, A.K. Cheetham; 2005 John-Wiley and Sons, Inc. (ISBN: 3-527-30686-2).

- "The Chemistry of Nanomaterials: Volume 2, Synthesis, Properties and Applications" Edited by C.N.R. Rao, A. Müller, A.K. Cheetham; 2005 John-Wiley and Sons, Inc. (ISBN: 3-527-30686-2).

- "Soft Matter: Volume 1, Polymer Melts and Mixtures" Edited by Gerhard Gompper and Michael Schick; 2006 John-Wiley and Sons, Inc. (ISBN: 3-527-30500-9).

- "Soft Matter: Volume 2, Complex Colloidal Suspensions" Edited by Gerhard Gompper and Michael Schick; 2006 John-Wiley and Sons, Inc. (ISBN: 3-527-31369-9).

- "Optics and Spectroscopy at Surfaces and Interfaces" by Vladimir G. Bordo and Horst-Günter Rubahn; 2005 John-Wiley and Sons, Inc. (ISBN: 3-527-40560-7).

- "Understanding Nanotechnology" by Michael L. Roukes (forward); 2002 Scientific American, Inc., and Byron Preiss Visual Publications, Inc. (ISBN: 0-446-67956-9).

- “Principles of Physical Chemistry: Understanding Molecules, Molecular Assemblies, Supramolecular Machines” by Hans Kuhn and Horst-Dieter Försterling; 2000 John-Wiley and Sons Ltd. (ISBN: 0-471-95902-2).