CENTRE FOR NANO SCIENCE AND TECHNOLOGY
INSTITUTE OF SCIENCE AND TECHNOLOGY
M.Sc (NANO TECHNOLOGY)
COURSE STRUCTURE w.e.f. 2010-2011

FIRST SEMESTER
Scheme of Instruction and Examination

Course No.	Name of the course	Periods per week			Maximum marks			Credits
		Lec	Lab	Total	Ext	Int	Total	
NT - 101	**Applied Mathematics and Numerical Methods**	4	-	4	60	40	100	8
NT - 102	**Elements of Solid State Physics**	4	-	4	60	40	100	8
NT - 103	**Introduction to Quantum Mechanics and Nanotechnology**	4	-	4.	60	40	100	8
NT - 104	**Introduction to Nanoscience & Technology**	4	-	4	60	40	100	8
NT- 105	**Fundamentals of Bioscience**	4	-	4	60	40	100	8
NT - 106	**Synthesis and Characterization Lab**	-	4	4	60	40	100	8
NT - 107	**Simulation Lab-I**	-	4	4	60	40	100	8
	Total	20	8	28	420	280	700	56

SECOND SEMESTER
Scheme of Instruction and Examination

Course No.	Name of the course	Periods per week			Maximum marks			Credits
		Lec	Lab	Total	Ext	Int	Total	
NT - 201	**Science and Technology of Thin Films**	4	-	4	60	40	100	8
NT - 202	**Synthesis of Nanomaterials**	4	-	4	60	40	100	8
NT - 203	**Physico Chemical effects of Nanomaterials**	4	-	4	60	40	100	8
NT - 204	**Nanoelectronics**	4	-	4	60	40	100	8
NT- 205	**Biomedical Applications of Nanotechnology**	4	-	4	60	40	100	8
NT - 206	**Fabrication and Characterization Lab**	-	4	4	60	40	100	8
NT - 207	**Simulation Lab-II**	-	4	4	60	40	100	8
	Total	20	8	28	420	280	700	56

THIRD SEMESTER
Scheme of Instruction and Examination

Course No.	Name of the course	Periods per week			Maximum marks			Credits
		Lec	Lab	Total	Ext	Int	Total	
NT - 301	**Advanced Nanomaterials Characterization**	4	-	4	60	40	100	8
NT - 302	**Synthesis and Characterization of Carbon Nano Tubes Application**	4	-	4	60	40	100	8
NT - 303	**Nanocomposites Synthesis Design and Applications**	4	-	4	60	40	100	8
NT - 304	**MEMS/NEMS Design and Applications**	4	-	4	60	40	100	8
NT-305	**Environmental Issues And Ethics**	4	-	4	60	40	100	8
NT - 306	**Fabrication and Characterization Lab**	-	4	4	60	40	100	8
NT - 307	**Simulation Lab-II**	-	4	4	60	40	100	8
	Total	20	8	28	420	280	700	56

FOURTH SEMESTER
Scheme of Instruction and Examination

Course No.	Name of the course	Period	Max. marks		
			Exam	Sess.	Total
NTT – 401	**Seminar**	One Month	Internal	100	100
NTT – 402	**Project**	Two Semesters	Excellent/Good /Satisfactory/ Not Satisfactory	-	-

CENTRE FOR NANO SCIENCE AND TECHNOLOGY
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SEMESTER – 1

NS-101 APPLIED MATHEMATICS AND NUMERICAL METHODS

UNIT 1: Algebra

Sequences – series – convergence and divergence- ratio test – comparison test – integral test – Cauchy's root test – raabe's theorem – Lagrange's mean value theorem – Cauchy's mean value theorem – generalized mean value theorem (Taylor's theorem)

UNIT 2: Functions of Variables

Functions of several variables – limit and continuity – partial differentiation – chain rule – total derivative – eulers theorem, jacobian – functional dependence, Maxima and minima of functions of two variables with and without constraints.

UNIT 3: Differential Equations

Differential equations of first order and first degree formation, Exact linear applications to Newton's law of cooling law of natural growth and decay, orthogonal trajectories, non homogeneous linear differential equations of second and higher order with constant coefficients with RHS term of the type e^{ax}, sin ax, cos ax, polynomial in x, e^{ax} v(x), xv(x) method of variation of parameters.

UNIT 4: Laplace Transforms

Laplace transform of standard functions – inverse transform linearity – first shifting theorem. Transforms of derivative and integrals – unit step function – second shifting theorem. Dirac's delta function – differentiation and integration transforms – multiple integrals , double and triple integrals – change variables – change of order of integration.

UNIT 5: Vector Differential Calculus

Vector differential calculus: gradient, divergence, curl and their related properties, sums, products, laplacian and second order operators. Vector integral calculus: vector integration – line integral, work done – potential function – area, surface and volume integrals, applications of green's theorem stoke's and gauss divergence theorem.

Text Books:

1.A text book of engineering mathematics, volume 2002 t.k.iyengar, b.krishna Gandhi, and others, chand and company
2.Engineering mathematics, b.v.ramana, tata mc graw hill 2002
3.Engineering mathematics, c.sankraiah, vijaya publications 2002
4.Engineering mathematics, 2002, p.nageswara rao, y.nageswara rao, y.narsimhulu, prabhakara rao

NS-102 ELEMENTS OF SOLID STATE PHYSICS

Unit 1: Crystal Structure
Crystalline and amorphous solids, Crystal lattice and crystal structure, Translational symmetry-space lattice, unit cell and primitive cell, symmetry elements in crystal, the seven crystal systems, some imperfections in crystals, cells-Miller indices,Miller-bravais indices, Indices of a lattice direction, The spacing of a set of crystal planes.

Unit 2: Reciprocal Lattice and Crystal Imperfections
Bragg law- Reciprocal lattice – Properties of Reciprocal lattice- Reciprocal lattice of simple cube- Reciprocal lattice of BCC- Reciprocal lattice of FCC- diffraction conditions- Brillouion zones. Importance of lattice imperfections- types of imperfection-Point defects-dislocations.

Unit 3: Bonding in Solids
Introduction-General nature of cohesion between two atoms in a solid-ionic bond, covalent bond –metallic bond-Vander walls, London interaction and Lennard Jones potential.

