CHEM 6287
Spring Semester, 2011
Syllabus

Course Title: Scanned Probe Techniques

Faculty: Dr. Lawrence A. Bottomley (ES&T L1-238, 404-894-4014)

Lecture: TR @ 1:30-3 in MS&E 1201A

Catalog Description: An in-depth analysis of the theory, practice and application of scanning probe microscopy techniques.

Learning Objectives:

Students completing this course will have:

- a fundamental understanding of the theoretical underpinnings behind each scanned probe technique
- an appreciation of the instrumental design attributes
- knowledge of the advantages and limitations of each technique,
- understand the protocols for sample preparation with each technique.

Suggested eTexts: **Scanning Probe Microscopy: Atomic Scale Engineering by Forces and Currents** - Adam Foster and Werner Hofer

Applied Scanning Probe Methods (Vol. 1-13) – Bharat Bhushan, ed.

Springer Handbook of Nanotechnology - Bharat Bhushan

Atomic Force Microscopy in Adhesion Studies - Jaroslaw Drelich and Kash L. Mittal, Eds.

Lecture Schedule

This course consists of the following components:

I. Scanning Tunneling Microscopy

- Historical perspectives for invention of STM
    - Optical & Electron microscopy
    - Profilometry
- Theory of tunneling
    - Atom-scale tunneling
    - Wavefunctions at surfaces

    - Imaging atomic states
  - Instrumentation
    - Vibration isolation
    - Piezo scanner design characteristics
    - Calibration
    - Tip preparation methods
    - Scaling & data sampling
  - Imaging modes
    - Constant current
    - Constant height
    - Feedback circuitry and amplifier tuning
  - Applications
    - Imaging surface topography
    - Imaging the local density of the states
    - Single molecule vibrational spectroscopy via inelastic tunneling spectroscopy
  - Image processing and analysis (how its done, why its done, what are the consequences of doing it)
    - Edge alignment
    - Flattening
    - Filtering
    - Correlation
    - Sectioning
    - Roughness
  - Representative applications in surface science
    - HOPG
    - Silicon
    - Screw dislocations
    - Liquid crystals (ordered aggregates)
    - DNA (single molecules)
    - Magnetic wires and clusters
    - Single molecule vibrational spectra
  - Demonstration

II. Atomic Force Microscopy

  - Mechanical properties of levers
  - Cantilever fabrication methods
    - Traditional method (Silicon, SiO_2, Si_3N_4)
    - SOI
    - Polymeric cantilevers
    - Tip sharpening methods
  - Cantilever deflection detection methods
    - Tunneling detection system
    - Capacitance detection system
    - Piezoresistive detection system

    - Optical detection systems
      - Optical lever/feedback
      - Deformable diffraction
  - Imaging modes
    - Contact
    - Non-contact
    - Intermittent contact
    - Lateral force imaging
  - Intermolecular forces
    - Force curves
    - Van der Waals forces
    - Jump to contact
    - Repulsion
  - Sources of Noise
  - Recognition and avoidance of image artifacts
  - Sample preparation methods
  - Representative applications in biological sciences
    - DNA
    - Proteins
    - Active transcription
    - Polymer melting
  - Demonstration

III. Force Spectroscopy

  - Force curve acquisition modes
    - Single
    - Force volume
    - Triggering
    - Environments
      - In vacuo
      - In air
      - In fluid
  - Conversion of deflection data into force-separation data
    - Calibration of detector response
    - Removal of scanner hysteresis
    - Removal of optical interference
    - Calculation of tip-surface distance
  - Interpreting force curve
    - Adhesion
    - Substrate compliance
    - Molecular stretching
  - Modeling adhesion
  - Modeling substrate compliance
  - Modeling molecular stretching events
    - Worm-like chain

        - Freely-jointed chain
    - Representative applications
        - Chemical force microscopy of monolayers
        - Polymers
        - Stretching single nucleic acids
        - Intercellular adhesion
    - Demonstration

IV. Force Modulation & Nanoindentation

- Theory
- Instrumentation
- Recent applications
    - Characterization of composites
    - Hydrogels

V. Magnetic Force and Magnetic Resonance Force Microscopy

- Theory
- Instrumentation
- Current challenges to implementation of MRFM
- Recent applications of MRM
    - Magnetic recording media
    - Characterization of composites

VI. Lateral Forces & Nanotribology

- Theory
- Calibration of lateral forces
- Recent Applications:

    - MEMS & Hard Disks
    - Boundary lubrication
    - Nano-confined fluids

VII. Scanning Capacitance Microscopy

- Theory
- Instrumentation
- Recent applications

VIII. Thermal Methods on the Nanoscale

- Theory
- Instrumentation
- Recent applications

IX. Nanofabrication with proximal probes

- STM
  - Eigler’s moving atoms
  - Snow’s nanoscale oxidation
- AFM
  - Nanolithography
  - Dip-pen lithography

X. Hyphenated Methods

- STM-Electrochemistry
  - Essential theory
  - Basic instrumentation
  - Advantages & limitations
  - Applications
    - Corrosion
    - Electrodeposition & Atomic layer epitaxy
- AFM-Electrochemistry
  - Essential theory
  - Basic instrumentation
  - Advantages & limitations
  - Applications
- Scanning Electrochemical Microscopy
  - Essential theory
  - Basic instrumentation
  - Advantages & limitations
  - Applications
- Tip-Enhanced Raman Spectroscopy
  - Essential theory
  - Basic instrumentation
  - Advantages & limitations
  - Applications

Assessment

Course grades will be determined by the student's performance on four, equally-weighted problem sets. Final grades will be given based on the following scale:

A (100 – 80%)
B (79 – 70%)
C (69 – 60%)
D (59 – 50%)
F (below 50%)

Academic Integrity

Students in this class are expected to abide by the Georgia Tech Honor Code and avoid any instances of academic misconduct, including but not limited to: (a) Possessing, using, or exchanging improperly acquired written or oral information in the preparation of a paper or problem set. (b) Substitution of material that is wholly or substantially identical to that created or published by another individual or individuals. (c) False claims of performance or work that has been submitted by the student.

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