Project Physics

Department of Physics

NANO PHYSICS

- **To be familiar with basic concepts of Nano Physics**
- **To understand various techniques used in Nano Physics**
- **To apply these concepts and techniques for practical applications**

Unit I

Introduction – Nano structures – Nano crystalline materials - Electron microscopy – Electron microscope – General consideration for imaging – Analytical and imaging techniques – Sample preparation – Advantages and Disadvantages of electron microscopes – Transmission electron microscope – Background – High resolution Transmission electron microscopy – Preparation and visualization of samples – Imaging simulation – Particle size analysis – Scanning electron microscope – detection of secondary electrons - detection of Backscattered electrons - Secondary electron imaging – Microscope imaging – Scanning probe microscopy

– Imaging structures.

Unit II

Atomic force microscopy – Theory – Piezoelectric ceramic transducer – AFM instrumentation – Imaging modes – Measuring images with AFM – Resolutions in Atomic force microscope - Probe surface interactions - Surface contamination – Electrostatic forces – Surface material properties – Vibrating sensing mode – Torsion modes – Mechanical surface modification – Electrical surface modification - Atomic force microscopy for nanoparticles – Qualitative analysis – Techniques – Direct growth by Chemical vapour deposition of AFM tips – CVD MWNT tip preparation - CVD SWNT tip preparation – Sample preparation – Nanolithography – Adhesive mask technique – Photolithography – resolution in projection systems – Limitations – Perspectives – Electron beam lithography – Electron energy deposition in matter – Spatial-phase-locked Electron beam lithography

Unit III

Fabrication of nanostructures – Milling – Lithographic processes – Lift-off process – Vapour phase deposition methods of fabrication – Plasma-assisted deposition methods of fabrication

– DC glow discharge – Magnetron sputtering – Vacuum arc deposition – Nanofabrication by scanning probe techniques – By Scanning force probes – Electrical structure generation by SFM – By Scanning tunneling microscope – Growth and characterization techniques – Molecular beam epitaxy – MBE apparatus – MOVPE – Liquid phase methods – Colloidal methods – Sol-gel methods – basic process –Electro deposition

Unit IV

Properties of individual nanoparticles – Metal nanoclusters – Magic numbers - Theoretical modelling of nanoparticles – Geometric structure – Electronic structure – Reactivity – Fluctuations – Magnetic clusters – Bulk to Nano transition – Carbon nanostructures – Carbon molecules – Carbon clusters – Carbon nanotubes – Applications of carbon nanotubes

Unit V

Quantum Wells, Wires and Dots – Preparation of quantum nanostructures – Size and dimensionality effects – Excitons – Single electron tunneling – Applications – Superconductivity – Microelctromechanical systems – Nanoelectromechanical systems

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SOLID STATE PHYSICS- I

- **To be familiar the basics of crystal structures**
- **To understand the concepts of crystal structures**
- **To apply the acquired knowledge and understanding to solve problems**

UNIT I: CRYSTAL PHYSICS

Periodic arrays of atoms: Lattice Translation vectors – Basis and the Crystal Structure – Primitive lattice cell – Fundamental types of lattices: Two and three dimensional lattice types – Miller indices of Crystal Planes – Simple crystal structures:NaCl, hcp – Diffraction of waves by crystals- Bragg law — Reciprocal Lattice Vectors – Laue equations – quasi crystals.

UNIT II: CRYSTAL BINDING AND ELASTIC CONSTANTS

Crystals of inert gases (Vander walls – London interaction) – Ionic Crystals (Madelung Constant) – Covalent crystals - Metals – Hydrogen bonds – Atomic Radii — Elastic Compliance and Stiffness Constants – Elastic waves in cubic crystals.

UNIT III: PHONONS

Quantization of Elastic waves (phonons) – phonon momentum – Inelastic scattering by phonons – phonon heat capacity – plank distribution- Density of states in one and three dimension – Debye and Einstein model of density of state– Anharmonic crystal interactions – Thermal resistivity of phonon gas – umklapp processes.

UNIT IV: FREE ELECTRON FERMI GAS

Free electron gas in three dimensions – Heat capacity of the electron gas- Electrical conductivity and ohms law– Hall effect – Wiedmann Franz law, Nearly Free Electron Model: Origin and Magnitude of energy gap – Bloch functions – Kronig Penny Model – wave equation of an electron in a periodic potential: Bloch theorem-crystal momentum of an electron.

UNIT V: SEMI CONDUCTORS, FERMI SURFACES AND METALS

Band gap – Equations of Motions – Effective Mass –physical interpretation of the effective mass- Fermi Surface and Metals: Reduced Zone Scheme – Periodic Zone Scheme – Construction of Fermi Surfaces- Fermi surface of Cu - Calculation of energy band: Tight binding method - Wigner Seitz method –Idea of de Has Van Alphen Effect

SOLID STATE PHYSICS – II

UNIT I: PLASMONS, POLARITONS AND POLARONS

Plasma optics, Dispersion relation for EM waves—Transverse and Longitudinal mode of plasma oscillations-Plasmons – Polaritons – Electron-Electron interaction – Electron- Phonon Interaction - Polarons – Optical reflectance – Excitons - Frenkelexcitons- weakly bound excitons

UNIT II: SUPERCONDUCTIVITY

Experimental survey – Occurrence of superconductivity- Destruction of superconductivity by magnetic Fields-Meissner effect- Isotope effect - Theoretical survey: Thermodynamics of the super conducting transition – BCS theory of superconductivity -–Type II Superconductors-Josephson Superconductor Tunneling- High temperature Super conductors-Critical Fields and critical currents

UNIT III: DIELECTRICS AND FERROELECTRICS

Macroscopic electric field –Depolarization Field-Local electric field of an atom- Dielectric constant and polarizability –Electronic polarizability- Structural phase transitions – Ferroelectric Crystals-Classification of Ferroelectric Crystal.

UNIT IV: DIA, PARA, FERRO AND ANTIFERROMAGNETISM

Quantum theory of Dia, Para Magnetism-HundRule-Ferromagnetic order-Curie point and the exchange integral - Magnons – Neutron Magnetic Scattering – Ferrimagnetic order – Antiferromagnetic order - Ferromagnetic Domains –Anisotropy Energy- - single Domain Particles – Magnetic bubble domains.

UNIT V: POINT DEFECTS

Lattice Vacancies – Diffusion – Colour centers –F Centers- –Shear strength of single crystals – slip- dislocations- Burgers vector – Stress fields of dislocations – dislocation densities - Alloys-Hume Rothery Rule-Order –Disorder Transformation- -Kondo effect.

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