Unit 4: Lattice Vibration
Phonons–experimental determination of dispersion relation, dynamics of linear chain of identical atoms, vibrations of a one–dimensional lattice with a basis-phonon process, phonon density states.

Unit 5: **Thermal Properties**
The Debye model, thermal properties of solids, Einstein's theory of specific heat, Debye's theory of lattice heat capacity.

Text Books:

1. An introduction to solid states electronic devices by Ajay kumar saxena Macmillan India Ltd
2. Solid state Physics by Kittel

Reference Books:
1. Introduction to Nanotechnology by Charles P.Poole Jr & Frank J. Owens; Wiley India Pvt. Ltd
2. The Feynman lectures on Physics; Vol I to III
3. Nano Technology and Nano Electronics – Materials, devices and measurement Techniques by WR Fahrner – Springer
4. Nano Technology – science, innovation and opportunity by Lynn E Foster; Prentice Hall -Pearson education.
5. Hand book of Nano structured materials, Vol I to V

NS-103 INTRODUCTION TO QUANTUM MECHANICS AND NANOTECHNOLOGY

Unit 1: Introduction

Why quantum mechanics, matter waves, length scales, De-Broglie hypothesis, wave particle duality, Heisenberg's uncertainty principle,Bohr corresponding principal.

Unit 2: **General postulates of Quantum Mechanics**

Probability density (postulate-I), relation between ψ and Φ (postulate-II), operator and expectation values (postulate-III and IV), Schrodinger equation (postulate-V).

Unit 3: **One Dimensional Barrier**

Free particles, the concept of potential, boundary conditions, potential step, square potential barriers.

Unit 4: Quantum Mechanics of Electronics

Electron as particle and electron as wave, Time independent Schrodinger equation and boundary contestation on the wave function, Analogies between quantum mechanics and classical electromagnetic, Probabilistic current density, multiple particle systems.

Unit 5: Free and Confined Electrons

Free electrons, the free electron gas theory of metals, electrons confined to abounded region of space and quantum numbers, electrons confined to atom, the hydrogen atom and the periodic table, quantum dots, wires, wells.

Text Books:

1. P.M.Mathews and K.Venkatesan, "A textbook of Quantum Mechanics", Tata McGraw Hill Publishing Company Ltd {Unit- I to III}
2. Quantum Mechanics – Schiff {Unit- I to III}
3. Quantum Mechanics by B.k.Agarwal and Hariprakash ,PHI{Unit- I to III}
4. Fundamentals of nanoelectronics by George W.Hanson Pearson education { Unit-IV,V}

Reference Books:

1. Introduction to Nanotechnology by Charles P.Poole Jr & Frank J. Owens, Wiley India Pvt. Ltd
2. The Feynman lectures on Physics; Vol I to III
3. Quantum mechanics by Brandsen & Joachem
4. Nano Terchnology and Nano Electronics – Materials, devices and measurement Techniques by WR Fahrner – Springer
5. Hand book of Nano structured materials; Vol I to V
6. Quantum Mechanics:- Pawling & Wilson
7. Quantum physics by A.Ghatak

NS-104 INTRODUCTIONS TO NANOSCIENCE & TECHNOLOGY

Unit 1: Background of Nanotechnology
Scientific Revolutions, Nanotechnology and Nanomachines,The Periodic Table, Atomic Structure, Molecules and Phases, Energy, Molecular and Atomic size, Surfaces and Dimensional Space, Top down and Bottom up approach.

Unit 2: Molecular Nanotechnology
Atoms by inference, Electron Microscopes, Scanning electron microscope, Modern transmission electron microscope, Scanning probe microscope-atomic force microscope, Scanning tunneling microscope, Self Assembly.

Unit 3: Nanopowders and Nanomaterials
What are nanomaterials? Preparation, Plasma arcing, chemical vapor deposition, Sol-gels, Electrodeposition, Ball milling, using natural nanoparticles, Applications of nanomaterials.

Unit 4: Nanoelectronics
Approaches to nanoelectronics, Fabrication of integrated circuits, MEMS, NEMS, Nano circuits, Quantum wire, Quantum well, DNA-directed assembly and application in electronics.

Unit 5: Applications
MEMS, NEMS, Coatings, Optoelectronic Devices, Environmental Applications, Nanomedicine.

Text Books

1. Introduction to Nanoscience and Nanotechnology Gabor L. Hornyak, *NanoThread, Inc., Golden, Colorado, USA*; H.F. Tibbals, *University of Texas Southwestern Medical Center, Dallas, USA*; Joydeep Dutta, *Asian Institute of Technology, Pathumthani, Thailand*; John J. Moore, *Colorado School of Mines, Golden, USA* \
2. Introduction to Nanotechnology by Charles P. Poole Jr and Frank J.Owens Wiley India Pvt Ltd.
3. Introduction to Nanoscience and Nanotechnology, Chatopadhyaya.K.K, and Banerjee A.N,
4. Introduction to nano tech by phani kumar
5. Introduction to Nano Technology by Charles P. Poole Jr and Frank J. Owens. Wiley India Pvt Ltd.
6. Introduction to Nanoscience and Nanotechnology, Chatopadhyaya.K.K, and Banerjee A.N,
7. NANOTECHNOLOGY Basic Science and EmergingTechnologies by Michael Wilson, Kamali Kannangara Geoff Smith, Michelle Simmons, Burkhard Raguse- **CHAPMAN & HALL/CRC PRESS 2002.**

NS-105 FUNDAMENTALS OF BIOSCIENCE

Unit 1: Cell Biology

Discovery of cells, properties of cells, cell Theory, complexity, different classes of cells, prokaryotic & eukaryotic systems, dimensions of cells, size & shape of prokaryotic cells. Cell division & cell cycle, Mitosis & cell division, meisois, the cell cycle interphase, The G1, S & G2 phases.

Unit 2: Proteins & Genetic Material

Introduction to Proteins, Protein structure, protein synthesis, protein folding, Structure of DNA, variation from Watson & crick model-Z-DNA & B-DNA,Denaturation & melting curves, Genome organization in prokaryote & eukaryotes, Enzymes, Molecular biology involved in replication, step by step process, Heteroduplexes,Transcription, Translation & Replication, m-RNA,r-RNA,t-RNA structures, transcription, Amino Acids are building blocks of proteins.

