PAPER – I Research Methodology

Unit I: Structural Studies

X-ray diffraction – Introduction – basic principles – characterization by XRD – examples of XRD characterization – Debye Scherer formula – FTIR – Introduction – basic principles – methodologies and accessories – interferences and artifacts.

Unit II: Microscopic Techniques

Scanning electron microscopy – Introduction – basics and primary modes of operation – instrumentation – sample requirements – applications – Transmission electron microscopy – Introduction - basic principles – TEM operation – specimen preparation – Sacanning tunneling microscopy – Introduction – basic principles and instrumentation – common modes of analysis and examples – sample requirements – artifacts – Atomic force microscopy – Introduction – basic principle – modes of operation – applications.

Unit III: Spectroscopic Techniques

Photoluminescence - Introduction – basic principles – common modes of analysis and examples - sample requirements - quantitative abilities – instrumentation - Spectroscopic Ellipsometry – Basic principles – Applications – Raman Spectroscopy – introduction – basic principles – instrumentation – sample requirements – bulk and microfocus Raman spectroscopic analysis – thin and thick films – Nuclear Magnetic Resonance – introduction – basic principles – structural and chemical information from solid state NMR line shapes – instrumentation - practical aspects and limitations – quantitative analysis.

Unit IV: Elemental Analysis

X-ray photoelectron spectroscopy – introduction – basic principles – analysis capabilities – more complex effects – surface sensitivity – instrumentation – applications – comparison with other techniques – X-ray Fluorescence – introduction – basic principles – instrumentation – analytical capabilities – applications – related techniques – Inductively coupled plasma mass spectrometry – introduction – basic principles and Instrumentation – sampling – quantification – interferences – novel sampling techniques.

Unit V: MATLAB

Introduction – basic commends and syntax – saving work – arrays and matrices – array operation – scripts and functions – more on functions – graphics – optimizing performance – advanced data structures – graphical user interfaces – object oriented programming – linking to FORTRAN or C.

Books for Study

1. C. Richard Brundle, Charles A. Evans Jr., Shaun Wilson (1992) Encyclopedia of Materials Characterization, Butterworth-Heinemann Publishers..
2. Tobin A. Driscoll (2003) Crash Course in MATLAB.
3. B. D. Cullity (1977) Elements of X-ray diffraction, Addison- Wesley Publishers.
4. Masuo Hosokawa, Kiyoshi Nogi, Makio Naito, Toyokazu Yokoyama (2007) Nanoparticle Technology Handbook, Elsevier Publishers.

PAPER – II Research Trends in Nanoscience and Technology

Unit I: Basic properties and measuring methods of nanoparticles

Size effect and properties of Nanoparticles - Particle size - Particle shape - Particle density - Melting point, surface tension, wettability - Specific surface area and pore - Composite structure - Crystal structure - Surface characteristics - Mechanical property - Electrical properties - Magnetic properties - Optical property of nanoparticle

Unit II: Structural control of nanoparticles

Structure construction and function adaptation of Nanoparticles - Particle size - Particle shape - Composite structure - Pore structure - Nanoparticle design for DDS - Nanotubes (CNT).

Unit III: Characteristics and behavior of nanoparticles and its dispersion systems

Introduction of nanoparticle dispersion and aggregation behavior - Single nanoparticle motion in fluid – Brownian diffusion - Adsorption properties and wettability of nanoparticle surface - Interactions between particles - Aggregation and dispersion, characterization and control - Rheology of slurry - Simulation of colloidal dispersion system.

Unit IV: Control of nanostructure of materials

Assembly of nanoparticles and functionalization - Nanoparticles arranged structures - Nanopore structure - Nanocomposite structure - Structure control of nanoparticle collectives by sintering and bonding - Self-assembly.

Unit V: Evaluation methods for properties of nanostructured materials

Functionality of nanostructures and their characteristic evaluation - Mechanical properties - Thermo physical properties - Electric properties - Electrochemical properties - Magnetic properties - Optical properties - Catalytic property - Properties of gas permeation and separation membranes .

Book for Study

1. Masuo Hosokawa, Kiyoshi Nogi, Makio Naito, Toyokazu Yokoyama (2007) Nanoparticle Technology Handbook, Elsevier Publishers.

