EMA 601 - Spring 2005
Micro- and Nanoscale Mechanics

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Joint Office Hours: W 1:20-3:00 pm, R 1:20-2:30 pm, location TBD
Other office hours available by appointment

Course Goals:

- to enhance students' appreciation of the current state and potential future impact of nanotechnology
- to demonstrate how specific physical behavior and engineering design requirements change with scale
- to show how engineering mechanics concepts can be used or appropriately adapted to describe behavior at the nanoscale, and to demonstrate the critical role that mechanics plays in the design and implementation of nanotechnology concepts
- to expose students to the cross-disciplinary intersections that occur between mechanics and materials science, chemistry, physics, and biology when working at the nano-scale.

Course Description:

This course will provide an introduction to nanoscale engineering with a direct focus on the critical role that mechanics needs to play in this developing area. Engineering is progressing to ever smaller scales, enabling new technologies, materials, devices, and applications. Mechanics enters a new regime where the role of surfaces, interfaces, defects, material property variations, and quantum effects play more dominant roles. We will discuss how mechanics becomes integrated with the fields of materials science, chemistry, physics, and biology at this scale. We will cover a variety of concepts and applications listed below, drawing connections to both established and new mechanics approaches. We will discuss the limits of continuum mechanics and present newly developed mechanics theories and experiments tailored to describe micro- and nano-scale phenomena. We will emphasize specific applications throughout the course.

Prerequisites:

Students should have a general understanding of mechanics and materials, and a deep curiosity in extending their knowledge beyond traditional bounds. This course is designed for students willing and able to work at least at the level of a first year graduate student. Literature reviews, critical peer discussion, individual and team problem assignments, a laboratory project, and student presentations will be an integral part of the course.

General Topic Areas Covered:
The topic areas listed are not necessarily a chronological list and may be interspersed amongst each other where connections between topics exist or logically complement each other.

- introduction to nanotechnology, overview of new opportunities, connections to mechanics
- brief overview of synthesis techniques
- overview of relevant mechanics concepts including mechanics of materials, fracture mechanics, contact mechanics, elasticity
- atomic structure of materials, phase transformations, defects, dislocations
- mechanical testing and material property determination at small scales including size-scale strength effects
- surface characterization including scanning probe techniques, surface forces, and diffusion
- using mechanics in micromachine (MEMS): application, design, performance, and testing
- theory, modeling, and computational techniques for mechanics modeling of nano-systems
- mechanics aspects in nano-biomaterials, molecular machines – possibly dropped for time constraints

Evaluation:
This course will incorporate the following types of assignments:

- **reflective writing assignments** asking students to evaluate information, draw inferences, identify cause and effect, and draw comparisons with examples from the literature *(reflective writing assignments will be posed as weekly email questions about the current lecture topics, students will respond with 1-2 paragraphs by Sunday evening using the forum on the course website)*

- **manuscript** presenting an in-depth critical review of a nano-science research topic that incorporates interdisciplinary issues; written as a technical article submission to a peer-reviewed journal; incorporates reviews and appropriate revisions; graded by the instructors *and* by peers *(due dates indicated in the syllabus)*

- **homework** sets based on individual effort and group work *(due dates indicated in the syllabus)*

- **laboratory** experiments on synthesis and characterization of nanoscale components, and construction of a microfluidic device that will filter nanoparticles from solution*(each student will keep a lab notebook for the course; a copy of the recent lab notebook pages are due on the lab due dates indicated in the syllabus; a final lab report is due at the completion of the lab series with the last lab assignment)*

Laboratory work will be conducted in teams although each student will construct a final device using the components and solutions created by the lab team. Each student will take on the leadership role for the lab group for at least one laboratory.