Unit 3: Molecular Biology of Cancer

Fundamentals of Cancer Biology Regulation of Cell cycle, mutations that cause changes in signal molecules, effects on receptor, Different forms of cancers, Diet and cancer, Ontogenesis, Identification of Ontogenesis, Retroviruses and Ontogenesis, detection of Ontogenesis, Growth Factor and Growth Factor receptors that are Oncogenes,Oncogenes / Proto Oncogene activity, Growth factors related to transformations.

Unit 4: Immuno Chemistry & Tissue Engineering

Introduction,Lymphocytes,their origin and differentiation,antigens,their structures and classification, complement and their biological functions, Introduction to cell and tissue culture, Tissue culture media (composition, preparation), Initiation and maintenance of callus and cell suspension culture, organogenesis.

Unit 5: Biosensor

What are Biosensors? Advantages and limitations, various components of biosensors Biocatalysis based biosensors, bioaffinity based biosensors & microorganisms based biosensors, biologically active material and analyte, Types of membranes used in biosensor constructions, Various types of transducers, principles and applications - Calorimetric, optical,potentiometric/amperometric conductrometric/resistormetric,Piezoelectric, semiconductor, impedimetric, mechanical and molecular electronics based transducers, Chemiluminiscene - based biosensors, Biosensors in clinical chemistry, medicine and health care, biosensors for veterinary, agriculture and food , Low cost- biosensor for industrial processes for online monitoring; biosensors for environmental monitoring.

Text Books

1. Cell and Molecular Biology by Gerald Karp(2nd Edition)(wiley publishers)
2. Cell and Molecular Biology-De Robertis and De Robertis 1998 Waverly Pvt.Ltd
3. Rpott I,Essential immunology, Vaccines conventional, subunit and recombinant,antidiotypic vaccine,Blackwell scientific publications,Oxford,1991.

Reference Books

1. The cell by cooper
2. Lehninger A.L, Nelson O.'L, M.M.Cox, Principles of Biochemistry, CBS Publications, 1993.
3. Biomedical Engineering fundamentals second edition.James E Bailey,David F.OCCIS.

SEMESTER - II

NS-201 SCIENCE AND TECHNOLOGY OF THIN FILMS

Unit 1: Vacuum Technology
Principles of vacuum pumps in range of 10^{-2} torr to 10^{-11} torr, principle of different vacuum pumps, roots pump, rotary, diffusion, turbo molecular pump, cryogenic-pump, ion pump, Ti-sub limitation pump, importance of measurement of vacuum, Concept of different gauges, bayet-albert gauge, pirani, penning, pressure control.

Unit 2: Conditions for the Formation of Thin Films
Environment for thin film deposition, deposition parameters and their effects on film growth, formation of thin films (sticking coefficient, formation of thermodynamically stable cluster – theory of nucleation), capillarity theory, microstructure in thin films, adhesion, properties of thin films, Mechanical, electrical, and optical properties of thin films, few applications of thin films in various fields, Quartz crystal thickness for measurement of film thickness

Unit 3 Physical Vapor Deposition Techniques
Thermal evaporation, resistive evaporation, Electron beam evaporation, Laser ablation, Flash and Cathodic arc deposition

Unit 4 Electrical Discharges used in Thin Film Deposition
Sputtering, Glow discharge sputtering, Magnetron sputtering, Ion beam sputtering, Ion plating, oxidizing and Nitriding, Atomic layer deposition (ALD), Importance of ALD technique, Atomic layer growth, Physics and technology

Unit 5 Chemical Vapor Deposition Techniques
Advantages and disadvantages of Chemical Vapor deposition (CVD) techniques over PVD techniques, reaction types, boundaries and flow, Different kinds of CVD techniques: Metallorganic CVD (MOCVD), Thermally activated CVD, Spray pyrolysis, etc.

Text Books & References

1. Thin Film Phenomenon by K.L. Chopra, McGraw-Hill
2. Methods of Experimental Physics (Vol 14) by G.L.Weissler and R.W. Carlson “Vacuum Physics and Technology”
3. A User’s Guide to vacuum Technology by J.F.O’Hanlon, John Wiley and Sons
4. Vacuum Physics and Techniques by T.A. Delchar, Chapman and Hall
5. Evaporation: Nucleation and Growth Kinetics” by J.P. Hirth and G.M.Pound, Pergamon Press

NS-202 SYNTHESES OF NANOMATERIALS

Unit 1: Introduction
Introduction to synthesis of nanostructure materials, Bottom-up approach and Top-down approach with examples, Nanotechnology generation.

Unit 2: Physical Methods
Inert gas condensation, Arc discharge, RF-plasma, plasma arc technique, electric explosion of wires, laser ablation, laser pyrolysis, ball milling, molecular beam epitaxy, electro-deposition

Unit 3: Chemical Methods
Nanocrystals by chemical reduction, photochemical synthesis, electrochemical synthesis, Nanocrystals of semiconductors and other materials by arrested precipitation, emulsion synthesis, sonochemical routes

Unit 4: Thermolysis Route
Thermolysis route – Flame spray pyrolysis, Flame spray Hydrolysis, solvated metal atom dispersion, sol-gel method, solvothermal and hydrothermal routes, solution combustion synthesis, Chemical vapor deposition techniques: Advantages and disadvantages of Chemical Vapor deposition (CVD) techniques over PVD techniques, reaction types, boundaries and flow, Different kinds of CVD techniques: Metallorganic CVD (MOCVD), Thermally activated CVD, plasma enhanced (RF-Wave) CVD, Low Pressure (LP) CVD, Atmospheric pressure (AP) CVD

Unit 5: Biological Methods
Biological methods – use of bacteria, fungi, actinomycetes for nano-particle sythesis-magnetotatic bacteria for natural synthesis of magnetic nano-particles

Text Books:

1. Inorganic Materials Synthesis and Fabrication by J.N. Lalena, D.A. Cleary, E.E. Carpenter, N.F. Dean, John Wiley & Sons Inc.
2. Introduction to Nano Technology by Charles P. Poole Jr and Frank J. Owens. Wiley India Pvt Ltd.
3. The Chemistry of nanomaterials: Synthesis, Properties and Applications, Vol-I by C.N.R. Rao, A. Muller and A.K. Cheetham

Reference Books:

