PREAMBLE

Nanoscience and Nanotechnology is a rapidly developing research area having enormous potential for technological applications. Universities and Research Institutes in India and world over have taken strong initiatives to start academic and research programmes in this field. A Centre for Nanoscience and Nanotechnology was started in the University in December 2006 with the aims of establishment of state-of-the-art laboratories for research and for offering academic programmes for the purpose of generating man power in this frontier area. The Centre is thriving for achieving these goals. The Centre has already set-up high level research facilities and offers two M. Phil courses - M. Phil Nanoscience and Nanotechnology, and M. Phil Nanobiology - and a Ph. D programme. University of Kerala is the first University in Kerala State to start an academic programmes in the area of Nanoscience and Nanotechnology. For further development of the Centre for Nanoscience and Nanotechnology and to generate man power in this area, it would be highly appropriate to start a Post Graduate programme in this area and this programme may be called M. Sc programme in Nanoscience.

Students having B. Sc Degree in Physics, Chemistry or Biology would have the required basic knowledge for undergoing a properly structured M. Sc programme in Nanoscience. The students completing the M. Sc course in Nanoscience should be competent enough to qualify GATE/NET/UGC examination to equip themselves for higher studies and for employment. Hence, the M. Sc course in Nanoscience has to be structured in such a way that students with a B. Sc Degree in Physics would learn enough core physics courses and courses in Nanoscience for the M. Sc course, students with a B. Sc Degree in Chemistry would learn enough core chemistry courses and courses in Nanoscience for the M. Sc course, and students with a B. Sc Degree in Biology would learn enough core biology courses and courses in Nanoscience for the M. Sc course. Initially, an M. Sc course in Nanoscience with eligibility for admission as a B. Sc degree in Physics of University of Kerala or equivalent degree from a recognized University/Institute may be started. The other two M. Sc courses with B. Sc in Chemistry or Biology (the exact subject/subjects to be decided) as the basic qualification for admission can be started during the coming years.

UNIVERSITY OF KERALA

CENTRE FOR NANOSCIENCE AND NANOTECHNOLOGY

M. Sc PROGRAMME IN NANOSCIENCE

The programme shall extend over a period of two academic years comprising of four semesters each of 5 months duration

Scheme (Curriculum Structure)

Course code	Course Title	Lecture L	Tutorial T	Practical P	Credit C
	Semester I				
NSP 511	Mathematical Physics	4	1	-	4
NSP 512	Classical Mechanics	4	1	-	4
NSP 513	Electrodynamics	4	1	-	4
NSP 514	Electronic Devices and Circuits	4	1	-	4
NSP 515	Electronics - Lab	9	3		
	Semester II				
NSP 521	Quantum Mechanics	4	1	-	4
NSP 522	Condensed Matter Physics	4	1	-	4
NSP 523	Spectroscopy	4	1	-	4
NSP 524	Introduction to Nanoscience and Nanotechnology	4	1	-	4
NSP 525	Nanoscience - Lab I			9	**3**

	Semester III				
NSP 531	Synthesis and Fabrication of Nanomaterials	4	1	-	4
NSP 532	Physics and Chemistry of Nanosolids	4	1	-	4
NSP 533	Nanoelectronics	4	1	-	4
NSP 534	Characterization Techniques for Nanomaterials	4	1	-	4
	Elective I	4	1	-	4
	Electives (one elective to be selected from the list below)				
NSP 53E1	Computational methods				
NSP 53E2	Thermodynamics and Statistical Mechanics				
NSP 53E3	Advanced Quantum Mechanics				
	Semester IV				
	Elective II	4	1	-	4
	Elective III	4	1	-	4
NSP 543	Nanoscience - Lab II			9	**3**
NSP 544	Project		11		4
	Electives (two electives to be chosen from the list below)				
NSP 54E1	Nanotechnology and Energy Applications				
NSP 54E2	Advanced Nanotechnology				
NSP 54E3	Advanced Materials and Devices				
NSP 54E4	Nanooptoelectronic Devices and Sensors				

NSP 511 MATHEMATICAL PHYSICS

Unit I

Vector analysis and matrices

Review of vector analysis-vector calculus operators-orthogonal curvilinear coordinates – Gradient,divergence,curl,Laplacian in cylindrical\ and spherical polar coordinates-orthogonal and unitary matrices-Hermitian matrices-diagonalization of matrices-normal matrices.

Complex analysis

Cauchy-Riemann conditions-Cauchy's integral theorem and formula-singularities and mapping-calculus of residues-dispersion relations.

Fourier series and applications

General principles of Fourier series-advantages and applications-Gibbs phenomenon-Discrete Fourier Transform-Fast Fourier transform.

Probability

Definitions and simple properties of probability-random variables-Chebychevsin equality and moment generating function-discrete and continuous probability distributions-binomial distributions-Poisson distributions-Gauss Normal distribution error analysis duf and least square fitting- chi-square and student 't' distributions.

Unit II

Differential equations

Partial differential equations-first order equations-separation of variables-singular points-series solutions and Frobenius method-non homogeneous partial differential equations-Green's functions-Laplace transforms and inverse Laplace transformsapplicationsto solution of simple differential equations.

Special functions

Bessel functions of the first kind-orthogonality-Neumann functions-Henkel functions modified Bessel functions-spherical Bessel functions-Legendre functions-generating function-recurrence relations and orthogonalility-associated Legendre function spherical harmonics-Hermite functions-Laguerre functions-Chebychevs polynomials hyper-geometric functions.

Unit III

Tensor analysis

Notations and conventions in tensor analysis-Einstein's summation convention covariant and contra variant and mixed tensors-algebraic operations in tensors symmetric and skew symmetric tensors-tensor calculus-Christoffel symbols-kinematics in Riemann space-Riemann—Christoffel tensor.

References

1. G. B. Arfken and H. J. Weber, Mathematical methods for Physicists, 7th Edition, Elsevier, 2012.
2. H. K. Dass and R. Verma, Mathematical Physics, S Chand & Co Pvt. Ltd., 2014.
3. A.W. Joshi, Matrices and Tensors in Physics, 3rd Edition, New Age International Pub., 2008.

NSP 512 CLASSICAL MECHANICS

Unit-I

Lagrangian mechanics

Mechanics of a particle and system of particles- constraints-D'Alembert'sprinciple and Lagrange's equations-simple applications of Lagrangian formulation-Hamilton's principle-techniques of calculus of variations-derivation of Lagrange's equations from Hamilton's principle-conservation theorems and symmetry properties.

Two body central force problem

Reduction to one body problem-equations of motion-equivalent one dimensional problem-differential equation for the orbit in the case of integrable power law potentials-Kepler's problem-inverse square law of force-scattering in central -Virial theorem-transformation of the scattering problem to laboratory coordinates.

Theory of small oscillations

Equilibrium and potential energy-theory of small oscillations-normal modes with examples-longitudinal vibrations- longitudinal vibrations of carbon dioxide molecule.

Unit II

Hamiltonian mechanics

Generalized momentum and cyclic coordinates-conservation theorems-Hamilton's equations-examples in Hamiltonian dynamics-canonical transformations-generatingfunctions-Poisson brackets-Liouville's theorem.

Hamilton-Jacobi equations

Hamilton-Jacobi equation-harmonic oscillator as an example-separation of variables in Hamilton-Jacobi equation-action angle variables-Kepler's problem.

