Visvesvaraya Technological University, Belagavi.
PhD Coursework Courses – 2018 (Nano Technology)
As per 2017 Regulation

Group – 1		
Sl. No.	**Course Code**	**Course Name**
1	16INT153	Nano composites and Applications
2	16INT154	Industrial Applications of Nanotechnology
3	16INT21	Design and Fabrication Techniques
4	16INT424	Micro-Nano Packaging

Group – 2		
Sl. No.	**Course Code**	**Course Name**
1	16INT24	Characterization Techniques
2	16INT22	Nanoelectronics
3	16INT252	MEMS and NEMS
4	16INT152	Thin Film Technology

Group – 3		
Sl. No.	**Course Code**	**Course Name**
1	16INT254	Nanophtonics
2	16INT41	Nanomaterials and Energy Systems
3	16INT421	Advances in Nanodevices
4	16INT14	Nanobiotechnology

Group – 4		
Sl. No.	**Course Code**	**Course Name**
1	16INT13	Synthesis and Processing Techniques
2	16INT151	Micro and Nano Fluidics
3	16INT422	Nano bioelectronics and Applications

Group – 5		
Sl. No.	**Course Code**	**Course Name**
1	16INT251	Sensors and Actuators
2	16INT23	Advanced Materials
3	16INT253	Nanotechnology and Drug Delivery Systems

Group – 6		
Sl. No.	**Course Code**	**Course Name**
1	16INT11	Quantum Mechanics and Mathematical Modelling
2	16INT12	Nanomaterials and Properties
3	16INT423	Nanotechnology and Environment

01	16INT153	Group-1	Nano composites and Applications
Exam Hours: 3 hours			**Exam Marks(Maximum):100**

Module-1

Introduction to nanocomposites: Definition of composite material, Classification based on matrix and topology, Constituents of composites, Interfaces and Interphases, Distribution of constituents, Nano-composites. Advantage of composite materials, mechanical properties, Thermal, electrical and electronic and optical properties. Super hard nanocomposites-designing and mechanical properties - stress-strain relationship, toughness, strength, and plasticity.

Module-2

Ceramic metal nanocompsites: Ceramic based nanoporous composites, metal matrix nanocomposites, natural nano-bioccomposites, bio-mimetic nanocompostes and biologically inspired nanocomposites, nanocompsites for hard coatings, DLC coatings, thin film naocomposites, modelling of nanocomposites, synthesis of various nanocomposites materials sputtering mechanical alloying

Module-3

,**Polymer nanocomposites:** Introduction to polymer composites, Processing of nanoparticles, binding mechanisms in nanoparticles,dispersion of nanoparticles, and stabilization of nanoparticles. Processing and fabrication of polymer nanocomposites, Melt blending, solvent casting, In-situ polymerization, solution polymerization, template synthesis, high shear mixing. Homogeneous/heterogenous nucleation, plasma promoted nucleation. Polymer nanocomposites with structural, gas barrier and flame retardant properties, carbon fiber reinforced polymer composites, elastomer and thermoplastic elastomer nanocomposites for propulsion systems, water borne fire retardant nanocomposites, hybrid composites for cosmetics, protective and decorative

Module-4

Natural nanocomposite systems: Spider silk, bones, shells; organic–inorganic nanocomposite formation through self-assembly. Biomimetic synthesis of nanocomposite material; use of synthetic nanocomposites for bone teeth replacement. Bioactive nanocomoposites in bone grafting and tissue engineering, inorganic/polymer nanocomposites for dental restoration and bone replacement applications.

Module-5

Bio ceramics for implant coating: Calcium phosphates-hydroxyepatites Ti6Al4V and other

biomedical alloys, implant tissue interfacing-metal organic CVD-use of tricalcium phosphate-biomimetic and solution based processing- osteoporosis- osteo plastic, regeneration of bones by using bio compatible ceramics, bioninteractive hydro gels- PEG coating and surface modifications, PEG hydrogels patterned on

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbooks:

1. Nanocomposite science and technology by P.M.Ajayan, L.S. Schadler and P.V. Braun, Wiley-VCH GmbH Co. 2003.

2. Encyclopedia of Nanotechnology by H.S.Nalwa, American Scientific Publishers, 2003.

3. Metalopolymernanocomposites, Ed A.D. Pomogailo andV.N.Kestelman, Springer-Verlag, 2005.

4. Composite materials, K.K. Chawala, 2nd ed., (1987) Springer-Verlag, New York.

Reference Books:

1. Biomedical nanostructures by Kenneth E.Gonsalves, Craig R. Halberstadt, Cato T. Laurencin, Lakshmi S. Nair. John-Wiley & Sons, 2008.