1. Encyclopedia of Nanotechnology by M.Balakrishna Rao and K.Krishna Reddy, Vol I to X, Campus books.
2. Encyclopedia of Nanotechnology by H.S. Nalwa
3. Nano: The Essentials – Understanding Nano Scinece and Nanotechnology – by T.Pradeep; Tata Mc.Graw Hill
4. Handbook of chemical Vapor deposition (cvd), Principles, technology, and applications, By Hugh o. Pierson, Second edition, Noyes publications, William Andrew Publishing, LLC

NS-203 PHYSICO CHEMICAL EFFECTS OF NANOMATERIALS

UNIT 1: Electronic Properties
Energy bands and gaps in semiconductors, Fermi surfaces ,localized particle, donors, acceptors, deep traps, excitons,mobility,size dependent effects, conduction electrons and dimensionality fermi gas and density of states, semiconducting nanoparticles

UNIT 2: Optical Properties
Photonic crystals, optical properties of semiconductors, band edge energy, band gap, dependence on nanocrystallins size, Quantum dots,opticaltransitions,absorption,interband transitions, quantum confinements.

UNIT 3: Luminescence Properties
Fluorescence/luminescence, photoluminescence/fluorescence, optically excited emission, electroluminescence, Laser emission of quantum dot,Photofragmentation and columbic explosion, phonons in nanostructures, luminescent quantum dots for biological labeling.

UNIT 4: Magnetic Properties
Introduction of magnetic materials, basics of ferromagnetism – ferro magnetic resonance and relaxation, magnetic properties of bulk nanostructures, magnetic clusters, dynamics of nanomagnets, nanopore containment of magnetic particles, nanocarbon ferromagnets, ferrofluids, electron transport in magnetic multilayers.

UNIT 5: Thermomechanical Properties
Thermomechanical behavior of thin film nanostructures – a general framework for the thermo mechanics of multi layer films, surface stress-scaling from macro to nano structures

Text Books:

1. Introduction to Nano Technology by Charles. P. Poole Jr & Frank J. Owens. Wiley India Pvt. Ltd.
2. Solid State physics by Pillai; Wiley Eastern Ltd.
3. Introduction to solid state physics 7^{th} edition by Kittel.; John Wiley & sons (Asia) Pvt Ltd.

Reference Books:

1. Nano Terchnology and Nano Electronics – Materials, devices and measurement
2. Techniques by WR Fahrner – Springer
3. Encyclopaedia of Nano Technology by M.Balakrishna rao and K.Krishna Reddy, Vol I to X Campus books.
4. Nano Technology - Science, innovation and opportunity by Lynn E. Foster. Prentice Hall Pearson education.
5. Hand book of Nano structured materials Vol I & V
6. Encyclopedia of Nano Technology by H.S.Nalwa

Journal References:

1.K K Nanda, Pramana J. Phys., Vol. 72, No. 4, April 2009
2.A.A.Shavtsburg & M.F.Gerald, Chemical Physics Letters 317 2000. 615–618
3.V P Skripov, V P Koverda and V N Skokov, Phys. Status Solidi A66, 109 (1981)
4.R Goswami and K Chattopadhyay, Acta Mater. 52, 5503 (2004)
5.V. Germain et al., J. Phys. Chem. B, Vol. 107, No. 34, 2003

NS-204 NANOELECTRONICS

Unit 1: Electrons subject to a Periodic Potential-Band Theory of Solids
Crystalline Materials,Electrons in a Periodic Potential ,Kronig—Penney Model of Band Structure Effective Mass.

Unit 2: Band Theory of Solids
Doping in Semiconductors, Interacting Systems Model, The Effect of an Electric Field on Energy Bands, Band structures of Some Semiconductors, Electronic Band Transitions — Interaction of Electromagnetic Energy and Materials,Graphene and Carbon Nanotubes , Carbon Nanofibers.

Unit 3: Single-Electron and Few-Electron Phenomena and Devices
Tunnel junction and applications of tunneling, Tunneling Through a Potential Barrier ,Potential Energy Profiles for Material Interfaces ,Metal—Insulator, Metal-Semiconductor, and Metal-Insulator-Metal Junctions, Applications of Tunneling , Field Emission, Gate—Oxide Tunneling and Hot Electron Effects in MOSFETs,Scanning Tunneling Microscope, Double Barrier Tunneling and the Resonant Tunneling Diode.

Unit 4: **Coulomb Blockade**
Coulomb Blockade, Coulomb Blockade in a Nanocapacitor, Tunnel Junctions, Tunnel Junction Excited by a Current Source, Coulomb Blockade in a Quantum Dot Circuit.

Unit 5: The Single-Electron Transistor
The Single-Electron Transistor Single-Electron Transistor Logic, Other SET and FET Structures, Carbon Nanotube Transistors (FETs and SETs), Semiconductor Nanowire FETs and SETs, Molecular SETs and Molecular Electronics.

Text Books and References

1. Nanoelectronics & Nanosystems: From Transistor to Molecular & Quantum Devices: Karl Goser, Jan Dienstuhl and others.
2. Concepts in Spintronics – Sadamichi Maekawa
3. Spin Electronics – David Awschalom
4. From Atom to Transistor-Supriyo Datta

NS 205 BIOMEDICAL APPLICATIONS IN NANOTECHNOLOGY

Unit 1: Drug Metabolism
Development of drug, Drug metabolism-physico chemical principles, radioactivity-pharma kinetics-action of drugs on human bodies.

Unit 2: Nano Drug Delivery Systems
Introduction, Manufacturing of Nanoparticles, Nanoparticles-Drug Deliveries, Drug Delivery Systems, Nanoparticles in Drug Delivery-Available Applications, Nanotechnology-Future understanding for Treatment, Materials, Targeting, Magnetic Separation, Magnetic Tweezers, Drug and Gene Delivery, Magnetic Resonance Imaging,Hyperthermia,Other Applications.

Unit 3: Nanotechnology in Cancer Drug Therapy:
Drug Resistance, Drug Toxicity, Drug Targeting, Drug Transport, Drug Dosage and Scheduling, Drug Concentration, Drug Release.

Unit 4: Micro/Nanomachining and Fabrication of Materials for Biomedical Applications
Introduction, Overview of Ion Implantation Process, Micro/Nanomachining of ‘‘Soft’’ Polymeric Biomaterials: Orthopedic Applications, Blood-Contacting Devices, Other Applications. Micro/Nanomachining of ‘‘Hard’’ Metallic Biomaterials: Dental Implants, Blood-Contacting Devices, Other Applications.