Rigid body dynamics

Generalized coordinates of rigid body-Euler's angles-infinitesimal rotations as vectors angular momentum and inertia tensor-Euler's equations of motion of a rigid body force freemotion of symmetrical top-motion of heavy symmetrical top.

Unit III

Introduction to non-linear dynamics and chaos

Linear and nonlinear systems - integration of second order non-linear differential equation - pendulum equation - phase plane analysis of dynamical systems - linear stability analysis - limit cycles.

References

1. H. Goldstein, C.Poolea S.Safko, Classical Mechanics, 3rd Edn, Pearson Education Inc., 2011 Print.
2. G. Aruldhas, Classical Mechanics, Prentice Hall of India Pvt. Ltd., 2013 Print.

NSP 513 ELECTRODYNAMICS

Unit I

Electrodynamics

Maxwell's equations – integral form- boundary conditions-scalar and vector potentials - gauge transformations - wave equations and their solutions - source free wave equations – time harmoinc fields - phasors – Helmhotz equations.

Plane Electromagnetic Waves

Plane waves in lossless media - TEM weaves - polarization of plane waves - plane waves in lossy media - flow of electromagnetic power - Poynting's vector - normal incidence at plane conducting boundary – oblique incidence at a plane conducting boundary – normal incidence at a plane dielectric boundary - oblique incidence at a plane dielectric boundary.

Unit II

Waveguides and Cavity Resonators

Waves between parallel plates – TE, TM and TEM waves – rectangular wave guides - TE and TM modes in rectangular wave guides – circular wave guide – dielectric wave guides – cavity resonators.

Radiation Theory

Dipole radiation – electric dipole radiation – magnetic dipole radiation – radiation from an arbitrary source.

Unit III

Special Theory of relativity

Proper time and four-vectors - Minkowski's geometry of space-time - Lorentz transformation in four dimensional space - covariant four dimensional formulation - force and energy - equations in relativistic mechanics - relativistic energy. Elements of general theory of relativity (qualitative study).

Relativistic Electrodynamics

Magnetism as a relativistic problem – transformation of the fields – electric field of a point charge moving uniformly – electromagnetic field tensor – electrodynamics in tensor notation –potential formulation of relativistic electrodynamics.

Motion of a charged particle in an electromagnetic field

Uniform E and B fields – non uniform fields – time varying E and B fields.

Reference

1. David K Cheng, Field and Wave Electromagnetics, Adison-Wesley, 2014 Indian Edition.
2. David J Griffiths, Introduction to Electrodynamics, 4rd Edition, Pearson Education, 2012 Indian Edition.
3. John D Krouse, Electromagnetics, 4th Edition, McGraw Hill International, 2005.
4. J. D. Jackson, Classical Electrodynamics, 3rd Edition, John Wiley & Sons, 1998.
5. K. D. Krori, Fundamentals of Special and General Relativity, PHI Learning Pvt. Ltd., 2010.

NSP 514 ELECTRONIC DEVICES AND CIRCUITS

Unit I

Frequency response of amplifiers

Review of frequency response of CR circuits – cut off frequencies – band width – Bode plots –single pole and two pole transfer functions – dominant pole – gain round off – frequency response of BJT amplifiers - series capacitance and low frequency response – shunt capacitance and high frequency response - high frequency characteristics of transistors.

Field Effect Transistor

Biasing of FET - small signal model - analysis of common souse and common drain amplifiers - high frequency response – FET and VVR and its applications - CMOS logic and logic packages

Power Amplifiers

Types of power amplifiers - series fed class A amplifier - series fed transformer coupled class B– push-pull circuits - harmonic distortion in amplifiers - class C and D amplifiers - design considerations.

Unit II

Operational Amplifier Circuits

Differential amplifier - ideal op-amp – inverting – non-inverting - voltage follower - differential configuration - real op-amp - inverting configuration, non-inverting configuration **-** op-amp parameters - effect of offset - frequency response - op-amp applications - buffer amplifier - mathematical operations – summing – differentiator – integrator - log amplifier - antilog amplifier - active filters – low pass, high pass, band pass, band reject filters - analogue computations - comparators – zero crossing detector - Schmitt trigger - wave form generators - phase shift oscillator - twin-T oscillator, astable multi vibrator, monostable multi vibrator, bistable multivibrator, triangular wave generator - sample and hold circuit - voltage regulators.

Monolithic timers and their applications

RS flip flop, basic timing concept, 555 functional diagram and pin configuration, astable multivibrator - monostable multivibrator - free running ramp.

Unit III

Digital Electronics - logic gates - Boolean algebra - decoder/demultiplexer – multiplexer –encoder - seven segment decoder - flip flops - RS, clocked RS, D, T, JK, MSJK flip flops - shift registers – counters - synchronous and asynchronous counters – cascade counters - semiconductor memories - RAM, ROM, PROM, EPROM - digital to analog convertors - ladder and weighted resistor type - analog to digital converters – countertype - successive approximation type - dual slope convertors - application of DAC and ADC converters.

References

1. Millmann J and Halkias C C, Integrated Electronics, Mc Graw Hill, 1991.
2. Robert Boylestad and Luis Nashelsky, Electronic Devices and Circuit theory, 11th Edition, PHI, 2012.
3. Ramakant A Gayakwad, Op-amps and Linear Integrated Circuits, PHI, 2006.
4. John D Ryder, Electronic Fundamentals and Applications, PHI, 1983.
5. **Donald P. Leach**, and **Albert Paul Malvino**, Digital Principles and Applications 5th Edn., Mc Graw Hill, 1994.

NSP 515 ELECTRONICS - LAB

List of Experiments - Minimum 10 experiments to be done

(More number of experiments may be included in the list)

1. Half wave and full wave rectifier with filter
2. Stabilized power supply
3. Phase shift oscillator
4. RC coupled amplifier with out and with feed back
5. Emitter follower
6. Astable multivibrator
7. RC differentiator and Integrator
8. Study of OP Amp circuits
9. Characteristics of JFET and MOSFET
10. Study of clipping and clamping circuits
11. SR and JK Flip Flops - construction using Logic Gates and study of truth tables
12. Study of active filters using OP amps (a) low pass (b) high pass (c) band pass for both first order and second order-gain/ roll off determination
13. Wave form generation using OP amp circuits: (a) astable and monostablemultivibrators (b) square, triangular and saw-tooth wave generation
14. IC 555 timer experiments (a) monsostable and astable multivibrators (b) VCO
15. BCD to decimal decoder and seven segment display using IC

NSP 521 QUANTUM MECHANICS

Unit - I

Inadequacy of Classical Physics (Experimental results and qualitative discussion only, Derivations not required) **-** particle aspect of radiation - black body radiation- Max Planck's quantum hypothesis, Photoelectric effect- Einstein's explanation, Bohr model of Hydrogen atom, Old Quantum theory- Wilson-Sommerfeld quantum conditions- Inadequacy of old quantum theory.

Foundations of wave mechanics - de Broglie concept of matter waves – superposition of plane waves – uncertainty of position and momentum – exact statement and proof of uncertainty principle – applications of uncertainty principle.

Time dependent Schrödinger equation – Development of time dependent Schroedinger equation, Physical significance of the wave function, ø- Probability interpretation, orthogonal, normalized and orthonormal functions, Probability current density, Limitations on ø, Expectation value of dynamical quantities, Ehrenfest's theorem. The general solution of time dependent Schrödinger equation for a free particle (one dimensional), Free particle propagator, Wave packet, Time dependent evolution of a wave packet, Group velocity and Phase velocity, Time independent Schrödinger equation, Stationary states- the Gaussian wave packet – spread of the Gaussian packet with time – principle of causality.

