

CHEM 360 Introduction to Nanotechnology

Prerequisite: CHEM352 (physical chemistry 1), CHEM350/CHEM650 (biophysical chemistry)

Instructor:

Meets once a week for 2.5 hrs

General Description:

The course is part of the major programs in Chemistry and the Master Program of Biochemistry. Undergraduate students who meet the pre- and co-requisites may take it as an elective to meet the requirements of their degree. Graduate students in Plan III of the revised Master Program of Biochemistry (see cover letter) may take it to meet the requirements of graduate level courses. Graduate students in Plan I or Plan II of the Master Program of Biochemistry may take it as an elective to meet the requirements of their degree.

Overarching Learning Objectives

The course fills two crucial needs of the Chemistry major and the Master program of Biochemistry: 1) teaching applications of nanotechnology and the latest techniques and tools used for nanotechnology research in across chemistry, materials, medicine, and photonics industries; 2) training of scientific literature reading and interpretation; 3) training in multidisciplinary science didactics. 4) Discusses current and future nanotechnology applications in engineering, materials, physics, chemistry, biology, electronics, and energy.

The course is a natural extension of Physical Chemistry I and II, Biophysical Chemistry. The course expands the knowledge taught in these courses by focusing on applications of quantum mechanics on the structural and functional studies of nanomaterials, and introducing to them the latest spectroscopies, tool, technologies, and applications of current nanotechnology and nanoscience research. The extensive training on scientific literature reading and communication are two new features complementing the existing curriculum of Chemistry and Biochemistry.

Learning Topics and course structure. The course will discuss various aspects of nanotechnology with an emphasis on chemical aspects of so-called bottom-up, “soft” nanotechnology. The course will cover nanoscale methodologies and materials with (potential) applications in electronics, biomaterials, sensors and will cover a range of top-down (lithography), and bottom-up (self-assembly) approaches to production of materials with nanoscale control. A variety of materials (organic, polymers, inorganic and biologically derived) will be discussed, including ‘smart’ responsive materials and surfaces. Frontier areas such as adaptive nanotechnology and nanoscale ‘systems’ will also be covered with up to date examples from ongoing nanoscience research at CUNY and elsewhere. Students will be encouraged to participate and suggest topics for discussion that are of particular interest. The course is in particular recommended for students who are considering a research career in the nanoscience area. Towards the end of the course, students will be required to give a ~20 min talk and write a short report on a nanotechnology subject of their choice. Introduction to the underlying principles and applications of the emerging field of nanotechnology and nanoscience. Intended for a multidisciplinary audience with a variety of backgrounds. Introduces tools and principles relevant at the nanoscale dimension.

3 credits, 3 hours of lecture once a week

Session 1: Introduction to Nanotechnology

	Session 2: Bottom-up nanofabrication
	Session 3: DNA nanotechnology
	Session 4: Top-down nanofabrication and surface analysis
	Session 5: Top-down fabrication techniques
	Session 6: Peptide nanotechnology: design rules
	Session 7: Peptide nanotechnology: aromatic peptide amphiphiles
	Session 8: Non-equilibrium systems: towards adaptive nanotechnology
	Session 9: Present and future applications
	Session 10: Mid Term Quiz
	Session 11: student presentations
	Session 12: student presentations
	Session 13: student presentations
	Session 14: student presentations
	Session 15: evaluation of presentation papers

Nanochemistry: A Chemical Approach to Nanomaterials, 2nd Edition,
 Geoffrey A Ozin (Author), André Arsenault (Author), Ludovico Cademartiri (Author)
 ISBN: 978-1-84755-895-4, RSC Publishing, Copyright: 2008 Additional materials will be provided by
 instructor, including review articles from scientific literature

Grading:

Evaluations:	Class Assignments & Participation	50 points
	Mid Term Quiz	50 points
	Final Presentation	50 points
	Final: 5-page paper to accompany presentation	50 points
		200

Mid-term Quiz: There will be a mid-term exam after Spring Recess, based on some of the topics previously covered. The format and content will be described in a separate document early in the semester.

Final assignment consists of two parts. Part I (50 points) = a presentation to be performed during class and Part II (50 points) = a 5 page paper (a brief) to accompany the presentation. You must choose a topic and agree it with the Professor.

Attendance at every lecture is mandatory. For each lecture, ~1 hour of reading before the lecture is expected. The presentations with 5-page paper should take 10-20 hours to prepare.

Outcomes for Introduction to Nanochemistry: This course will introduce the student to the theories and principles of nanotechnology from a chemical perspective; upon successful completion of this course, a student should be able to:

- Define nanotechnology
- understand what is special about the nanoscale
- demonstrate conceptual understanding of top-down and bottom-up fabrication
- understand the instrumental methods used to measure and make nanomaterials
- explain how biomolecules may be used in materials fabrication

GENERAL EDUCATIONAL OUTCOMES:

- Students will communicate effectively: reading, writing, listening and speaking.
- Students will reason quantitatively.
- Students will employ concepts and methods of the natural and physical sciences to make informed judgments.