Unit 5: Bioimaging
Core/shell structured nanoparticles for bioimaging, inorganic core/shell nanoparticles, silver/silica in fluroscence imaging, iron oxide/silica in magnetic imaging.

Text Books:

1. Leon Lachman et at –at Theory and Practice of Industrial Pharmacy,3rd Edition,Lea and Febiger, 1986.
2. Nanotechnology importance and applications-M.H.Fulekar
3. BioMEMS and Biomedical Nanotechnology-Volume I Biological and Biomedical Nanotechnology.
4. BIOMEDICAL NANOSTRUCTURES Edited by Kenneth E. Gonsalves, Craig R.Halberstadt, Cato T. Laurencin, Lakshmi S. Nair

Reference Books:

1. ADVANCED MAGNETIC NANOSTRUCTURES- Edited by David Sellmyer, Ralph Skomski- springer.
2. BIOMEDICAL APPLICATIONS OF NANOTECHNOLOGY- EDITED BY Vinod Labhasetwar, Diandra L. Leslie-Pelecky
3. Core/shell structured nanoparticles for biomedical applications by nagarajan sounderya and youg zhang, springer publications

SEMESTER – III

NS-301 ADVANCED NANOMATERIALS CHARACTERIZATION

Unit 1: Compositional and Structural Characterization Techniques

X-ray Photoelectron Spectroscopy (XPS), Energy Dispersive X-ray analysis (EDAX), Principles and applications of X-ray diffraction: Electron diffraction, Electron probe microanalysis (EPMA), Ion beam techniques: SIMS & RBS.

Unit 2: Surface Characterization Techniques

High resolution microscopy, Scanning electron microscopy (SEM), Transmission electron microscopy(TEM), Atomic force microscopy(AFM), Scanning tunneling microscopy(STM).

Unit 3: Spectroscopic Techniques

Fourier Transform infrared (FTIR) spectroscopy, Raman spectroscopy techniques: micro Raman and laser Raman.

Unit 4: Electrical Characterization Techniques

Measurement of resistivity by 4-prob method, Hall measurement, Sebecek coefficient measurements, nano indentation techniques, electron beam induced current measurement (EBIC).

Unit 5: Thermal and Magnetic Characterization

VSM, Thermal analysis, impedance and ferroelectric measurements.

Text Books:

1.Nano: The Essentials -Understanding Nano Scinece and Nanotechnology by T.Pradeep, Tata Mc.Graw Hill
2.Introduction to Nano Technology by Charles. P. Poole Jr and Frank J. Owens, Wiley India Pvt Ltd.
3. A practical approach to X-Ray diffraction analysis by C.Suryanarayana
4. Electron Microscopy and analysis by P.J. Goodhew and F.J. Humpreys
5. Scanning electron microscopy and x-ray microanalysis by J.I. Goldstein
6. Characterization of nanostructured materials by Z.L. Wang
7. Modern Raman Spectroscopy: A practical approach by E. Smith and G.Dent
8. Principles of Instrumental analysis by D.A. Skoog, F.J. Hollen and T.A. Nieman

Reference Books:

1.Nanotechnology : Principles and Practices – Sulabha K. Kulkarni – Capital Publishing Comany
2.Specimen preparation for Transmission Electron microscopy by John & Bravmno et al, published by MRS
3.Photoelectron spectroscopy by JHD Eland, Butterworth & Co. publishers, 2nd education.
4.Encyclopedia of Nanotechnology by H.S. Nalwa

NS-302 SYNTHESIS AND CHARACTERIZATION OF CARBON NANO TUBES APPLICATION

Unit 1: Introduction to CNT

Introduction, History, Discovery, Carbon Nano tubes Carbon clusters and Fullerenes.

Unit 2: Structure & Classification

Structures and types of Carbon Nano tubes, graphene structures, Solid Disordered carbon Nanostructures, Nano structured crystals, Crystal structure, Alkali-Doped C60, Larger and Smaller Fullerenes.

Unit 3: Synthesis and Growth

Synthesis of CNTs by Flame, CVD, Laser & Arc process, growth of CNTs: tip growth, basal growth, Mechanism involved in growth of CNTs.

Unit 4: Properties of CNT

Electrical, Vibrational, Mechanical Properties of CNTs, optical properties & Raman spectroscopy of CNTs, Mechanical reinforcements and their application in modern day.

Unit 5: Modern Day Applications

Application of CNTs for Lithium & Hydrogen adsorption & storage, Fuel cell applications and energy storage, Chemical Sensors applications of CNTs

Text Books:

1.Introduction to Nanotechnology by Charles P. Poole Jr and Frank J.Owens Wiley India Pvt Ltd.
2.Nanotechnology, A gentle introduction to the next big idea by Mark Ranter, Daniel Ranter Pearson education

Reference Books:

1.Encyclopaedia of Nanotechnology by M.Balakrishna rao and K.Krishna Reddy, Vol I to X Campus books.
2. Encyclopedia of Nanotechnology by HS Nalwa
3. Nanotechnology – science, innovation and opportunity by Lynn E.Foster. Prentice Hall Pearson education.
4. Nano:The Essentials – Understanding Nano Scinece and Nanotechnology by T.Pradeep; Tata Mc.Graw Hill

NS-303 NANOCOMPOSITES SYNTHESIS DESIGN AND APPLICATIONS

Unit 1: Introduction to Nanocomposites

Introduction to Nanocomposites, Composite material, Mechanical properties of Nano composite material: stress - strain relationship, toughness, strength, plasticity, Synthesis methods for various nanocomposite materials: sputtering, mechanical alloying, sol-gel synthesis, thermal spray synthesis.

Unit 2: Classification of Composites

Ceramic-Metal Nanocomposites, Ceramic based nanoporous composite, Metal matrix nanocomposites, Polymer-based nanocomposites Carbon nanotube based nanocomposites and Natural nanobiocomposites, Biomimetic nanocomposites and Biologically inspired nanocomposites, Nano composites for hard coatings, DLC coatings, Thin film nanocomposites, Modeling of nanocomposites.

Unit 3: **Evaluation & Testing of Nanocomposites**

Evaluation of mechanical properties of nanocomposites: Nano Indentation, Types of indentation: Oliver & Pharr, Joslin-Oliver, Vickers indenter process.