Eigenvalue Problems in one-dimension - infinite square well – finite square well – The potential step – the

Unit II

Eigenvalue problems in three-dimension - separation of Schrödinger equation in Cartesian co-ordinates – the free particle – three dimensional box – square well in three dimensions.

Spherically symmetric systems – potential barrier – barrier tunnelling - application to a-decay linear harmonic oscillator – oscillator wave functions and parity.spherical harmonics and their properties – the hydrogen atom.

Matrix mechanics - linear vector spaces and their properties - Hilbert space - orthogonal systems - linear transformations and operators - hermitian operators and their properties – commuting and non-commuting operators – commutator algebra – change of basis and unitary transformations – matrix representation of operators and vectors – Dirac bra-ket notation – co-ordinate representation and momentum representations.

Equations of motion – Schrodinger, Heisenberg and interaction pictures - operator method for linear harmonic oscillator.

Unit III

Approximate Methods - the Variational method of approximation - principle of the method – variational method for the ground state of a system – ground state of hydrogen atom – anharmonic oscillator – variational method for the excited states.

Time-independent perturbation theory - stationary perturbation theory for non degenerate and degenerate levels - anharmonic oscillator with cubic and quadratic perturbations - Stark effect in hydrogen.

WKB approximation - WKB method - the connection formulas – energy levels in a potential well - barrier tunneling - application to alpha decay - application to bound state - validity of WKB approximation.

References

1. Leonard I. Schiff, Quantum Mechanics, McGraw Hill, 2010.
2. A. Ghatak, Introduction to Quantum Mechanics, Macmillan, 1996.
3. P. M. Mathews and K. Venkatesan, A text book of quantum mechanics, 2nd Edn., TMH, 2010.
4. G. Aruldhas, Quantum Mechanics, 2nd Edn., PHI Learning Pvt Ltd, 2009.

NSP 522 CONDENSED MATTER PHYSICS

Unit I

Crystal physics

Lattice points and space lattice - basis and crystal structure - unit cells and lattice parameters - symmetry elements in crystals – space groups - Bravais lattice - density and lattice constant relation - crystal directions - planes and Miller indices - reciprocal lattice - allotropy and polymorphism in crystals - imperfections in crystals.

Lattice vibrations and thermal properties

Dynamics of identical atoms in crystal lattice - dynamics of linear chain - experimental measurement of dispersion relation - anharmonicity and thermal expansion - specific heat of solids - classical model - Einstein's model - Debye model - thermal conductivity of solids - role of electrons and phonons - thermal resistance of solids.

Free electron and band theory

Electrons moving in one dimensional potential well - Fermi-Dirac statistics - effect of temperature on Fermi distribution - electronic specific heat - electrical conductivity of metals - Wiedmann-Franz-Lorentz law - electrical resistivity of metals - Hall effect - energy bands in solids **- Kronig-Penny** model - construction of Brillouin zones - nearly free electron model – conductors, semiconductors and insulators - elementary ideas of Fermi surfaces.

Unit II

Semiconductors

Free carrier concentration in semiconductors - mobility of charge carriers of semiconductors - Hall effect in semiconductors - semiconductor junction properties.

Dielectric and magnetic properties of materials

Dipole moment – polarization - local electric field in an atom - dielectric constant and its measurement – polarizability - classical theory - Peizo, pyro and ferro electric properties of crystals - ferroelectric domains - classification of magnetic materials - atomic theory of magnetism - Langevin's theory - paramagnetism and quantum theory - Weiss molecular exchange field -ferromagnetic domains - anti ferromagnetism – ferrites.

UNIT III

Superconductivity

Meissner effect - Type I and Type II superconductors - thermal properties - isotope effect - London equations - London penetration depth - coherence length BCS theory - flux quantisation - Josephson effect - applications of superconductors.

References

1. Charles. C. Kittel, Introduction to Solid State Physics, Wiley Student Edition, 2007.
2. M. A. Wahab, Solid State Physics, Narosa Publishing House, 1999.
3. N. W.Ashcroft and N. D. Merwin, Solid State Physics, Thomson Press (India) Ltd., 2003.
4. M. Ali Omar, Elementary Solid State Physics, Pearson Education Inc., (1999)
5. S. O. Pillai, Solid State Physics, 3rd Edn., New Age International Pvt. Ltd (1999)

NSP 523 SPECTROSCOPY

Unit I

Group theory

Definitions of a group - elementary properties - sub groups - homomorphism and isomorphism of groups - representation of groups - similarity transformation and classification of symmetry operations - matrix representation of point group - reducible and irreducible representations - character of a matrix - orthogonality theorem - rules derived from orthogonality theorem (proof not required) - setting up of character tables of simple groups such as C_{2V} and C_{3V} on the basis of rules - the four areas of the character table - reduction of reducible representations to irreducible representations - applications of character tables to spectroscopy - transition moment operators - application of character table to orbitals - construction of hybrid orbitals - symmetry adapted LCAO.

Unit II

Rotation of Molecules

The rotation of molecules – rotational spectra of diatomic molecules – rigid rotator - intensities of spectral lines – effect of isotopic substitution – non-rigid rotator - spectra of non-rigid rotator – rotational spectra of linear and symmetric top molecules.

Vibration of Molecules

Origin of infrared transitions - experimental techniques of IR spectroscopy - simple harmonic oscillator - anharmonic oscillator - diatomic vibration - rotation of diatomic molecules - selection rules – vibration-rotation spectrum of carbon monoxide - interaction of rotation and vibration - vibrations of polyatomic molecules – influence of rotation on the spectra of poly atomic molecules.

Raman Spectroscopy

Classical theory of Raman effect - experimental techniques - pure rotational Raman spectra - vibrational Raman spectra – rule of mutual exclusion - Raman spectrometer - structure determination from Raman and infrared spectroscopy.

Unit III

Electronic Spectra of Atoms

Quantum state of an electron system in an atom - electronic wave functions – shape of atomic orbitals - hydrogen atom spectrum - electronic angular momentum - orbital angular momentum - electron spin angular momentum - total electronic angular momentum – fine structure of hydrogen atom - Stern-Gerlach experiment - spin-orbit coupling - relativistic correction - spectroscopic terms – selection rules – exchange symmetry of wave functions - Pauli's exclusion principle - many electron atoms - building principle - spectra of Li and hydrogen like elements - L-S and j-j coupling schemes - total angular momentum – term symbols - spectra of helium - Zeeman effect – magnetic moment of atom - Launde's g factor - normal Zeeman effect - emitted frequencies in anomalous Zeeman transitions - nuclear spin and hyperfine structure.

Electronic Spectra of Diatomic Molecules

The Born-Oppenheimer approximation - vibrational coarse structure - Frank Condon principle - dissociation and pre dissociation - rotational fine structure of electronic-vibration transitions **-** Fortrat diagram - electronic structure of diatomic molecules - electronic angular momentum –molecular hydrogen spectrum.

NMR spectroscopy

Nuclear magnetic resonance spectra - basic principle - experimental techniques – idea of chemical shift and spin orbit coupling – applications.

ESR spectroscopy

Electron spin resonance spectra – basic principle- experimental techniques – idea of hyperfine structure – hydrogen - applications.