References

1. William A. Goddard Ill, Donald W. Brenner, Sergey E. Lyshevski, Gerald J. Iafrate (2007) Handbook of Nanoscience, Engineering and Technology, CRC Press.
2. Robert W. Kelsall, Ian W. Hamley, Mark Geoghegan (2005) Nanoscale Science and Technology, John Wiley & Sons, Ltd.

PAPER – III (Optional-1): Nanoscale Science and Technology

Unit I: Nanophysics

Development of bright phosphors using glasses incorporating semiconductor nanoparticles - Development of fuel cells - Development of a high-performance secondary battery by controlling the surface structure - Expression of optical function by nanostructure using femto second laser processing - Evaluation and applications of dispersing carbon nanotube in the polymers - Development of photonic crystals based on nanoparticle assembly - Electrical conductive CNT dispersed Si_3N_4 ceramics - Enhancement of the performance of insulating materials - Development of novel ferroelectric materials - A dye-sensitized solar cell utilizing metal nanoparticle - Sensing based on localized surface plasmon resonance in metallic nanoparticles - Generation of metal nanoparticles using reactive plasma arc evaporation - Formation of thick electronic ceramic films with bonding technique of crystalline fine particles and their applications - Closely packed colloidal crystal assembled with nanoparticles and its application for smart materials with tunable structural color.

Unit II: Nanochemistry

Surface modification of inorganic nanoparticles by organic functional groups - Instantaneous nanofoaming method for fabrication of closed-porosity silica particle- Development of photocatalyst inserted into surface of porous aluminosilicate - Fabrication technique of organic nanocrystals and their optical properties and materialization - Dispersion control of Al_2O_3 nanoparticles in ethanol - Development of new cosmetics based on nanoparticles - Liquid-crystalline inorganic nano and fine particles - Development of functional skincare cosmetics using biodegradable PLGA nanospheres - Development of high-performance electrochemical reactors - Barium titanate nanoparticles synthesized under sub and supercritical water conditions - Zeolite membrane - Development of new phosphors - Development of polymer-clay nanocomposites by dispersion of particles into polymer materials

Unit III: Nanobiology

Application of quantum dots for bio-medical engineering - Bio-imaging with quantum dots - Pinpoint drug and gene delivery - Delivery to the brain - Development of the thermoresponsive magnetic nanoparticle and its deployment in the biotechnology field - Addressing of nanoparticles by using DNA molecules - Nanoparticle formation of DNA (globule transformation) - Development and multi-functionalization of high-functional separation membranes - Design of nanoparticles for oral delivery of peptide drugs

Unit IV: Nanoengineering

AC overhead transmission line audible-noise reduction measures using surface improvement - Development of optical memory using semiconductor nanoparticles - Nozzle-free inkjet technology - Dendrimers and their application to organic electronics devices - Ceramic filter for trapping diesel particles - Microelectronics packaging by metal nanoparticle pastes - Dispersion of fine silica particles using alkoxysilane and industrialization

Unit V: Environmental and safety issues with nanoparticles

Nanoparticles and environment - Nanoparticles in atmospheric environment - Ground water environments and Nanoparticles - Nanoparticles in exhaust gases - Nanoparticles in wastewater - Indoor environments and nanoparticles - Industrial processes and nanoparticles ; Safety of nanoparticles- Problems caused by nanoparticles - Health effects on nanoparticles - Safety assessment for the nanoparticles ; Removal of nanoparticles - Principle of particle removal - Removal of nanoparticles suspended in gas - Removal of nanoparticles in liquid

Book for Study

1. Masuo Hosokawa, Kiyoshi Nogi, Makio Naito, Toyokazu Yokoyama (2007) Nanoparticle Technology Handbook, Elsevier Publishers.

Reference

1. William A. Goddard Ill, Donald W. Brenner, Sergey E. Lyshevski, Gerald J. Iafrate (2007) Handbook of Nanoscience, Engineering and Technology, CRC Press.
2. Vladimir P. Torchilin (2006) Nanoparticulates as Drug Carriers, Imperial College Press.
3. M. Reza Mozafari (2007) Nanomaterials and Nanosystems for Biomedical Applications, Springer.