EXPECTED STUDENT LEARNING OBJECTIVES:

- give a brief history of nanoscience, give examples of nanomaterials, and be familiar with synthetic routes to prepare nanomaterials.
- Students will evaluate and explain the scientific theory of the relationship between the sizes of nanoparticles and color.
- Students will be familiar with using the AFM and STM microscopes to analyze nanomaterials, such as gold nanoparticles and carbon nanotubes; SEM and TEM microscopic and spectroscopic (UV-Vis and IR) data of such nanomaterials in the literature. Student should be able to explain the various theories, sample preparation techniques, and the limitations and benefits of each method of analysis
- Students will be able to demonstrate how various nanomaterials can be used to analyze problems and develop solutions in biological, electronic and composite fields understand the roles of nanostructures in applications in biomedicine, photonics and electronics.

Introduction to Nanochemistry Session Guide:

A brief historic overview of nanoscience, starting with Feynman's famous lecture "There's plenty of room at the bottom". What is special about the nanoscale? Some of the unexpected and counterintuitive properties that materials may have at the nanoscale will be discussed, including structural color, superhydrophobicity and nanostructured adhesion. The importance of the surface will be emphasized. Top-down and bottom-up fabrication methods will be introduced conceptually with key examples to set the scene.

Bottom-up nanofabrication: The idea of using self-assembly for fabrication of nanoscale materials is based on the concept that might be able to take advantage of natural forces (non-covalent interactions) in order to get molecules or particles to organize themselves into a desired architecture. A device that can build itself may be much cheaper and versatile while there is potentially less redundancy and waste in production. It's a wonderful idea, and conceptually it works very well as shown by biological examples. However, scientists are currently very far from achieving nature's functionality and complexity in molecular self assembly. What's critical now is an understanding of the mechanisms by which self assembly can occur -the natural forces - be they chemical, physical, thermodynamic *etc.* This lecture will focus on self-assembly as an approach to nanofabrication. It will explained how building blocks, typically polymers, functionalised particles and biomolecules may be designed to produce nanoscale structures. There will be a discussion about kinetics and thermodynamics of formation of these structures.

DNA nanotechnology: DNA is of course the instruction language of living systems, but its precise and predictable supramolecular complementarity suggests that it may also be a remarkable building block for formation of nanoscale structures of precisely defined size and shape. The discussion will focus on the pioneering work by Seeman on design rules of DNA nanostructures. This will be followed by the origami methods developed by Rothemund. Examples of nanostructures, including DNA/nanoparticle hybrids that can form very precisely organized structures, as in particular shown by Mirkin, will be discussed. Very recent examples that use RNA as a potentially more versatile alternative, will also be discussed.

Top-down nanofabrication and surface analysis: Complementing the bottom-up approach, top-down approaches are achieving ever better resolution and precision in fabrication. Favoured by the electronics industry, top-down approaches often use highly sophisticated equipment and ultra clean environments. Several top-down nanofabrication methods will be discussed, including UV lithography, scanning probe methods including dip pen nanolithography and the range of soft lithography methods introduced by Whitesides. There will be a discussion of self-assembled monolayers (SAMs) and their applications. Methodology for surface analysis will be discussed, including atomic force microscopy and chemical surface analysis methods. Emphasis in this lecture will be on those fabrication methods that are easily accessible in most chemistry labs, with more specialized approaches discussed in the next lecture. The integration of top down and bottom up methods will be touched upon.

Top-down fabrication techniques: This topic will provide an overview of nanoscale fabrication methods available today, including electron beam lithography and the latest 3D nanofabrication methodology. This session will include self-study of literature provided.

Peptide nanotechnology: design rules: While DNA provides the encoding language of life (and clearly is useful in nanoscale fabrication- see session 3) peptides and proteins are potentially even more versatile as they are the expression language of living systems- providing the structure, molecular recognition and catalysis essential for the functioning of living systems. Minimal mimics of such structures have enormous potential in nanotechnology. This lecture will focus on the design rules that allow peptides to be exploited as building blocks for the assembly of nanomaterials. These design rules are either derived by copying nature (α -helix, β -sheet) or may exploit entirely new designs based on peptide derivatives (peptide amphiphiles, π -stacking systems). The lecture will examine the features that can be introduced to allow self-assembly to be controlled and directed by application of an externally applied stimulus, such as pH, light or enzyme action. The applications of designed self-assembly peptide systems in biotechnology (3D cell culture, biosensing) and technology (nanoelectronics, templating) will be examined.