Unit 4: Processing of Nanocomposites

Processing of polymer nanocomposites, properties of nanocomposites, Salt infiltration, Powder mixing, Intrusion method, Exfoliation & interaction, Gel-casting impregnation techniques: Hot melt impregnation, solution impregnation.

Unit 5: Applications

Application of nanocomposites in modern industry, homeland security, law enforcement, defense, structural and civil applications.

Text Books:

1. Introduction to Nanotechnology by Charles P. Poole Jr and Frank J.Owens Wiley India Pvt Ltd.
2. Nanotechnology and Nano Electronics – Materials, devices and measurement techniques by WR Fahrner, Springer publications
3. Nanocomposite Science & Technology by P.M. Ajayan, L.S. Schadler and P.V. Braun, Wiley-VCH GmbH Co.
4. Introduction to Nano Technology by Charles. P.Poole Jr and Frank J. Owens; Wiley India Pvt Ltd.
5. Nanotechnology, A gentle introduction to the next big idea by Mark Ranter, Daniel Ranter Pearson education

Reference Books:

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2. Encyclopedia of Nanotechnology by HS Nalwa
3. Nanotechnology – science, innovation and opportunity by Lynn E.Foster. Prentice Hall Pearson education.
4. Nano:The Essentials – Understanding Nano Scinece and Nanotechnology by T.Pradeep; Tata Mc.Graw Hill

NS-304 MEMS /NEMS DESIGN AND APPLICATIONS (ELECTIVE-I)

Unit 1: Introduction to MEMS and NEMS

MEMS and NEMS – multidisciplinary nature of MEMS/NEMS – working principles: as micro sensors (acoustic wave sensor, biomedical and biosensor, chemical sensor, optical sensor, capacitive sensor, pressure sensor and thermal sensor), micro actuation (thermal actuation, piezoelectric actuation and electrostatic actuation – micro gripers – micro motors – micro valves – micro pumps – accelerometers – micro fluidics and capillary electrophoresis, active and passive micro fluidic devices.

Unit 2: Materials for MEMS/NEMS

Silicon – Compatible material systems, Silicon, Silicon oxide and nitride, Thin metal films, Polymers, Other materials and substrates, Glass and fused quartz substrates, Silicon carbide and diamond, Gallium Arsenide and other group III-V compound semi conductors, Shape - memory alloys transduction, Important material properties and physical effects, Pizoresistivity, Pizoelectricity and thermoelectricity, Inter atomic bonds, Material structures.

Unit 3: MEMS/NEMS Design, Processing and Technologies

Basic process tools, Epitaxy, Oxidation, Sputter deposition, Evaporation, Chemical vapor deposition, spin on methods, Lithography, Lift off process, Bulk Micro machining, Etching processes – Wet etching, Plasma etching, Ion milling, Wafer bonding – Silicon fusion bonding, Anodic bonding, Silicon direct bonding, sol gel deposition methods, Self assembled mono layers, EFAB, LIGA electromagnetic micro drive, DRIE.

Unit 4: MEMS/NEMS Scaling issues and Packaging

Introduction – Scaling of physical systems – Geometric scaling, Mechanical system scaling, Thermal system scaling, Fluidic system scaling, Electrical system scaling,Packaging-package design considerations, Process steps, Wafer thickness and dicing issues, Thermal management, Hermetic packaging, Electrical//Micro fluidic/and optical interconnects, Quality control-reliability and failure modes and analysis, Signal mapping transduction.

Unit 5: MEMS/NEMS Applications

Applications in automotive industry – health care – aerospace – industrial product consumer products – lab on chip – molecular machines – data storage devices – micro reactor – telecommunications, Servo systems.

Text Books:

1. “An introduction to Micro electro mechanical systems Engineering” by Nadim Malut and Kirt Williams – Second edition – Artech House, Inc, Boston
2. “Micro electro mechanical systems Design”./ by James J Allen- CRC Press – Taylor and Francis Group
3. “Mechanics of micro electro mechanical systems “ by Nicolae Lobontiu and Ephrahim Garcia Kluwer. Academic Publishers – Boston

Reference Books:

1. “Springer Hand Book of Nano Technology “ by Bharath Bhushan – Springer
2 “ Nano and Micro electro Mechanical systems” by Sergey Edward Lysherski – CRC Press

NS -305 ENVIRONMENTAL ISSUES AND ETHICS

Unit 1: Nanotechnology and the Environment:
Introduction and potential rewards, Green nanotechnology and its principles, Nano-convergence and Environmental Engineering, different environmental systems, Potential impacts of nanomaterials on organisms and ecosystems, Environmental applications, Nanotechnology and Our Energy Challenge of nanomaterials, Nanotechnology and Renewable Energy

Unit 2: Classification of Nanoscale Materials
Origin, Composition and Structure, Types and Uses of Nanoparticles, Free versus Fixed Nanoparticles, engineered nanoparticles, Properties of Nanoscale Materials, Effect of Increased Surface Area, Influence of Quantum Effects, Types of Nanomaterials and Applications of Titanium Dioxide, Zero-Valent Iron, Silver, Carbon Black, Carbon Nanotubes, Fullerenes in environment cleaning.

Unit 3: Nanoparticle Transport, Aggregation and Deposition
Physicochemical Interactions, Brownian motion, Van der waals interactions, Electrostatic interactions, Solvency Force, Born repulsion, Acid-base interactions and the hydrophobic effect, Aggregation, Aggregation kinetics and particle stability, Formation of nanoparticle aggregates, Ionic strength effects, Deposition, Particle deposition in porous media, Detachment, Effect of surface roughness, Nanoparticle Behavior in Heterogeneous Systems, Naturally occurring organic matter(NOM) and particle charge, NOM adsorption and nanoparticle, Nanoparticle transport and diffusion in matrices such, as gels and biofilms.

Unit 4: Concepts of Pollution Control
Zero-Valent Iron (ZVI), Forms of nZVI, Particle Characteristics, Effects of Particle Size, *In Situ* Remediation with nZVI (nano ZVI), Potential Risks, Case Studies, Nease Chemical Site, Naval Air Engineering Station-New Jersey, Other Technologies, Nanomaterials for Groundwater Remediation, Introduction, Reactivity, Fate, and Lifetime, Reactive, Adsorbent, and catalytic nanoparticles, insitu and ex-situ reactions, Reaction products, intermediates and efficiency, effect of physico-chemical parameters in remediation, Delivery and Transport Issues, Injection methods and delivery vehicles, Transport.