PAPAER -III (Optional-2): Nanostructured Thin Films and Surface Physics

Unit I: Physics of Thin Films

Introduction: Overview of film growth - techniques and physics; Solid State Physics - crystal structure and defects - packing arrangements - close packed planes - thermodynamic vacancy concentration; Thermodynamics - change in free energy - Ellingham diagrams - phase diagrams:one component - triple point - binary solid solution - binary eutectic; Kinetics - Fick's Laws - Diffusion coefficient – Arrhenius plot; Nucleation and Growth: Homogeneous nucleation - critical radius - nucleation rate; Film formation: Trapping - capillarity model (heterogeneous nucleation) - Growth modes - island growth - zone models - columnar growth; plasma physics; Deposition parameters and their effects on film growth.

Unit II: Film Deposition

Vacuum - kinetic theory of gasses – flow – substrates – cleaning; Evaporation - basic steps, point versus surface sources purity – hardware; Sputtering - sputter yield – alloys – heating - methods: DC/RF- magnetron – reactive - ion assisted - ion sources - ion etching; MBE - epitaxial films - misfit - strain; CVD - reaction types - boundaries and flow - LPCVD, PECVD, LECVD, MOCVD.

Unit III: Film Characterization

Introduction – Film Thickness : Optical Methods for Measuring Film Thickness - Mechanical Techniques for Measuring Film Thickness; Chemical Characterization – Electron Spectroscopy – X-ray Energy Dispersive Analysis (EDX) – Auger Electron Spectroscopy (AES) – Rutherford Backscattering (RBS) – Secondary Ion Mass Spectroscopy.

Unit IV: Properties of Thin films

Optical Properties : n, k – metals – dielectrics – semiconductors - optics of transparent films-multiple coatings - effective medium theory; Electrical Properties: resistance/resistivity – metals - insulators – models - discontinuous films; Magnetic Properties : Hall effect complications, magnetoresistance, magnetic properties; Mechanical Properties : Stoney formula - thermal stress – relaxation.

Unit V: Surface Modification of Thin Films and Applications

Lasers and Their Interactions with Surfaces - Laser Modification Effects and Applications - Ion-Implantation Effects in Solids - Ion-Beam Modification Phenomena and Applications – Applications: Films for Magnetic Recording - Band-Gap Engineering and Quantum Devices – Thin Film Solar Cells.

Books for Study:

1. The Materials Science of Thin Films, Milton Ohring (1992) Academic Press.
2. Nanostructured Materials for Solar Energy Conversion, Edited by Tetsuo Soga (2006) Elsevier.

Books for reference:

1. Fundamentals of Vacuum technology, Walter Umrath (1998)
2. Hand book of thin film Technology, L. Meissel and Glang
3. Thin Film Phenomena, K. L. Chopra
4. Ultra thin Magnetic Structures III – Fundamentals of Nanomagnetism, J.A. C. Bland and B. Heinrich, Springer (2004) ISBN 3540219536
5. Thin Film Solar Cells, K. L. Chopra and S. R. Das
6. Vacuum Deposition of thin films, L. Holland
7. The Use of Thin Films in Physical Investigation, J. C. Anderson
8. Thin Film Technology, Berry, Koil and Horris

Paper-III (Optional-3): Nanocomposites and Biomaterials

Unit I: Materials For Life- Metals

Metallic biomaterials – Stainless steel, CoCr alloys, Titanium alloys. Dental metals, Corrosion of metallic implants. **Bioceramics**. Resorbable bioceramics, Non resorbable bioceramics, Bioactive ceramics and Synthesis of bioceramics. **Polymers**. Polymers as biomaterials, Chemogradient surfaces for cell interaction and surface modification for biocompatibility

Unit II: Nanocomposite Biomaterials

Structure – Properties, Anisotropy of composite materials, Particulate composite materials, Fibrous composite materials, Porous materials, Biocompatibility, Toxicity of Nanomaterials.
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Unit III: Biologic Biomaterials

Collagen-Structure and properties, biotechnology of collagen- Isolation, Purification and matrix Fabrication Technology-Design of Resorbable collagen based medical implants- tissue Engineering for tissue and organ- Cell-Biomaterials Interactions at micro and nanoscale.

