CE/ME 486/686 Fundamentals of Nanotechnology and Nanomaterials
Department of Civil and Environmental Engineering
North Dakota State University

Instructor:	**Dr. Kalpana Katti**
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Course Theme

- Definition of Nanotechnology:
  The essence of nanotechnology is the ability to work at the molecular level, atom by atom, to create large structures with fundamentally new molecular organization. Nanotechnology is concerned with materials and systems whose structures and components exhibit novel and significantly improved physical, chemical, and biological properties, phenomena, and processes due to their nanoscale size. (10^{-9}-10^{-7} m range)
- The goal is to exploit these properties by gaining control of structures and devices at atomic, and molecular levels and to learn to efficiently manufacture and use these devices. Maintaining the stability of interfaces and the integration of these "nanostructures" at micron-length and macroscopic scales are all keys to success.
- Material behavior at the nanoscale is not necessarily predictable from response observed at large size scales.
- ***The most important changes in behavior are not explained by order of magnitude size reduction, but by new phenomena that are intrinsic to the nanoscale.*** These phenomena include size confinement, predominance of interfacial phenomena and quantum mechanics. Once it becomes possible to control feature size, it will also become possible to enhance material properties and device functions beyond what we currently know how to do or even consider as feasible.

Applications:

- Being able to reduce the dimensions of structures down to the nanoscale leads to the unique properties of carbon nanotubes, quantum wires and dots, thin films, DNA-based structures, and laser emitters. Such new forms of materials and devices herald a revolutionary age for science and technology, provided we can discover and fully utilize the underlying principles.

The above is excerpted from the National Nanotechnology Initiative: The Initiative and its Implementation Plan http://www.nano.gov/nni2.htm

Course Description

This course reviews principles of nanotechnology, nanomaterials and develops a framework for their understanding. The basic tools of nanotechnology: nanoscale characterization, physics and materials design will be discussed in the context of current engineering applications.

Prerequisites

Senior standing in Engineering or Sciences.

Course Outline

Lectures	TOPIC	SUBTOPIC
1-2	Introduction to nanotechnology	
3-9	Materials Characterization at the nanoscale	Lecture 3:Limits of spatial resolution Lecture 4,5: Electron microscopy: scanning and transmission Lecture 6,7:Atomic Force Microscopy Lecture 8,9: Different energy scales in spectroscopic characterization: electronic, vibrational and rotational
10-16	Physics at the nano scale	Elements of quantum mechanics Lecture 10: uncertainty principle, schroedinger equation Lecture 11,12: free electron gas, fermi dirac distribution Lecture 13: energy bands Lecture 14,15: semiconductors Lecture 16: quantum wires and dots
17-22	Nanofabrication	Lecture 17: Lithography Lecture 18,19: self assembly Lecture 20-22: contact imprinting, nanomanipulators
23-26	Biomimetic nanotechnology	Lecture 23: Applications to biomaterials Lecture 24-26: Examples: structural, medical, electronic
27-33	Nanomaterials	Lecture 26,27: Buckeyballs: properties and uses Lecture 27-30: carbon nanotubes, properties and uses Lecture 31-33: novel nanocomposite systems
24-40	Current Nanotechnology	Lecture 34: Introduction: coupling of mechanical-electronic systems Lecture 35,36: Molecular electronics Lecture 37,38: Bioelectronics: DNA computing, binding of semiconductors and biological macromolecules Lecture 39,40: The future in nanotechnology

Textbooks and References

- Due to the continuously evolving nature of this field, current research papers will be important study material for this course. These papers will be provided by the instructor. In addition several handouts will be provided. Some books will be placed in the reference section in the library.

Learning Objectives

After taking this course, students should be able to do the following:

- Understand and explain the principles of nanotechnology. (A, E, H)
- Familiarize with the characterization tools of nanotechnology and be able to select appropriate tools. (A, B, E)
- Ability to apply fundamentals of nanotechnology in wide variety of engineering applications including new materials design. (A, B, C, E, H, J, M)
- Ability to understand and participate in new innovations in the field of nanotechnology. (A, B, E, H, J, M)
- Work in interactive teams (D)
- Written and oral communication skills (G)

Grading Policy

Category	**Points**
Homework	100
Term paper (for graduate credit)	100
Class participation	50
Quizzes	50
Exams (2)	200
Final exam	100
Total undergraduate/graduate)	500/600

Grading Distribution

90.0 - 100.0 %	A
80.0 - 89.9 %	B
70.0 - 79.9 %	C
60.0 - 69.9 %	D
Below 60.0 %	F

The lower bounds on the grade distributions may be adjusted if necessary.

Assessment Tools used by Instructor to evaluate student learning for each of the learning objectives

Specific problems on tests will be used to assess student learning.
Some homeworks will be used to assess student learning.
Project and presentation will be used to assess student learning.
Ability to work in teams will be assessed through class participation activities.

Homework Problems

Homework assignments will be posted on the course website. It is important to do the homework problems if you want to learn how to apply the principles learned in class. Homework must be presented neatly and well-organized or it will be turned back for resubmission for half credit.

Term paper for Graduate Credit

For graduate credit, students must turn in a state-of-the-art term paper on one of the different sub-areas of nanotechnology as pre-assigned by the instructor.

Quizzes

There will be surprise quizzes that will be done in class.

Class Participation

Each student will teach a topic for about 15 minutes to the whole class. Topics for each student will be assigned at the beginning of the semester. This activity will promote active learning in the class. The student will obtain necessary course material prior to teaching the topic. Students may use chalkboard and/or overheads. In addition there will be group activities done in class. Groups will be formed of 2-3 students and will vary in each activity.

Exams

Exams will be open book. Exams 1, and 2 are not comprehensive, but some material will carry over from previous chapters in many cases. Final exam will be comprehensive. No make-up of missed exams is allowed except in cases of documented illness or emergency. Please call me or the CE department secretary Jan Lofberg (231-7244) if you cannot make it to an exam because of illness or an emergency.

Academic Honesty Statement

All work in this course must be completed in a manner consistent with NDSU University Senate Policy, Section 335: Code of Academic Responsibility and Conduct (http://www.ndsu.nodak.edu/policy/335.htm). Violating this code will result in a penalty or penalties to be determined by the instructor depending on the seriousness and circumstances of the offense. The instructor may: (1) fail the student for the particular assignment or test; (2) give the student a failing grade; or (3) recommend that the student drop the course.

CEA Honor System: All work in this course must be completed in a manner consistent with NDSU University Senate Policy, Section 335: Code of Academic Responsibility and Conduct (http://www.ndsu.nodak.edu/policy/335.htm) and the CEA Honor System available at http://www.ndsu.nodak.edu/ndsu/cea/.

Students With Special Needs

Any students with disabilities or other special needs please contact the instructor as soon as possible to make arrangements for appropriate accommodations.

A through M in Learning Objectives refer to

ABET Outcomes:

A. an ability to apply knowledge of mathematics, science and engineering

B. an ability to design and conduct experiments, as well as to analyze and interpret data

C. an ability to design a system, component, or process to meet desired needs

D. an ability to function on multi-disciplinary teams

E. an ability to identify, formulate, and solve engineering problems

F. an understanding of professional and ethical problems

G. an ability to communicate effectively

H. the broad education necessary to understand the impact of engineering solutions in a global and societal context

I. a recognition of the need for, and ability to engage in life-long learning

J. a knowledge of contemporary issues

K. an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice

L. an ability to design, develop, implement, and improve integrated systems that include people, materials, information, equipment and energy

M. an ability to integrate systems using appropriate analytical, computational and experimental practices.