Laboratory experiments will include the following modules:

Lab 1: Functionalization of a silver coated substrate with a decanethiol monolayer followed by contact angle characterization

Lab 2: Atomic Force Microscopy characterization of the silver substrate and the functionalized silver created in Lab 1

Lab 3: Construction of a microfluidic device on the functionalized substrate created in Lab 1 followed by creation of a nylon filter within the device

Lab 4: Synthesis of collodial gold nanoparticles in an aqueous solution http://www.mrsec.wisc.edu/edetc/cineplex/gold/index.html

Lab 5: Testing of nanofilter device using the nanoparticle solution created in Lab 4

Lab 6: Atomic Force Microscopy imaging of filtered nanoparticles from Lab 5

An on-line video-based lab manual is available at:

http://www.mrsec.wisc.edu/edetc/nanolab/fluidics/index.html

Grades in the course will be decided with the following weighting:

Class Participation/Weekly Emails	10%
Homework Sets	30%
Laboratory Reports	30%
Manuscript	30%

Required Text:
A.N. Cleland (2003) Foundations of Nanomechanics
Note: we will follow this text directly for certain sections of the class, but other sections will rely on other supplementary sources including texts, journal articles, and notes.

References on Reserve:
See the course webpage http://courses.engr.wisc.edu/ecow/get/ema/601/crone/
for a complete listing of reserve items and on-line references.

Books on reserve at Wendt:

A.N. Cleland (2003) Foundations of Nanomechanics	T174.7 C554 2003
G. Timp (1999) Nanotechnology	T174.7 N373 1999
K.E. Drexler (1992) Nanosystems: Molecular Machinery, Manufacturing, and Computation	T174.7 D74 1992
Gere (2001) Mechanics of Materials	TA405 G44 2001
Cook and Young (1999) Advanced Mechanics of Materials	TA405 C843 1999
Johnson (1985) Contact Mechanics	TA350 J57 1985

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Date	Week	Lecture #	Instructor	Topic	Due Dates
1/18	1	1	WCC	Introduction to nanotechnology	
1/20		2	RWC	Overview of new opportunities and connections to mechanics	
1/25	2	3	WCC	Laboratory overview	
1/27		4	WCC	Overview of synthesis techniques - Bottom up - Top down	
2/1	3	5	RWC		
2/3		6	RWC	Atomic structure of materials	lab groups assigned
2/8	4	7	WCC	Phase transformations and size scale	Labs begin
2/10		8	RWC	Underpinnings of mechanics, elasticity relations	
2/15	5	9	RWC		HW #1 due
2/17		10	RWC		Manuscript topic choice due
2/22	6	11	RWC		
2/24		12	RWC	Defects and dislocations	Lab #1 due. Notes for Lab #2 handed out.
3/1	7	13	RWC	Surfaces, and surface characterization techniques	
3/3		14	RWC	Scanning probe microscopy - AFM - atomic scale studies of friction and adhesion	HW #2 due
3/8	8	15	RWC		Manuscript outline due
3/10		16	WCC	Mechanical testing and material property determination at small scales, topics such as - applying load on small scale structures - measuring strain on small scale structures - cantilever deflection as a detection technique - size-scale strength effects - impact of size on thin film ductility and fracture - capillary forces and tall walls	Lab #2 due
3/15	9	17	WCC		
3/17		18	WCC		
3/29	10	19	WCC		
3/31		20	WCC		Lab #3 due HW #3 due
4/5	11	21	WCC	Nano-bio-mechanics	Manuscript draft due
4/7		22	WCC	Experimental mechanics at the cellular scale	
4/12	12	23	WCC	Using mechanics in micromachines (MEMS): - soft MEMS architectures (fluid mixing, adhesion and membrane forces, experiments and models) - hard MEMS: applications, design, performance, and testing - the issue of tribology in traditional MEMS	Lab #4 due
4/14		24	cancel		
4/19	13	25	RWC		Manuscript comments returned to authors
4/21		26	RWC		
4/26	14	27	RWC	Nanotubes and nanocomposites	HW #4 due
4/28		28	RWC		Lab #5 due
5/3	15	29	DM	Theory, modeling, and computational techniques for mechanics modeling of nano-systems including MD of fracture mechanics, mixed atomistic/continuum modeling of sliding friction	
5/5		30	DM or IS		Manuscript final draft due Lab #6 due