Unit IV: Bone Biology and Scaffold Design

Biology of the skeleton system,.Bone physiology, Osteoblasts, Osteocytes, Organic and Inorganic Matrices, Signaling Molecules for Tissue Engineering, Design and Fabrication of Scaffolds. Artificial implants

Unit 5: Micro and Nano Systems in Biomedicine

Niosomes as nanocarriers Liposomes derived nanocarrier systems, New lipds and glycolipids for gene delivery, Release advantages of liposomal dendrimers

References:

1. **Biomaterials**, CRC Press, Taylor and Francise Group. Joyce Y. Wong, Joseph D. Bronzino
2. **Bone Tissue Engineering,** CRC Press. Jeffrey O. Hollinger, Thomas A. Einhorn, Bruce A. Doll and Charles Sefeir
3. **Nanomaterials and Nanosystems for Biomedical Applications,** Springer Publications. M. Reza Mozafari.
4. **Nanotoxicology Characterization, Dosingand Health Effects,** Nancy A. Monteiro-Riviere, C. Lang TranInforma HealthCare, New York, 2007

PAPER – III (Optional-4): Nanotechnology for Electrochemical Energy Systems

Unit I: Fundamentals of Electrochemical Principles and Electrochemical Techniques

Polaraizations- anodic and cathodic polaraizations - Butler –Volmer equations, Tafel equations- Tafel slope-three electrodes cell, reference electrodes, Galvanostatic polaraizations –Cyclic Voltammetry-Chronopotentiometric-Chronoamprometric techniques.

Unit II: Electrodeposition of Nanomaterials and Corrosion

Electrodeposition principles – electroplating of nanocrystalline metals and alloys – electroless plating of Nickel-Anodization and formation of self assembled alumina films, pulsed electrochemical deposition and synthesis of nanostructured materials by template process- corrosion potential, corrosion current density, corrosion rate, exchange current density, corrosion control – design, selection of corrosion resistant materials – nano coating for corrosion prevention, corrosion inhibitors, electrochemical techniques – polarization curves, Tafel extrapolation, linear polarization, AC impedance methods – electrochemical impedance spectroscopy .

Unit III: Nanomaterials for Batteries and Fuel Cells

Nanomaterials utilization in primary batteries- Dry Lechlanch cells- Alkaline batteries- Zn/Air, Lithium batteries. Nanomaterial utilization in secondary batteries - Lead Acid, Nickel Cadmium, Lithium ion Batteries and Fuel cells. Battery characteristics.

Unit IV: Nanotechnology for Solar Cells

Basic principles of solar cells and nanomaterials applications, Amorphous Silicon Solar cells, Photo electrochemical cells (PEC) for conversion of light energy to electrical energy, PEC cells based on nano CdSe and GaAs - Dye sensitiseded solar cells (DSSC) .

Unit V: Hydrogen Storage

Hydrogen storage for automotive applications – methods of storage – storing hydrogen as a gas, high pressure gas cylinders, liquid hydrogen storage, storage via chemical reactions, hydrogen in metals, metal hydrides, complex hydrides, hydrogen uptake in carbon nanotubes.

References:

1. D. Pletcher and F. C. Walsh, Industrial Electrochemistry, Chapman and Hall, London, 1990.
2. J. J. Moore, J. Dutta, G. L. Hornyak, H. F. Tibbals, Introduction to Nanoscience and Nanotechnology, CRC Press, 2008.
3. Mario Pagliaro, Giovanni Palmisano, and Rosaria Ciriminna, Flexible Solar Cells, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim. 2008.
4. D. R. Crow**,** Principles and Applications of Electrochemistry, CRC Press, 1994.

5. S. Rani, Electroanalytical Methods, MJP Publishers, 2008.
6. Ali Eftekhari (Ed.) Nanostructured Materials in Electrochemistry, WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, 2008.
7. Herbert H Uhlig and Winston Revie, Corrosion and Corrosion Control – An Introduction to Corrosion Science and Engineering, Third Edition, John Wiley & Sons, 1985.
8. Mars G. Fontana, Corrosion Engineering, Third Edition, McGraw Hill Inc., 1987.
9. Rajnarayan, Metallic Corrosion and Prevention, Oxford Publications, 1983.
10. B. Viswanathan and Aulice Sciboh, Fuel cells, Principles, and Applications, University Press (India) Ltd., 2006.
11. N.V. Parthasarathy, Electroplating Handbook, Prentice Hall, 1992.