Peptide nanotechnology: aromatic peptide amphiphiles: Aromatic peptide amphiphiles are gaining popularity as building blocks for the bottom-up fabrication of nanomaterials, including gels. These materials combine the simplicity of small molecules with the versatility of peptides, with a range of applications proposed in biomedicine, nanotechnology (including electronic and photonic structures), food science, cosmetics, *etc.* Despite their simplicity, a wide range of nanostructures morphologies has been described. In this lecture, the structural features which govern the self-assembly of aromatic peptide amphiphiles will be discussed. It is clear that the molecular structure of these components significantly influences the self-assembly process and resultant supramolecular architectures. A number of modes of assembly have been proposed, including parallel, antiparallel, and interlocked antiparallel stacking conformations. In addition, the co-assembly arrangements of aromatic peptide amphiphiles are reviewed. Applications in electronics, photonics and biomedicine will be discussed.

Responsive materials and non-equilibrium systems: towards adaptive nanotechnology: Nanoscale systems can switch between different states and are therefore responsive to their environment. These smart nanostructures have applications in many areas, including sensing, controlled release, environmental clean-up, *etc.* Most existing responsive materials operate under thermodynamic control- *i.e.* upon switching of their environmental properties, they relax towards a thermodynamic minimum, unresponsive state. This inherently presents limitations to the structures that may be produced and to their inherent responsiveness. In many cases, the lowest free energy structures may not be those with the desired properties. In particular, dynamic, multicomponent and asymmetric structures are not accessible using equilibrium approaches. Therefore, there is an increased interest in the development of

non-equilibrium structures, where energy input is required to facilitate formations of these materials. *During this session, students are divided into small groups to discuss the concept of adaptive nanotechnology. They will be asked to present findings of their groups back to the class.*

Present and future applications: A number of developments in soft nanotechnology are now making real progress towards applications. This lecture will provide an up to date review of the latest literature. Areas that will be included are biomaterials and tissue engineering, sensing and bioinspired green energy devices. Students are expected to contribute significantly to the discussion at this stage of the course.

Accommodations for disabled students: Students with a disability are encouraged to contact Prof. Ulijn during the first week of class about any necessary accommodations, in accordance with campus policy and Americans with Disabilities Act laws.

Policy on academic integrity: Hunter College regards acts of academic dishonesty (e.g., plagiarism, cheating on examinations, obtaining unfair advantage, and falsification of records and official documents) as serious offenses against the values of intellectual honesty. The College is committed to enforcing the CUNY Policy on Academic Integrity and will pursue cases of academic dishonesty according to the Hunter College Academic Integrity Procedures.”

Hunter College required statements for syllabi

1. Academic Integrity Statement: “Hunter College regards acts of academic dishonesty (e.g., plagiarism, cheating on examinations, obtaining unfair advantage, and falsification of records and official documents) as serious offenses against the values of intellectual honesty. The College is committed to enforcing the CUNY Policy on Academic Integrity and will pursue cases of academic dishonesty according to the Hunter College Academic Integrity Procedures.”
2. ADA Statement: “In compliance with the ADA and with Section 504 of the Rehabilitation Act, Hunter College is committed to ensuring educational access and accommodations for all its registered students. Hunter College’s students with disabilities and medical conditions are encouraged to register with the Office of AccessABILITY for assistance and accommodation. For information and appointment contact the Office of AccessABILITY located in Room E1214 or call (212) 772-4857 /or VRS (646) 755-3129.”
3. Hunter College Policy on Sexual Misconduct “In compliance with the CUNY Policy on Sexual Misconduct, Hunter College reaffirms the prohibition of any sexual misconduct, which includes sexual violence, sexual harassment, and gender-based harassment retaliation against students, employees, or visitors, as well as certain intimate relationships. Students who have experienced any form of sexual violence on or off campus (including CUNY-sponsored trips and events) are entitled to the rights outlined in the Bill of Rights for Hunter College.
 - a. Sexual Violence: Students are strongly encouraged to immediately report the incident by calling 911, contacting NYPD Special Victims Division Hotline (646-610-7272) or their local police precinct, or contacting the College's Public Safety Office (212-772-4444).
 - b. All Other Forms of Sexual Misconduct: Students are also encouraged to contact the College's Title IX Campus Coordinator, Dean John Rose (jtrose@hunter.cuny.edu or 212-650-3262) or Colleen Barry (colleen.barry@hunter.cuny.edu or 212-772-4534) and seek complimentary services through the Counseling and Wellness Services Office, Hunter East 1123.

CUNY Policy on Sexual Misconduct Link: <http://www.cuny.edu/about/administration/offices/1a/Policy-on-Sexual-Misconduct-12-1-14-with-links.pdf>”