UNIVERSITÀ DI PISA

PHYSICS OF SURFACES AND INTERFACES

MASSIMILIANO LABARDI

Academic year	2019/20
Course	PHYSICS
Code	092BB
Credits	3

Modules	Area	Type	Hours	Teacher(s)
FISICA DELLE SUPERFICI E INTERFACCE	FIS/03	LEZIONI	18	MASSIMILIANO LABARDI

Learning outcomes

Knowledge
The Course provides a general introduction to the physics of surfaces and interfaces, focusing on basic concepts rather than specific details, and explores physical phenomena underlying some of the most important techniques and methods for surface analysis.

Assessment criteria of knowledge
Discussion with students during class and office hours.

Skills
The course promotes development of critical thinking and summary skills, aimed to spot fundamental concepts underlying the subject.

Assessment criteria of skills
Discussion with students during class and office hours.

Behaviors
Autonomous study of the subject is promoted.

Assessment criteria of behaviors
Discussion with students during class and office hours.

Prerequisites
To attend the course in the most profitable manner, general knowledge of fundamental aspects of structure of matter is recommended.

Syllabus
The program of the course is comprised of the following topics:
PART I: Phenomenology of surfaces and interfaces
Introduction to surfaces and interfaces. Surface/volume ratio.
Microscopic interpretation of intermolecular forces. Interaction energy between ions, frozen and mobile permanent dipoles. Keesom energy. Interaction energy with induced dipoles: Debye induction energy, London dispersive energy. Frequency dependence of atomic polarizability. Ionization energy. Van der Waals energy. Casimir-Polder effect. Van der Waals forces between macroscopic bodies. Additivity of Van der Waals interaction. Adsorption, adhesion, cohesion. Hamaker constant.
Liquid surfaces. Interfacial thickness. Surface free energy and surface energy. Thermodynamics of interfaces in equilibrium: Gibbs theory. Definition of interface and Gibbs dividing plane. Interfacial excess. Solvent-solute case: relative adsorption. Surface tension. Thermodynamic potentials at the interface. Chemical potential, self-energy, entropy of mixing. Euler relation and Gibbs-Duhem relation. Thermodynamic definition of surface tension. Surface tension and interfacial excess. Gibbs adsorption isotherm. Surface activity: case of ionic, apolar, and amphiphilic solutes. Colloidal aggregates. Critical micellar concentration. Thermodynamics of colloidal aggregation. Pressure difference across a curved surface: Young-Laplace equation. Vapor pressure at a curved surface: Kelvin equation. Supersaturation pressure. Theory of homogeneous nucleation. Heterogeneous nucleation. Wetting. Wetting line and contact angle. Young equation. Cases of partial, complete, and no wetting. Capillarity phenomena. Capillary condensation. Particle adhesion by capillarity. Capillary rise. Trapping of particles at the interface. Thin film formation. Spreading coefficient. Dewetting. Pseudo partial wetting and wetting layer. Thin film deposition: dip coating and spin coating. Detergency. Measurement of surface tension: Wilhelmy plate method. Contact angle measurement: drop observation method.

PART II: Surface characterization techniques
Interaction of photon and electron beams with matter. Lambert-Beer law. Penetration length. Elastic and anelastic scattering of electrons. Secondary and backscattered electrons. Excitation volume. Atomic excitation and relaxation processes. X-Ray Photoelectron spectroscopy (XPS). Experimental setup for XPS. Interaction zone for photon excitation. Collection efficiency. Escape depth (ED) and anelastic mean free path. Measurement of energy dependence of ED. Angular dependence of ED. Information from XPS spectra. Chemical shift. Surface shift. Auger electron spectroscopy (AES). Auger processes. Comparison with XPS. Instrumentation for AES. Electron source by thermionic emission and field emission. Cylindrical mirror analyzer. Electron multiplier.
Scanning probe microscopy. Beam vs local probes. Atomic force microscope. Working principle: typical setup. Piezoelectric scanners and raster scan. Constant height mode and constant force mode. Interaction steepness and atomic resolution. Cantilever force sensors. Optical lever deflection detection method. Static mode of operation: contact mode. Jump-in-contact and jump-off-contact points. Lateral force and local friction coefficient measurement. Bidirectional optical lever. Dynamic modes of AFM. Problems arising in static mode: thermal noise. Response function of the cantilever as a simple harmonic oscillator. Tapping mode. Phase imaging. Effect of conservative and dissipative interactions on resonance curve. Frequency-modulation mode. Combined scanning probes. Auxiliary distance control. Electrostatic Force Microscopy. Dependence of electric force on distance and electric properties of dielectrics. Voltage-modulated force detection. Dielectric constant, surface charge and contact potential measurement. Kelvin probe method. Kelvin probe force microscopy.
Nanotribology. Friction at a contact point measured by AFM. Stick-slip dissipation: Tomlinson model. Friction of atomic layers. Quartz crystal microbalance (QCM). Gravimetric and non-gravimetric QCM. Interfacial viscosity and slip time.
Visit to research laboratories with different cantilever and tuning fork based atomic force microscopes.

Bibliography

Butt, Graf, Kappl, Physics and Chemistry of Interfaces, Wiley, 2003
Lecture notes (avaliable, in Italian, on elearning website of Physics Department:

https://elearning.df.unipi.it/enrol/index.php?id=254
Additional material in English is available on the same website.

Non-attending students info

For students not attending the class, the form of the standard oral exam is compulsory.

Assessment methods

Oral exam, or presentation, in seminar form, of a detailed study concerning one of the topics of the course.

Class web page

https://elearning.df.unipi.it/enrol/index.php?id=254

Notes

The course is composed by at least 18 hours of class teaching and one visit to research laboratories where experiments of surface physics using scanning probe microscopy are performed.

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