Mossbauer spectroscopy

Principle - applications – structural methods - quadrupole effects – effect of magnetic fields.

References

1. F. Albert Cotton, Chemical Applications of Group Theory, 3nd Ed., Wiley Interscience, 1990.
2. Colin N. Banwell and Elaine M Mac Coah, Fundamentals of Molecular Spectroscopy, 4th Edn. Ta,ta McGraw Hill, New Delhi, 2001.
3. B. Straughen and S.Walker, Spectroscopy Vol. I, Chapman and Hall Ltd., New Delhi, 1976.
4. H. E. White, Introduction to Atomic Spectroscopy, Mc Graw Hill Inc., 1st Edn., 1934.
5. G. Aruldhas, Molecular Structure and Spectroscopy, 2nd Rev. Edn., PHI, 2007.

NSP 524 INTRODUCTION TO NANOSCIENCE AND NANOTECHNOLOGY

UNIT I

Characteristic lengths of electrons in solids - nanoparticles - surface to volume ratio - grain boundary volume - surface energy - lattice contraction. Nanostructures - nanostructured materials – semiconductor nanoparticles - quantum confinement - artificial atoms - quantum dots, quantum wires and quantum wells – blue shift of band gap. Magic numbers - theoretical modelling of nanoparticles - geometric structure – electronic structure – reactivity. Biology on nanoscale - Nature's nanostructures – biological building blocks – sizes of building blocks and nanostructures.

Synthesis of nanomaterials - bottom-up and top-down approaches - metal nanoparticles – properties of individual nanoparticles – consequences of small particle size - increase of mechanical frequencies in small systems - dominance of viscous forces - disappearance of frictional forces. (Ref. 1– 4)

UNIT II

Effect of grain size on mechanical properties – mechanical properties of consolidated nanograined materials - nanoindentations - superplasticity – nanoceramics – nanopendulum – vibrations of a nanometer string – the nanospring.

Linear and non-linear optical properties of semiconductor quantum dots – photoluminescence of quantum dots - optical properties of metal nanoparticles – surface plasmon resonance (SPR) - size, shape and composition dependence of SPR - dephasing of SPR - non-radiative decay of the SPR - plasmon wave guiding.

(Ref. 1,2,5,6)

UNIT III

Vibrational properties – finite one-dimensional monatomic lattice – ionic solids – experimental observations – vibrational spectroscopy of surface layers of nanoparticles – phonon confinement – effect of dimension on lattice vibrations - effect of dimension on vibrational density of states – effect of size on Debye frequency – phase transitions – specific heats of nanocrystaline materials – melting points of nanoparticle materials. (Ref. 1,7)

References:

1. Frank J. Owens, Charles P.Poole Jr, The Physics and Chemistry of Nanosolids, John Wiley & Sons, 2008.
2. Dieter Vollath, Nanomaterials: An introduction to Synthesis, Properties, and Applications (second edition), Wiley-VCH, 2013.
3. Charles P. Poole Jr, Frank J. Owens, Introduction to Nanotechnology, Wiley India Edition, 2006.
4. Edward L. Wolf, Nanophysics and Nanotechnology – An Introduction to Modern Concepts in Nanoscience, Wiley – VCH, 2006.
5. A.S. Edelstein, R.C. Cammaratra, Nanomaterials: Synthesis, Properties and Applications (second edition), CRC Press, 1998.
6. V. I. Klimov (Ed.), Smiconductor and Metal Nanocrystals – Synthesis and Electronic and Optical properties, Marcel Dekker Inc., 2004
7. Kenneth J. Klabunde (Ed.), Nanoscale Materials In Chemistry, John Wiley & Sons, 2001.

NSP 525 NANOSCIENCE - LAB I

List of Experiments - Minimum 10 experiments to be done

(More number of experiments may be included in the list)

1. Analysis of given X-ray diffraction pattern.
2. X-ray diffraction – structure evaluation and identification of a material.
3. Interpretation of electron diffraction pattern (SAED pattern).
4. Determination of e/k
5. Determination of particle size of given material using He-Ne laser
6. Determination of Fermi energy of copper
7. Study of variation of resistance of a semiconductor with temperature
8. Hall effect in a semiconductor
9. Study of arc spectra
10. Study of hydrogen spectrum
11. Absorption spectrum of $KMnO_4$ solution

12. Interpretation of vibration spectra of simple molecules using Raman and IR spectra.
13. Study of dielectric constant
14. Measurement of resistivity of low and high resistivity semiconductors – four probe method
15. Photocurrent measurement in a semiconductor
16. Measurement of magnetoresistance of semiconductors
17. Magnetic susceptibility – Quinke's method
18. Determination of thickness of a film by envelope method and calculation of band gap using the given transmittance spectrum of the film.
19. Synthesis of silver nanoparticles by chemical reduction method and recording of UV-visible spectra – study of plasmon resonance.

NSP 531 SYNTHESIS AND FABRICATION OF NANOMATERIALS

UNIT I

Synthesis of zero-dimensional nanostructures - fundamentals of homogeneous nucleation - subsequent growth of nuclei - colloidal nanosynthesis - inorganic surface modification - shape control - phase transition and phase control - nanocrystal doping - synthesis of metallic (Au, Ag) nanoparticles - synthesis of semiconducting nanoparticles (CdSe, CdS) - synthesis of oxide nanoparticles - sol-gel method - synthesis of multicomponant nanostructures - fundamentals of heterogeneous nucleation - synthesis of nanoparticles.

Epitaxial core–shell nanoparticles – core-shell quantum dots - type I and type II core- shell quantum dots - quantum dot quantum wells.- sonochemical synthesis of nanoparticles – spray pyrolysis - electrospinning. (Ref. 1 – 3)

UNIT II

Synthesis of 1D nanostructures - spontaneous growth - vapour-liquid-solid growth - template based synthesis - electrochemical deposition - electrophoretic deposition - template filling – synthesis of GaN nanostructures – synthesis of ZnO nanowires and hetrostructures - GaP nanostructures.

Synthesis of 2D nanostructures - fundamentals of film growth – physical vapour deposition – sputtering - chemical vapour deposition - atomic layer deposition - self assembly – Lagmuir-Blodgett films.

Lithography techniques - optical lithography - electron beam lithography - focussed ion beam lithography - X-ray lithography. (Ref. 1, 4)

UNIT III

Nanomanipulation and nanolithography - manipulation by scanning tunnelling microscope - manipulation of atoms, molecules, and nanoclusters by scanning tunnelling microscope - manipulation of single atoms, single molecules and nanoclusters by atomic force microscope – nanolithography - soft lithography- micro contact printing, molding, nanoimprint - dip-pen nanolithography. (Ref. 1, 5)

References

1. Guozhong Cao, Nanostructures and Nanomaterials- Synthesis, properties and Applications, Imperial college press, 2004.
2. Victor I. Klimov (Ed.), Semiconductor and Metal Nanocrystals- Synthesis and Electronic and Optical properties, Marcel Dekker, Inc., 2004.
3. Challa Kumar (Ed.), Semiconductor Nanomaterials, Wiley-VCH, 2010.
4. S. C. Tjong, Nanocrystalline Materials – Their Synthesis- Structure, Property Relationships and Applications, Elsevier, 2006.
5. Ampere A Tseng (Ed.), Nanofabrication-Fundamentals and Application, World Scientific, 2008.

