Title: Small-Scale Mechanical Behavior
Course Number: Mechanical Engineering E8990 (Special Topics Course)
Prerequisites: ENME E3105 or equivalent; APMA E4200 or equivalent.
Instructor: Professor Jeffrey W. Kysar (jk2079@columbia.edu)
Term: Spring 2009
Time: Mondays, 4:10 pm to 6:40 pm.
Room: TBA
Class format: Lectures (14 total), Weekly homework sets, Final examination

Description in Bulletin: Introduction to the mechanical behavior of small scale components, structures and devices. Review of variational calculus as used to derive governing equations of beam and plate theory. Deformation and vibration of beams and plates. Stress, deformation, and substrate curvature in thin films. Fracture, delamination, bulging, buckling and of thin films. Equilibrium and stability of surfaces. Small scale mechanical characterization including: nanoindentation, thin film bulge test, and electron microscopy methods.

Syllabus:

1. Overview of governing equations to solve problems of mechanical deformation
    a. No previous experience with Elasticity will be required for this course.
2. Thermodynamics of deformed solids
    a. Free energies
    b. Thermodynamic definition of elastic properties
    c. Elastic properties under isothermal and adiabatic conditions
    d. Linear and non-linear elastic properties
3. Overview of variational calculus with applications to
    a. Beam theory
    b. Plate theory
4. Vibrations in cantilever and double-cantilever beams
    a. Resonant frequencies
    b. Modes
    c. Q-factor
5. Stresses in thin films
    a. Measurement of stresses in thin films
    b. Wafer curvature and Stoney equation
    c. Stresses due to different deposition processes
6. Overview of fracture mechanics
    a. Classification of different types of crack and fracture behaviors
    b. Singular stress state at crack tip
    c. Energy release rate upon crack advance and fracture criterion
7. Delamination and fracture in thin films
    a. Morphologies of fracture
    b. Energy release rates and fracture criterion
8. Equilibrium and stability of surfaces
    a. Chemical potential
    b. Diffusion of atoms and atomic vacancies
    c. Morphology of thin films under various deposition conditions
9. Mechanical characterization of small deforming volumes
    a. Nanoindentation
    b. Thin film bulge test
    c. Beam and membrane indentation
10. Mechanics of Graphene and Carbon Nanotubes
    a. Linear and non-linear elastic properties
    b. Mechanical characterization