2. Nanobiotechnology II: Edited by Chad A. Mirkin and Christof M. Niemeyer, Wiley-VCH, 2006.

02	16INT154	Group-1	Industrial Applications of Nanotechnology
Exam Hours: 3 hours			Exam Marks(Maximum):100

Module-1

Nanotechnology in Electrical and Electronics Industry: Advantages of nano electrical and electronic devices –Electronic circuit chips – Lasers - Micro and Nano-Electromechanical systems – Sensors, Actuators, Optical switches, Bio-MEMS –Diodes and Nano-wire Transistors - Data memory –Lighting and Displays – Filters (IR blocking) – Quantum optical devices – Batteries - Fuel cells and Photo-voltaic cells – Electric double layer capacitors – Lead-free solder – Nanoparticle coatings for electrical products

Module-2

Nanotechnology in Biomedical and Pharmaceutical Industry: Nanoparticles in bone substitutes and dentistry – Implants and Prosthesis - Reconstructive Intervention and Surgery – Nanorobotics in Surgery – Photodynamic Therapy - Nanosensors in Diagnosis– Neuro-electronic Interfaces – Protein Engineering – Drug delivery – Therapeutic applications

Module-3

Nanotechnology in Chemical Industry: Nanocatalyts – Smart materials – Heterogenous nanostructures and composites – Nanostructures for Molecular recognition (Quantum dots, Nanorods,Nanotubes) – Molecular Encapsulation and its applications – Nanoporous zeolites – Self-assembled Nanoreactors -Organic electroluminescent displays

Module-4

Nanotechnology in Agriculture and Food Technology: Nanotechnology in Agriculture -Precision farming, Smart delivery system – Insecticides using nanotechnology – Potential of nano-fertilizers - Nanotechnology in Food industry - Packaging, Food processing - Food safety and bio-security – Contaminant detection – Smart packaging

Module-5

Nanotechnology In Textiles And Cosmetics Nanofibre production: Electrospinning – Controlling morphologies of nanofibers – Tissue engineering application – Polymer nanofibers - Nylon-6 nanocomposites from polymerization - Nano-filled polypropylene fibers - Bionics– Swim-suits with shark-skin-effect,Soil repellence, Lotus effect - Nano finishing in textiles (UV resistant, antibacterial, hydrophilic, self-cleaning, flame retardant finishes) – Modern textiles (Lightweight bulletproof vests and shirts, Colour changing property, Waterproof and Germ proof, Cleaner kids clothes, Wired and Ready to Wear) Cosmetics – Formulation of Gels, Shampoos, Hair-conditioners (Micellar self-assembly and its manipulation) – Sun-screen

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
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- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbooks:

1. Mark A. Ratner and Daniel Ratner,Nanotechnology: A Gentle Introduction to the Next Big Idea, Pearson (2003). 10 NT – 12–13 – SRM – E&T

2. Bharat Bhushan,Springer Handbook of Nanotechnology, Barnes & Noble (2004).

3. Neelina H. Malsch (Ed.),Biomedical Nanotechnology, CRC Press (2005)

Reference Books:

1. Udo H. Brinker, Jean-Luc Mieusset (Eds.), Molecular Encapsulation: Organic Reactions in Constrained Systems,Wiley Publishers (2010).

2. Jennifer Kuzma and Peter VerHage, Nanotechnology in agriculture and food production, Woodrow Wilson International Center, (2006).