NSP 532 PHYSICS AND CHEMISTRY OF NANOSOLIDS

UNIT I

Low dimensional systems - density of states in semiconductor materials - quantum wells, quantum wires and quantum dots - lithographically defined quantum dots - epitaxially self-assembled quantum dots - colloidal quantum dots - weak confinement regime - strong confinement limit - quantum-chemical calculations for semiconductor clusters - exciton - dark exciton – quantum dot lasers.

Quantum wire devices - transport in one dimensional electron systems (1 DES)- ideal 1DES - semiconductor 1DESs - silicon 1DESs - semiconductor quantum dots as zero dimensional electron systems (0 DES). (Ref. 1-4)

UNIT II

Magnetism in nanostructures – characteristics of nanomgnetic materials - magnetic properties of single-domain particles – superparamagnetism – coercivity of small particles - measurements of superparamagnetism and blocking temperature –aniferromagnetic nanoparticles.

Electrical properties of semiconductor nanocrystals – theory of electron transfer between localized states – photoinduced charge transfer at nanoscale semiconductor interface – electrical conduction in bulk nanostructured - charge transport in nanocrystal films.

Superconductivity in nanomaterials – introduction – zero resistance – Meissner effect – dependence of superconducting properties on size effects – resistivity and sheet resistance – proximity effect – superconductors as nanomaterials – tunnelling and Josephson junctions – superconducting quantum interference device (SQUID). (Ref. 5 – 7)

UNIT III

Nanophotonics – foundations for nanophotonics – free-space propagation – confinement of photons and electrons – propagation through a classically forbidden zone – localization under a periodic potential – nanoscale optical interactions – near-field optics –theoretical modelling of near-field nanoscopic interactions – photonic crystals – basic concepts – theoretical modelling of photonic crystal – features of photonic crystals - methods of fabrication – photonic crystals and optical communication. (Ref. 8)

References

1. Omar Manasresh, Introduction to Nanomaterials and Devices, John Wiley and Sons, 2012.
2. Gunter Schmid (Ed.), Nanoparticles- From Theory to Application, Wiley-VCH, 2004.
3. S. V Gaponenko, Optical Properties of Semiconductor Nanocrystals, Cambridge University Press,1998.
4. Byung- Gook Park, Sung Woo Hwang, Young June Park, Nanoelectronic Devices, Pan Stanford Publishing, 2012 .
5. Kenneth J. Klabunde, Nanoscale Materials in Chemistry, John Wiley and Sons, 2001.
6. Victor I. Klimov (Ed.), Semiconductor and Metal Nanocrystals- Synthesis and Electronic and Optical properties, Marcel Dekker, Inc.,2004.
7. Frank J Owens, Charles P.Poole Jr., The Physics and Chemistry Nanosolids, John Wiley and Sons, 2008.
8. Paras N Prasad, Nanophotonics, Wiley- Interscience, 2004.

NSP 533 NANOELECTRONICS

UNIT I

Nanoscale electronics – Moore's law - limits of microminiaturization in silicon – scaling - milestones of silicon technology – estimation of technology limits – introduction to nanoscale electronics – three-dimentional nanostructures – two-dimensional nanostructures – one-dimensional nanostructures – MOSFET scaling trend

– MOSFET scaling theory - dopant number fluctuation - scaling limits of charge based devices - examples of quantum electronic devices - short-channel MOS transistor - electronic devices based on nanostructures- MODFETs- heterojunction bipolar transistors - resonant tunnel effect - tunneling diode- resonant tunneling diode - hot electron transistors - resonant tunneling transistor. (Ref. 1 – 4)

UNIT II

Single electron tunnelling - Coulomb blockade- single electron transistor (SET) - performance of SET - fabrication of SET - operation of single electron transistors - mesoscopic arrays with nanoelectrodes - from single particle properties to collective charge transport - one, two and three dimensional arrangement of particles - logic circuits with single electron transistors- bias conditions for SETs - design scheme for SET logic circuits.

Carbon nanostructures – fullerene – graphene – carbon nanotubes (CNTs) – synthesis of carbon nanotubes – functionalization - doped carbon nanotubes - geometrical structure - electronic structure of graphene - electronic structure of CNT - metallic and semiconducting CNTs - electron transport in CNTs – operation and performance of CNFETs - CNT circuits - scaling of CNFETs to the sub-10 nanometer regime – prospects of an all-CNT nanoelectronics. (Ref. 1, 5 – 8)

UNIT III

Spintronics – spin-diffusion length - spin dependent resistivity in transition metal alloys - giant magnetoresistance (GMR) – Mott's two-current model – experiments on GMR - GMR spin valve - spin injection - spin injection into a non-magnetic conductor - spin injection in semiconductors - magnetic random access memory (MRAM) - silicon-based spin transistor - design and fabrication - electrical characterization – spin-FETs – spin-MOSFETs. (Ref. 8 – 11)

References

1. K. Goser, P. Glosekotter, J. Dienstuhl, Nanoelectronics and Nanosystems: From Transistors to Molecular and Quantum Devices, Springer, 2004.
2. Seng Ghee Tan , Mansoor B. A. Jalil, Introduction to the Physics of Nanoelectronics, Woodhead Publishing Limited, 2012.
3. Byung- Gook Park, Sung Woo Hwang, Young June Park, Nanoelectronic Devices, Pan Stanford Publishing, 2012.
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5. Gunter Schmid (Ed.), Nanoparticles – From Theory to Application, Wiley-VCH, 2004.
6. Rainer Waser (Ed.), Nanoelectronics and Information Technology- Advanced Electronic Materials and Novel Devices (2nd Corrected Ed.), Wiley- VCH, 2005.
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10. Thomas Heinzel, Mesoscopic Electronics in Solid State Nanostructures, 2nd Ed., Wiley-VCH, 2007.
11. Y.B Xu and S.M Thompson (Eds), Spintronic Materials and Technology, Taylor & Francis, 2007.

NSP 534 CHARACTERIZATION TECHNIQUES FOR NANOMATERIALS

Unit I

X-ray diffraction – X-ray diffractometer – determination of crystal structure – determination of particle size - identification of materials.

Spectroscopic methods - UV-Visible, infrared and Raman spectroscopy, photoluminescence spectroscopy – principle - instrumentation – recording and interpretation of the spectra.

Unit II

Electron spectroscopy - X-ray photoelectron spectroscopy (XPS), ultra-violet photoelectron spectroscopy (UPS) - Auger electron spectroscopy (AES) - X-ray fluorescence spectroscopy

Microscopy - optical microscopy - electron microscopy – transmission electron microscopy (TEM) – high resolution transmission electron microscopy (HRTEM) - scanning electron microscopy (SEM) – micro analysis - EDS and WDS - scanning probe microscopy - scanning tunneling microscopy (STM) – atomic force microscopy AFM)

Unit III

Thermal analysis- TGA, DTA, DSC. VSM and SQUID magnetic measurements - electrical conductivity - two probe and four probe methods - dynamic light scattering techniques – BET technique.

References

1. S. Zhang, Lin Li, A. Kumar, Materials Characterisation Techniques, CRC press, 2008.
2. Y. Leng, Materials Characterisation: Introduction to Microscopic and Spectroscopic Methods, John Wiley & Sons (Asia), 2008.
3. D.A. Skoog, F.J. Holler, S. R. Crouch, Instrumental Analysis, Cengage Learning, 2007.
4. W. W. Wendlandt, Thermal Methods of Analysis, John Wiley, 1974.
5. D. B. Williams and C. B. Carter, Transmission Electron Microscopy, Vol. I-III, Springer, 1996.