Unit 5: Toxicological Properties of Nanoparticles and Nanotubes
Introduction to toxicology, principles of toxicology, dosage-Response curve, classification of toxicity, factors affecting toxicity, LC50, LD 50, Air borne Particles, Effects of Carbon Black Carbon Nanotubes, Fullerenes, Quantum Dots, other nanoparticles and TiO2, Nanoparticles and the Brain, New Engineered NPs and the Cardiovascular System, Human Effects of Nanoparticle Exposure and toxicology of Nanoparticles, NP Characterization, Epidemiology:- Occupational Exposure, Environmental Exposure, Human Challenge Studies, Risk Assessment of Engineered NPs.

Text Books and References

1. Concept Document “Nanoscience & Technology Initiative” of DST, GOI, New Delhi, 2002.
2. Winner, Langdon, “Societal Implications of Nanotechnology”, Testimony to ---- on science of the US House of Representatives, 2003.
3. Ethics in Engineering, M.Martin & R. Schinzinger, 4th edition, McGraw-Hill[0-07-283115-4];
4. Nanotechnology Regulation and Policy Worldwide (Artech House), Jeffrey H. Matsuura 2006.
5. Nanoscale issues and perspectives for the nano century, Edited by Nigel M. de S. Cameron, M. Ellen Mitchell, willey 2007
6. Nanotechnology and the Environment, Kathleen Sellers,Christopher Mackay, Lynn L. Bergeson, Stephen R. Clough, Marilyn Hoyt, Julie Chen, Kim Henry, Jane Hamblen, crc press, 2009
7. Nanotechnology,consequences for human health and the environment- issues in environmental science and technology, editors: r.e. Hester and r.m. Harrison, rsc publication - 2007
8. Essentials of Toxicology. *Klaassen CD, Watkins JB III, eds. New York: McGraw-Hill, 2003.*
9. Introduction to Toxicology, 3rd Edition. 2002. John Timbrell. Taylor and Francis Publishing. ISBN 0-415-247-632
10. Hayes, A. W. 2001. Principles and Methods of Toxicology, 4th ed. Taylor and Francis. Phila. PA.

SEMINAR- SPEECH DELIVERABLES BY DISTINGUISHED SCIENTISTS

Nanotechnology & Society

Introduction to Societal Implications of Nanoscience and Nanotechnology, Nanotechnology Goals: Knowledge and scientific understanding of nature, Industrial manufacturing, materials and products, Medicine and the human body, Sustainability: Agriculture, water, energy, materials and clean environment, Space exploration, National security, moving into the market.

Approach to Nano Regulation and Law

Regulating Nanotechnology, The Regulatory System, The Rhetoric Behind Nanotechnology, Nanotechnology: Is It Legal, Nanotechnology: A Market Force, Public Perception, A New Law for Nanotechnology, Regulatory Uncertainties: EPA,TSCA, FIFRA, CERCLA,RCRA,CWA, CAA,EPA Conclusion, FDA, CPSC, NRC, OSHA,USDA,Regulatory Politics Behind the Science of Nanotechnology, Patenting Trends in Nanotechnology, Nanotechnology Patents on the Rise, Beyond the Numbers: Emerging Trends in, Nanotechnology Patenting, Science Policy and Nanotechnology, The Administration of the National Nanotechnology Initiative, The Development of Nanotechnology Policy , The Lewis Paradox: The Abolition of Man, The Challenge to the Policy Community

Ion implantation

From Wikipedia, the free encyclopedia
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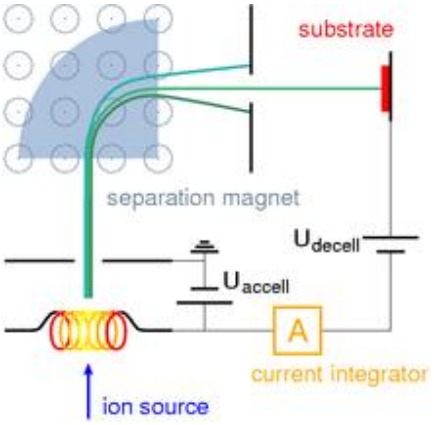
An ion implantation system at LAAS technological facility in Toulouse, France.

Ion implantation is a materials engineering process by which ions of a material are accelerated in an electrical field and impacted into another solid. This process is used to change the physical, chemical, or electrical properties of the solid. Ion implantation is used in semiconductor device fabrication and in metal finishing, as well as various applications in materials science research. The ions can introduce both a chemical change in the target, in that they can introduce a different element than the target or induce a nuclear transmutation, and a structural change, in that the crystal structure of the target can be damaged or even destroyed by the energetic collision cascades.

Contents

[hide]

[edit] General principle



Ion implantation setup with mass separator

Ion implantation equipment typically consists of an ion source, where ions of the desired element are produced, an accelerator, where the ions are electrostatically accelerated to a high energy, and a target chamber, where the ions impinge on a target, which is the material to be implanted. Thus ion implantation is a special case of particle radiation. Each ion is typically a single atom or molecule, and thus the actual amount of material implanted in the target is the integral over time of the ion current. This amount is called the dose. The currents supplied by implanters are typically small (microamperes), and thus the dose which can be implanted in a reasonable amount of time is small. Therefore, ion implantation finds application in cases where the amount of chemical change required is small.

Typical ion energies are in the range of 10 to 500 keV (1,600 to 80,000 aJ). Energies in the range 1 to 10 keV (160 to 1,600 aJ) can be used, but result in a penetration of only a few nanometers or

less. Energies lower than this result in very little damage to the target, and fall under the designation ion beam deposition. Higher energies can also be used: accelerators capable of 5 MeV (800,000 aJ) are common. However, there is often great structural damage to the target, and because the depth distribution is broad, the net composition change at any point in the target will be small.

