NP 427 Local/non local spectroscopies 9 ECTS

Organisation :

Effective duration: 12 weeks
Lectures : 42 hrs
Tutorial : 8 hrs
Practicals : 20 hrs (8 hours at SOLEIL synchrotron)
Projects : 10 hrs
Total : 80 h

Examination :

Written examination, project report

Teachers :

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Plan of lectures (53 hrs)

CHAPTER I. SCANNING TUNNELING MICROSCOPY/SCANNING TUNNELING SPECTROSCOPY (10 hrs)

1. STM/STS theory elements
    a. basic idea and history of STM
    b. electronic structure vs surface topography
    c. tunnelling spectroscopy

2. Technology
    a. STM design : vibration and thermal drift
    b. STM mechanics : course approach, scanning
    c. STM electronics : signal generation, detection
    d. Tip preparation
    e. Design examples

3. Applications
    a. Surface structure : metals and semiconductors
    b. Local electron spectroscopy : charge density wave and superconductors
    c. Inelastic tunnelling spectroscopy : vibration modes of molecules
    d. Atom and molecule manipulation

CHAPTER II ELECTRON SPECTROSCOPIES FOR SURFACES AND NANO-OBJECTS (20 hrs)

1. Interaction between radiation and matter
    a. Maxwell equations
    b. Fermi's Golden Rule
    c. Photoemission/photoabsorption processes. The phenomenology of photoemission.

2. Spectroscopic instrumentation, vacuum technology

3. UV photoemission
    a. Band mapping, surface states
    b. Determination of molecular symmetries

4. Inner shell excitation spectra: XPS and NEXAFS
    a. X-ray absorption cross section, timescales in inner shell excitation, lifetimes, Born-Oppenheimer approximation, the Franck-Condon principle
    b. Transition energies: Electronic ground state vs excited/core-ionized states, the Hartree Fock Formalism, around the Koopman's theorem, the transition state method, new DFT approaches.
    c. Transition Intensities (the sudden approximation), satellites, multiplets
    d. Core-level binding energy shifts at surfaces: The reference level problem: metals, adsorbates, semiconductors, insulators.
    e. Surface core-level shifts, adsorbate induced core-level shifts.
    f. Photoelectron diffraction
    g. NEXAFS/XANES spectroscopy. Applications to the characterization of surface adsorbates.

5. Spectromicroscopy/microspectroscopy

6. Inverse photoemission
    a.The physics of transition in IPE: matrix elements and the Golden Rule; Conservation Rules and Symmetry
    b. Applications: 2 D systems, nearly free electron metals and transition metals, band mapping , adsorbate induced states, measurement of the transport gap in molecular crystals
    c. High Energy IPE: Bremsstrahlung isochromat spectroscopy

CHAPTER III. SPECTROSCOPIES FOR THE SOLID STATE (12 HRS)

1. Low Energy Spectroscopies
    a. IR and Vis spectroscopies of solids
    b. Solid state optics, photoluminescence
    c. Phonons
    d. Spectroscopy of semiconductors (absorption, gap measurements)
    e Defects in solids: the colored centers

2. High Energy Spectroscopies
    a. X-ray absorption (XANES and EXAFS)
    b. Inelastic scattering of X-rays and electrons. Complementariness with neutron scattering.
    c. Electronic microscopy. Energy loss spectroscopy

Tutorials (8 hrs)

1. Photoemission. The semiquantitative use of XPS to determine film thicknesses. Application: the Si/SiO_2 system (introductory to SOLEIL TP)
2. Group theory applied to spectroscopy (chemistry and Solid State Physics)
3. The reciprocal space. Applications to band mapping, electron diffraction etc.
3. NEXAFS. Determination of molecular orientations.

Laborations (16 hrs)

(1) Scanning tunnelling spectroscopy (4 hrs)
(2) Virtual XPS/NEXAFS experiment at LCPMR. Data processing/fitting with IGOR. Data interpretation (4 hrs)
(3) practical at SOLEIL synchrotron,. Si(111) oxidation by O_2. Measurement of band bending, work function changes, real time oxide growth followed by O 2s +Si 2p photoemission. (8 hours)

Project (10 hrs)

The aim of a project is to give the student the opportunity to study in detail a topic by directed reading and independent study including a critical review of literature.
Research using academic journals, textbooks and computer-based resources;
Topics: Scanning tunnelling microscopy and spectroscopy applied to different kind of objects. Electron spectroscopies for surfaces and nano-objects. All photon spectroscopies for bulk analysis.