NSP 53E1 COMPUTATIONAL METHODS

UNIT I

Non-linear algebraic equations - bisection method - iteration method - convergence criterion - acceleration of convergence- Aitken’s (delta) 2 process - method of false position - Newton-Raphson method - generalised Newton’s method – Lin-Bairstow method - solution of non-linear equations.

Eigen values and eigenvectors - determinant of a matrix - eigen value problem - largest and smallest eigen values - House Holder’s method - eigen values of a symmetric tri-diagonal matrix - QR method - singular values of decomposition.

UNIT II

Interpolation - finite differences – forward, backward and central differences - differences of a polynomial - Newton’s formula for interpolation - central difference interpolation formulae - Gauss’s central difference formulae - Stirling’s formula- Bessel’s formula - Everette’s formula - interpolation of unevenly spaced points – Lagrange’s interpolation formula - divided differences and Newton’s general interpolation formula - Interpolation with Cubic splines.

Curve fitting - least square curve fitting procedure - fitting a straight line – non-linear curve fitting - curve fitting by sum of exponentials - weighted least square approximation - linear and non-linear - methods of least squares for continuous functions.

UNIT III

Numerical differentiation - derivation of numerical differentiation formula from Newton's difference formulae - cubic spline method.

Numerical integration Trapezoidal rule - Simpson's 1/3 rule - Simpson 3/8 rule - use of cubic splines - Newton - Cotes integration formula - numerical calculation of Fourier integrals - Trapezoidal rule - Filon's formula - Monte Carlo Method – applications - numerical integration - Monte Carlo summation.

Solution of ordinary differential equations - solution by Taylor's series - Picaid's method of successive approximations - Euler's method - modified Euler s method - Runge- Kutta method.

References

1. S. S, Sastry, Introductory methods of Numerical Analysis, 3 Ed., Prentice Hail India Pvt Ltd., 2000.
2. D. V. Griffiths and I. M. Smith, Numerical methods for Engineers, Oxford University Press, 1993.
3. Samuel D Conte and Carl de Boor., Elementary Numerical analysis, 3rd Ed., Mc-Graw Hill International Ed.
4. E. V. Krishnamoorthy and S. K. Sen, Numerical Algorithms, Affiliated East West Press Pvt Ltd., 1986.

NSP 53E2 THERMODYNAMICS AND STATISTICAL MECHANICS

Unit I

Thermodynamics

First and second laws of thermodynamics - Thermodynamic criteria for equilibrium and spontaneity -The third law of thermodynamics - Need for the third law - Nernst heat theorem - Apparent exception to third law - Applications of third law - Thermodynamics of irreversible processes: Simple examples of irreversible processes - General theory of nonequilibrium processes - Entropy production - The phenomenological relations - Onsager reciprocal relations - Application to the theory of diffusion, thermal diffusion, thermoosmosis and thermomolecular pressure difference - Electrokinetic effects - The Glansdorf-Pregogine equation.

Unit II

Phase transitions

Triple point-Van der Waals equation equation and phase transitions-first and second order phase transitions-Ehrenfest's equations-Ising model-Yang and Lee theory of phase transitions-London theory of phase transitions (Chapter 12 of Satyparakash)

Unit III

Foundations of classical andstatistical physics Phase space-ensembles-Lioville's theorem-statistical equilibrium-microcanonical ensemble-partition functions and thermodynamic quantities-Gibb's paradox-Maxwell-Boltzmann distribution laws-grand canonical ensemble (Chapter 6 and 7 of Satyparakash)

Quantum statistics

Quantum statistics of classical particles-density matrix in microcaonical,canonical and grand canonical ensembles-Bose Einstein statistics and Bose Einstein distribution law-Maxwell Boltzmann statistics and Maxwell Boltzmann distribution law—Fermi Dirac statistics and Fermi Dirac distribution law-comparison of three types of statistics, applications of quantum statistics-Planck radiation laws-Bose Einstein gas and Bose Einstein condensation—Fermi Dirac gas-electron gas in metals-thermionic emission ,statistical theory of white dwarfs.(Chapter 8 of Satyaprakash)

References

1. Satyaprakash, StatisticalMechanics, Kedarnath Ram Nath Publishers, Meerut and Delhi (2009)
2. B. K. Agarwal and HariPrakash,QuantumMechanics, Prentice Hall of India (2002)
3. S. Devanarayanan, Quantum Mechanics, Sci Tech Publications (India) Pvt. Ltd (2005)
4. D. J. Griffiths, Introduction to Quantum Mechanics, Second Edition, Pearson Education Inc(2005)
5. G. Aruldas, Quantum Mechanics, 2nd Edition, PHI learning Pvt Ltd (2009).

NSP 53E3 ADVANCED QUANTUM MECHANICS

Unit I

Angular momentum - orbital angular momentum – commutation relations – angular momentum as the generator of infinitesimal rotations – eigen values and eigen functions of L^2 and L_z – the rigid rotator. General angular momentum – spectrum of J^2 and J_z – matrix representation of angular momentum operators - spin angular momentum – evidences of electron spin – Stern-Gerlach experiment – Pauli's theory of electron spin – properties of Pauli matrices – electronic states in a central field. Addition of angular momenta – Clebsch-Gordan coefficients and their evaluation – spin states of two particles of spin 1/2.

Time–dependant perturbation theory - Harmonic perturbation – transition probability - transition to continuum states – transition probability per unit time – Fermi's golden rule. Interaction with classical radiation field – absorption and stimulated emission – electric dipole approximation - Einstein's A and B coefficients - selection rule for emission and absorption of light radiation - sudden and adiabatic approximation.

Unit II

Collision Theory - elastic scattering – differential and total scattering cross-sections - scattering amplitude - method of partial waves – expansion of a plane wave in terms of partial waves – scattering by a central potential – phase shift – optical theorem - scattering by a hard sphere - low energy scattering – s-wave scattering by a square well - Ramsauer-Townsend effect - scattering of neutrons by protons - resonance scattering – Briet-Wigner formula. Zero energy scattering – scattering length. Green's function technique of solving inhomogeneous differential equation – first Born approximation - validity of Born approximation. Applications - scattering amplitude in the case of spherically symmetric potential - screened Coulomb potential leading to Rutherford scattering formula.

Many electron atoms - identical particles – indistinguishability and exchange symmetry – Fermion and Boson assemblies. Symmetric and anti-symmetric wave functions – construction from unsymmetrized functions - exclusion principle – Slater determinant. Spin angular momentum – spin matrices and Eigen functions – spin functions for two electrons - Helium atom - spin functions for three electrons - the He atom. Central field approximation – Hartree-Fock equation – direct term and exchange term.

Unit III

Relativistic wave equations - Schrödinger relativistic theory and it's failures - Dirac's relativistic equation – free-particle equation - position probability density - expectation values - matrices for á and â - free-particle solutions and energy spectrum – existence of states with negative energy - spin of the Dirac particle - significance of negative energy states – Dirac particle in electromagnetic fields - spin-orbit interaction - Dirac's equation for a Central field – the Hydrogen atom - Lamb shift. Relativistic co-variance – covariance of the Dirac equation – Zitterbewegung theory of positron.

Elements of Field Quantization – quantization of the non-relativistic Schrödinger equation – systems of bosons and fermions. Relativistic fields – quantization of the electro-magnetic field.