The energy of the ions, as well as the ion species and the composition of the target determine the depth of penetration of the ions in the solid: A monoenergetic ion beam will generally have a broad depth distribution. The average penetration depth is called the range of the ions. Under typical circumstances ion ranges will be between 10 nanometers and 1 micrometer. Thus, ion implantation is especially useful in cases where the chemical or structural change is desired to be near the surface of the target. Ions gradually lose their energy as they travel through the solid, both from occasional collisions with target atoms (which cause abrupt energy transfers) and from a mild drag from overlap of electron orbitals, which is a continuous process. The loss of ion energy in the target is called stopping and can be simulated with the binary collision approximation method.

[edit] Application in semiconductor device fabrication

[edit] Doping

The introduction of dopants in a semiconductor is the most common application of ion implantation. Dopant ions such as boron, phosphorus or arsenic are generally created from a gas source, so that the purity of the source can be very high. These gases tend to be very hazardous. When implanted in a semiconductor, each dopant atom can create a charge carrier in the semiconductor after annealing. A hole can be created for a p-type dopant, and an electron for an n-type dopant. This modifies the conductivity of the semiconductor in its vicinity. The technique is used, for example, for adjusting the threshold of a MOSFET.

Ion implantation was developed as a method of producing the p-n junction of photovoltaic devices in the late 1970s and early 1980s,[1] along with the use of pulsed-electron beam for rapid annealing,[2] although it has not to date been used for commercial production.

[edit] Silicon on insulator

One prominent method for preparing silicon on insulator (SOI) substrates from conventional silicon substrates is the *SIMOX* (**S**eparation by **IM**plantation of **OX**ygen) process, wherein a buried high dose oxygen implant is converted to silicon oxide by a high temperature annealing process.

[edit] Mesotaxy

Mesotaxy is the term for the growth of a crystallographically matching phase underneath the surface of the host crystal (compare to epitaxy, which is the growth of the matching phase on the surface of a substrate). In this process, ions are implanted at a high enough energy and dose into a material to create a layer of a second phase, and the temperature is controlled so that the crystal

structure of the target is not destroyed. The crystal orientation of the layer can be engineered to match that of the target, even though the exact crystal structure and lattice constant may be very different. For example, after the implantation of nickel ions into a silicon wafer, a layer of nickel silicide can be grown in which the crystal orientation of the silicide matches that of the silicon.

[edit] Application in metal finishing

[edit] Tool steel toughening

Nitrogen or other ions can be implanted into a tool steel target (drill bits, for example). The structural change caused by the implantation produces a surface compression in the steel, which prevents crack propagation and thus makes the material more resistant to fracture. The chemical change can also make the tool more resistant to corrosion.

[edit] Surface finishing

In some applications, for example prosthetic devices such as artificial joints, it is desired to have surfaces very resistant to both chemical corrosion and wear due to friction. Ion implantation is used in such cases to engineer the surfaces of such devices for more reliable performance. As in the case of tool steels, the surface modification caused by ion implantation includes both a surface compression which prevents crack propagation and an alloying of the surface to make it more chemically resistant to corrosion.

[edit] Other applications

[edit] Ion beam mixing

Ion implantation can be used to achieve ion beam mixing, i.e. mixing up atoms of different elements at an interface. This may be useful for achieving graded interfaces or strengthening adhesion between layers of immiscible materials.

[edit] Problems with ion implantation

[edit] Crystallographic damage

Each individual ion produces many point defects in the target crystal on impact such as vacancies and interstitials. Vacancies are crystal lattice points unoccupied by an atom: in this case the ion collides with a target atom, resulting in transfer of a significant amount of energy to the target atom such that it leaves its crystal site. This target atom then itself becomes a projectile in the solid, and can cause successive collision events. Interstitials result when such atoms (or the original ion itself) come to rest in the solid, but find no vacant space in the lattice to reside. These point defects can migrate and cluster with each other, resulting in dislocation loops and other defects.

[edit] Damage recovery

Because ion implantation causes damage to the crystal structure of the target which is often unwanted, ion implantation processing is often followed by a thermal annealing. This can be referred to as damage recovery.

[edit] Amorphization

The amount of crystallographic damage can be enough to completely amorphize the surface of the target: i.e. it can become an amorphous solid (such a solid produced from a melt is called a glass). In some cases, complete amorphization of a target is preferable to a highly defective crystal: An amorphized film can be regrown at a lower temperature than required to anneal a highly damaged crystal.

[edit] Sputtering

Some of the collision events result in atoms being ejected (sputtered) from the surface, and thus ion implantation will slowly etch away a surface. The effect is only appreciable for very large doses.

[edit] Ion channelling

A diamond cubic crystal viewed from the <110> direction, showing hexagonal ion channels.

If there is a crystallographic structure to the target, and especially in semiconductor substrates where the crystal structure is more open, particular crystallographic directions offer much lower stopping than other directions. The result is that the range of an ion can be much longer if the ion travels exactly along a particular direction, for example the <110> direction in silicon and other diamond cubic materials. This effect is called *ion channelling*, and, like all the channelling effects, is highly nonlinear, with small variations from perfect orientation resulting in extreme differences in implantation depth. For this reason, most implantation is carried out a few degrees off-axis, where tiny alignment errors will have more predictable effects.

Ion channelling can be used directly in Rutherford backscattering and related techniques as an analytical method to determine the amount and depth profile of damage in crystalline thin film materials.

[edit] Hazardous Materials Note

In the ion implantation semiconductor fabrication process of wafers, it is important for the workers to minimize their exposure to the toxic materials used in the ion implanter process. Such

hazardous elements, solid source and gasses are used, such as arsine and phosphine. For this reason, the semiconductor fabrication facilities are highly automated, and may feature negative pressure gas bottles safe delivery system (SDS). Other elements may include antimony, arsenic, phosphorus, and boron. Residue of these elements show up when the machine is opened to atmosphere, and can also be accumulated and found concentrated in the vacuum pumps hardware. It is important not to expose yourself to these carcinogenic, corrosive, flammable, and toxic elements. Many overlapping safety protocols must be used when handling these deadly compounds. Use safety, and read MSDSs.

[edit] High Voltage Safety

High voltage power supplies in ion implantation equipment can pose a risk of electrocution. In addition, high-energy atomic collisions can, in some cases, generate radionuclides. Operators and maintenance personnel should learn and follow the safety advice of the manufacturer and/or the institution responsible for the equipment. Prior to entry to high voltage area, terminal components must be grounded using a grounding stick. Next, power supplies should be locked in the off state and tagged to prevent unauthorized energizing.