PHYSICS OF NANOSTRUCTURES – (30 h)

PART I: "Introduction to the Nanostructures" (Vittorio Pellegrini – 12h)

A. Introduction to the nanostructures (2h):
-Quantum wires and dots,
-Nanotubes and nanowires,
-Graphene,
-Biomolecules, atoms
-Methods of synthesis of nanostructures.
(Proposed date: 26 May – afternoon)

B. Theory of electronic states in nanostructures(2h):
-Fock-Darwin states in quantum dots
-Dirac fermions in graphene
-Optically-active transitions in biomolecules
(Proposed date: 27 May – morning)

C. Optical and transport properties of nanostructures(2h):
-Inter-shell electronic excitations in quantum dots
-Multi-excitons and photoluminescence in quantum dots
-Coulomb blockade and conductance quantization
-Vibrational spectra and photochromic behavior in biomolecules
-STM spectroscopy of atoms
(Proposed date: 3 June – afternoon)

D. Nanostructures for quantum computation and nanoelectronics(2h):
-Spin qubit in quantum dots
-Spin coherence ad Rabi oscillations of spin states in quantum dots
-Transport in hybrid superconductor-semiconductor nanostructures
(Proposed date: 4 June – morning)

E. A few applications of nanostructures(2h):
-In-vivo cellular imaging with biomolecules, single-molecule FRET
-Hydrogen storage in graphene
-Nanowire lasers
(Proposed date: 16 June – afternoon)

F. Nanostructures in the next 20 years?(2h):
-nanoelectronics with single atoms
-Fractional nanoelectronics
-Drug delivery nano-devices
(Proposed date: 17 June – morning)

Part II: "Electron microscopy of nanostructures" (Corrado Spinella – 8h)

A. Conventional TEM
1. High resolution imaging: ultimate resolution of a TEM
2.Phase contrast: bright field and dark field
3. Visibility of nanoclusters in amorphous or crystal matrix

B. Electron energy loss spectroscopy (EELS) and energy filtering TEM (EFTEM)
1. The post-column image filtering system
2. EELS features: low-loss spectra (plasmons) and analysis of the high-loss structures
3. EFTEM chemical mapping by the “three windows” methodology
4. Imaging from the bulk and surface plasmon excitations
5. Spectroscopy and imaging of Si nanoclusters embedded in a SiO_2 host

Part III: “Scanning probe microscopy in nanoscience” (Vito Raineri – 8h)

A. Scanning probe microscopy: surface morphology
1. General concepts and instruments design
2. Scanning tunnelling microscopy: physical outset
3. Static atomic force microscopy: physical outset
4. Dynamic atomic force microscopy: physical outset
5. Surface morphology and image filtering
6. Basics on physics of surface (atomic reconstruction, disordered morphology, statistic and fractal description of disorder, defects definition in disordered surfaces)
7. Lateral force microscopy, friction and nanoscale rheology

B. Scanning probe microscopy: spectrometry
1. Curves of forces and nanoindentation

C. Scanning probe microscopy: local (nanoscale) transport measurements
1. Scanning ballistic electron emission microscope
2. Scanning barrier microscope
3. Determination of local barrier in semiconductor/metal interfaces
4. Transport in nanoSchottky
5. Scanning electrostatic force microscope
6. Local surface potential in semiconductors
7. Nanoscale charge distribution in dielectrics
8. Scanning spreading resistance microscope
9. Scanning capacitance microscope
10. 2D carrier and mobility distribution in nanostructures and advanced materials
11. Carrier compensation profiling in advanced materials
12. Scanning impedance microscopy
13. nanoscale imaging of dielectric properties

D. Scanning probe microscopy: nanolithography
1. Anodization and nanopatterning
2. nanomanipulation

D. Scanning probe microscopy: the infinite instrument
1. conductive atomic force microscope and molecules
2. magnetic force microscope and nanodomains
3. scanning thermal microscope

Part IV: “Laboratory Experiences on Nanostructures” (Francesco Priolo – 2h)

1. Photoluminescence of semiconductor quantum dots
2. Electrical properties of quantum dot arrays