References

1. Leonard I. Schiff, Quantum Mechanics, McGraw Hill, 2010.
2. A. Ghatak, Introduction to Quantum Mechanics, Macmillan, 1996.
3. P. M. Mathews and K. Venkatesan, A text book of quantum mechanics, 2nd Edn., TMH, 2010.
4. G. Aruldhas, Quantum Mechanics, 2nd Edn., PHI Learning Pvt Ltd, 2009.

NSP 54E1 NANOTECHNOLOGY AND ENERGY APPLICATIONS

UNIT I

Introduction to solar energy conversion - sun as an energy source - generation of photovoltaic solar cells - solar cells based on single pn junctions - silicon crystalline cells - basic mechanisms in solar cells – current-voltage characteristics of pn junction - limitations of energy conversion in solar cells - maximum efficiency of solar cells - concepts for improving the efficiency of solar cells - tandem cells

Thin film solar cells - first generation thin film solar cells - amorphous silicon alloy solar cells - CdTe based thin film solar cells - CIS based thin film solar cells - next generation thin flm solar cells - thin film silicon, microcrystalline-silicon, GaAs - organic solar cells - high efficiency thin film solar cells. (ref. 1- 3)

UNIT II

Nanocrystalline solar cells – dye sensitization bulk semiconductors - dye sensitised solar cells (DSSCs) – electron transfer steps, efficiency parameters and preparation of DSSC – working principle of nanostructured solar cells – quantum dot solar cells – nanocrystalline dye sensitized solar cells – cell operation – materials – issues regarding cell operation.

Nanoscale conversion materials for electrochemical energy storage – current electrode materials – conversion electrodes – anode materials – metal-air batteries – Li-air batteries – Mg-air battery – Li-ion batteries – transition metal oxides as electrode materials – SnO_2 electrodes – cathode materials – sulfides – fluorides – solid state reactions in conversion electrodes – size and interface effects. Graphene nanosheets for supercapacitors – grapheme nanosheets for Li-ion battery – carbon nanotubes/conducting polymers composites for capacitor – carbon nanotubes/metal oxides composites for capacitor. (Ref. 4 – 7)

UNIT III

Fuel cells – introduction - fuel cell performance parameters - operational parameters - nanomaterials for fuel cell technologies – low temperature fuel cells - cathode reaction – anodic reaction – practical fuel cell catalyst – electrolytes – membrane electrode assembly – high temperature fuel cells. (Ref. 8, 9)

References

1. Edward L. Wolf, Nanophysics of Solar and Renewable Energy, Wiley-VCH, 2012
2. Peter Wurfel, Physics of Solar Cells: From Basic Principles to Advanced Concepts (2nd, updated & expanded edition), Wiley-VCH, 2009.
3. Y. Hamakawa (Ed.), Thin-Film Solar Cells: Next Generation Photovoltaics and its Applications, Springer, 2004
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5. Rafael Luque, Rajender S Varma (Eds.), Sustainable Preparation of Metal Nanoparticles: Methods and Applications, RSC publishing, 2013
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7. S. R. S. Prabaharan and M. S. Michael, Eds., Nanotechnology in Advanced Electrochemical power sources, Pan Stanford Publishing, 2015.
8. Alessandro Lavacchi, Hamish Miller, Francesco Vizza, Nanotechnology in Electrocatalysis for Energy, Springer, 2013
9. J. G. Martinez (Ed.), Nanotechnology for the Energy Challenge, Wiley-VCH, 2010.

NSP 54E2 ADVANCED NANOTECHNOLOGY

UNIT I

Carbon-based nanomaterials for electrochemical energy storage – principle of a supercapacitor – carbons for electric double layer capacitors – carbon-based materials for pseudo-capacitors – lithium-ion batteries – anodes based on nanostructured carbons – anodes based on Si/C composites – origins of irreversible capacity of carbon anodes.

Nanotechnology for carbon dioxide capture – CO_2 capture processes – nanotechnology for CO_2 capture – porous coordination polymers (PCPs) for CO_2 capture – molecular modeling of CO_2 adsorption on PCPs. (Ref. 1)

UNIT II

Nanostructured organic light emitting devices – organic-light emitting diodes (OLEDs) and polymer-based light emitting diodes (PLEDs) – quantum confinement and charge balance for OLEDs and PLEDs – multilayer structured OLEDs and PLEDs – charge balance in a polymer blended system – phosphorescent materials for OLEDs and PLEDs – enhancement of light out-coupling –

Hydrogen generation and storage - efficient photocatalytic dissociation of water into hydrogen and oxygen – hydrogen production by semiconductor nanomaterials – need for nanomaterials – nanomaterials based photoelectrochemical cells for H_2 production – application of nanotubes and nanodisks - nanostructured materials for hydrogen storage – hydrogen storage by physisorption - hydrogen storage by chemisorptions. (Ref. 1)

UNIT III

Nanoscale technology in biological systems – learning from nature – DNA nanotechnology – nanoparticles for biological assays - core-shell nanoparticles for drug delivery and molecular imaging – therapeutic applications of nanoparticles – application of nanoparticles for noncancer applications – physiological and uptake of particles – nanoparticles and hyperthermic cancer therapeutics – nanoparticles and thermal ablation - targeting nanoparticles to specific sites for tumor ablation – in vivo anticancer platform delivery - superparamagnetic nanoparticles of iron oxides for MRI applications. (Ref. 2 – 4)

References

1. J. G. Martinez (Ed.), Nanotechnology for the Energy Challenge, Wiley-VCH, 2010.
2. Ralph S. Greco, Fritz B. Prinz, R. Lane Smith (Eds.), Nanoscale Technology in Biological Systems, CRC Press, 2005.
3. Chella Kumar (Ed.), Nanomaterials for Medical Diagnosis and Therapy, Wiley-VCH, 2007
4. Rob Burgess, Understanding Nanomeducine – an Introductory Text Book, Pan StanfordPublishing, 2012

NSP 54E3 ADVANCED MATERIALS AND DEVICES

Unit I

Nanosilicon - structure of crystalline silicon – electrical properties of silicon – amorphous silicon – model of the amorphous state – electronic structure of the amorphous state – silicon clusters – silicon nanocrystals – luminescence of silicon nanoparticles – effect of hydrogen passivation of silicon nanoparticles – effect of surface oxygen – production of porous silicon – structural characteristics of porous silicon – luminescence of porous silicon – physical methods of producing nanosilicon – ion implantation of silicon in SiO_2 – laser ablation of crystalline silicon– applications of nanosilicon in solar energy – silicon solar cell – improving the efficiency of solar cells with nanocrystal silicon - photovoltaic windows. (Ref. 1)

Unit II

Optoelectronic devices - optical sources – LEDs, Device configuration and efficiency – LED structures – Heterojunction -LED, surface emitting LED, edge emitting LED, Junction Laser,- Operating principle – Heterojunction Laser-Photodetectors, photoconductors, Pin photo diode, heterojunction diodes, avalanche - photodiodes, basic idea of photo transistors

Nano-microelectromechanical systems (NEMS/MEMS) – MEMS fabrication techniques – NEMS fabrication techniques – NEMS/MEMS motion dynamics – MEMS devices and applications – NEMS devices and applications. (Ref. 2, 3)

Unit III

Molecular electronics - Scope of molecular electronics – molecular scale electronics – biological world – materials foundations – bonding in organic compounds - crystalline and nanocrystalline materials — polymers – polymer structure and crystallinity – liquid crystal phases - liquid crystal displays – organic diodes and field effect transistors – integrated organic circuits – organic light emitting displays – molecular scale electronics – molecular device architecture – molecular rectification – electronic switching and memory devices – resistive bistable devices – flash memories – three dimensional architecture – optical and chemical switches – quantum computing. (Ref. 4)

References

1. A.A. Ischenko, G.V. Fetisov and L.A. Aslanov, Nanosilicon – Properties, Synthesis, Applications, Methods of Analysis and Control, CRC Press, 2015.
2. Pallabh Bhattacharya, Semiconductor Optoelectronic Devices, PHI 1995
3. G. L.Hornyak, H. F. Tibbals, J. Dutta and J. J. Moore, Introduction to Nanoscience and Nanotechnology, CRC Press, 2009
4. Michael C Petty, Molecular Electronics- From Principles to Practice, Wiley, 2007.

NSP 54E4 NANOOPTOELECTONIC DEVICES AND SENSORS

Unit I

Fabrication of quantum dots (QDs) for nanophotonic devices – fabrication of self-assembled QDs – shortening emission wavelengths of self-assembled QDs – controlling the density of self-assembled QDs – fabrication of ultrahigh density QDs –nanopositioning technique for quantum structures with dioxide mask – artificially prepared nanoholes for arrayed QD structure fabrication –fabrication technique of Si nanoparticles as Si-QD structures.

Nanomaterials processing for device manufacturing –classification of CNTs using microfluidics – dielectrophoretic phenomenon on CNTs – separation of semiconducting CNTs – deposition of CNTs by microrobotic workstation - carbon nanotube schottky photodiodes – review of CNT photodiodes – design of CNT Schottky photodiodes – symmetric and asymmetric Schottky photodiodes . (Ref. 1, 2)

Unit II

Nanophotonics recording device for high-density storage – thermally assisted magnetic recording simulation – the ‘Nanobeak’, a near-field optical probe – bit patterned medium with magnetic nanodots – near-field optical efficiency in hybrid recording.

CNT field-effect transistor based photodetectors – back gate CNTFET – back gate Au-CNT-Au transistor - back gate Ag-CNT-Ag transistor - back gate Au-CNT-Ag transistor - middle gate transistors – multi gate transistors – detector array using CNT-based transistors.

Optical sensors using grapheme – fabrication of grapheme-based devices – electrical and optical behaviors of various graphene-based devices. Nanoantennas on nanowire - based optical sensors – nanoantenna design consideration for IR sensors – nanoantenna near-field effect – fabrication of nanosensor combined with nanoantenna – photocurrent measurement of nanosensor combined with nanoantenna. (Ref. 1, 2)

Unit III

Quantum dot nanophotonic waveguides – conceptual formation and modeling of the device – QD gain Vs pump probe – FDTD modeling for interdot coupling – monte carlo simulation for transmission efficiency – fabrication of QD waveguides – DNA directed self-assembled fabrication – programmable DNA directed self-assembly – self assembly through APTES – multiple QD type waveguide fabrication.

Design of photonic crystal waveguides – photonic bandgap of photonic crystals – photonic crystal cavity – basic design of photonic crystal defect – defect from dielectric constants and dielectric size – effect from lattice number – photoresponses of CNT-based IR sensors with photonic crystal cavities – photocurrent mapping of the CNT-based IR sensors with photonic crystal cavities. (Ref. 1, 2)

References

1. Motoichi Ohtsu (Ed.), Nanophotonics and Nanofabrication, Wiley-VCH, 2009.
2. Ning Xi, King Wai Chiu Lai (Eds.), Nanooptoelectronic Sensors and Devices – Nanophotonics from Design to Manufacturing, Elsevier, 2012.

NSP 543 NANOSCIENCE - LAB II

List of Experiments - Minimum 8 experiments to be done

(More number of experiments may be included in the list)

1. X-ray diffraction of nanoparticles – identification, particle size and strain determination.
2. X-ray diffraction – study of effects of doping.
3. Synthesis of ZnS quantum dots and determination of size using Scherrer's equation.
4. Synthesis of semiconductor nanoparticles and study of blue shift.
5. Synthesis of ZnO nanoparticles of two different sizes and determination of band gap.
6. Synthesis of nanoparticles by soil-gel method and determination of structure and size of the particles.
7. Synthesis of silver nanoparticles by polyol method and study of surface plasmon resonance.
8. Synthesis of rod-like silver nanoparticles and recording of UV-Vis spectra – study of plasmon resonance
9. Doping of silica glass with silver nanoparticles by ion exchange method and study of surface Plasmon resonance.
10. Synthesis of metal oxide nanoparticles by high energy ball milling and determination of their structure and particle size.
11. Synthesis of nanostructured CuO films by oxidation of given nanostructured Cu films and determination of band gap and its resistivity at different temperatures.
12. Deposition of nanostructured semiconductor film by spray pyrolysis and determination of its structure and band gap.
13. Study of electrochemical properties of semiconductor nanoparticles using cyclic voltametry.
14. Photoluminescence spectra of semiconductor nanopaticles – study of energy levels.
15. Preparation of nanostructured films using the given nanoparticles and determination of structure.
16. I – V characteristic of a DSSC
17. Study of photocatalytic activity of semiconducting oxide nanoparticles.

UNIVERSITY OF KERALA
CENTRE FOR NANOSCIENCE AND NANOTECHNOLOGY
M. Sc NANOSCIENCE

Time : 3 Hours **Max. Marks : 60**

Part A

Answer any *FOUR* questions. Each question carries 3 marks.

1.

2.

4.

5.

6. **(3 x 4 = 12 marks)**

Part B

Answer *ALL* questions. Each question carries 10 marks.

7 A (i)

(ii)

OR

7B (i)

(ii)

8A (i)

(ii)

OR

8B (i)

(ii)

9A (i)

(ii)

OR

9B (i)

(ii)

(10 x 3 = 30 marks)

Part C

Answer any *THREE* questions. Each question carries 6 marks.

10.

11.

12.

13.

14.

15. **(6 x 3 = 18 marks)**

Model Question Paper (For courses NSP 524 to NSP 534 and NSP 54E1 to NSP 54E4)

UNIVERSITY OF KERALA

CENTRE FOR NANOSCIENCE AND NANOTECHNOLOGY

M. Sc NANOSCIENCE

Time : 3 Hours **Max. Marks : 60**

Part A

Answer any *EIGHT* questions. Each question carries 3 marks.

1.

2.

4.

5.

6.

7.

8.

9.

10.

11.

12. **(3 x 8 = 24 marks)**

Part B

Answer *ALL* questions. Each question carries 12 marks.

13 A (i)

(ii)

OR

13 B (i)

(ii)

14 A (i)

(ii)

OR

14 B (i)

(ii)

15 A (i)

(ii)

OR

15 B (i)

(ii)

(12 x 3 = 36 marks)

* * *

Appendix IV

UNIVERSITY OF KERALA

CENTRE FOR NANOSCIENCE AND NANOTECHNOLOGY

M. Sc PROGRAMME IN NANOSCIENCE

Regulation, Scheme and Syllabus

(The Regulation for the M. Sc course in Nanoscience will be the same as that forthe existing M. Sc courses in the Departments of the University of Kerala)

Eligibility for admission : B. Sc degree in Physics of University of Kerala or equivalent degree from a recognized University/Institute.

With effect from 2016 Admission

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