03	16INT21	Group-1	Design and Fabrication Techniques
Exam Hours: 3 hours			Exam Marks(Maximum):100

Module-1

The Science of Miniaturization: Miniaturization of Electrical and Electronic Devices, Moore's law and technology road map, Quantum Mechanical Aspects, Simulation of the Properties of Molecular Clusters,

Formation of the Energy Gap, Confinement Effects, Discreteness of Energy Levels, Tunneling Currents.

Module-2

Nanofabrication by Photons: Principles of Optical Projection Lithography, Process of Optical Lithography. Photoresists Characteristics. Optical Lithography at Shorter Wavelengths-Deep UV, Extreme UV and X-ray Lithography. Optical Lithography at HighNumerical aperture. Near-Field Optical Lithography

Module-3

Nanofabrication by Ion Beam: Introduction, Liquid Metal Ion Sources, Focused Ion Beam Systems, Ion Scattering in Solid Materials , FIB Direct Nanofabrication , Ion Sputtering, Ion Beam AssistedDeposition, Applications, Focused Ion Beam Lithography, Ion Projection Lithography.

Module-4

Nanofabrication by Scanning Probes: Introduction, Principles of Scanning Probe Microscopes, Exposure of Resists- Exposure of Resist by STM, Exposure of Resist by NSOM, Additive Nanofabrication, Field Induced

Deposition, Dip-Pen Nanolithography, Subtractive Nanofabrication-Electrochemical Etching, Field Induced Decomposition, Thermomechanical Indentation, Mechanical Scratching, High Throughput Scanning Probe

Module-5

Fabrication of micro/nanodevices: Microfluidic Devices - Microchannels, Microfilters,Microvalves, Micropumps, Microneedles, Microreserviors, Micro-reaction chambers. Lithium Ion Battery and Super

capacitors device fabrication, Operating and structure of Solar cells-CIGS solar cells, Dye-Sensitized solar

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbooks:

1. Guozhong Cao, Nanostructures & Nanomaterials Synthesis, Properties G; Z: Applications, World Scientific Publishing Private, Ltd., Singapore (2004).

2. W.R.Fahrner, Nanotechnology and Nanoelectronics – Materials, Devices, Measurement Techniques, SpringerVerlag Berlin, Germany (2006).

3. R. H. J. Hannink and A. J. Hill, Nanostructure control of materials, Woodhead Publishing Limited and

CRC Press LLC, Cambridge, England (2006).

4. Zheng Cui, Nanofabrication, Principles, Capabilities and Limits, Springer Science + business media, New York (2008).

ReferencesBooks:

1. Hari Singh Nalwa, Handbook of Nanostructured Materials and Nanotechnology(Vol. 3)- Electrical Properties, Academic Press, San Diego, USA (2000).

2. Huff, Howard, Into The Nano Era: Moore's Law Beyond Planar Silicon CMOS (Vol. 106), Springer Series in Materials Science, Springer-Verlag Berlin (2009).

3. Marc J. Madou, Fundamentals of Microfabrication: The Science of Miniaturization, 2nd Edition, CRC Press, California, USA (2002).

4. Kostya (Ken) Ostrikov and ShuyanXu, Plasma-Aided Nanofabrication: From Plasma Sources to Nanoassembly, WILEY-VCH Verlag GmbH & Co. KGaA (Weinheim) (2007).

04	16INT424	Group-1	Micro-Nano Packaging
Exam Hours: 3 hours			**Exam Marks(Maximum):100**

Module-1

Fundamentals of the Design and Packaging Process: Systems Engineering, Quality Concepts, Engineering Documentation, Design for Manufacturability, ISO9000, Bids and Specifications, Reference and Standards Organizations. Introduction to Micro and nano systems packaging, role of packaging as IC and device packaging, fundamentals of electrical package design, Single Chip, Multi-chip, IC assembly, and Wafer Level Packaging.

Module-2

Surface Mount Technology: Introduction, Surface Mount Device Definitions, Substrate Design Guidelines, Thermal Design Considerations, Adhesives, Solder Joint Formation, Parts, Reflow Soldering, Cleaning

and Prototype Systems. Direct Chip Attach - Overview of Die Assemblies, Known Good Die, Chip on Board,

Module-3

Circuit Boards:- Overview, Basic Circuit Board Design, Prototypes, DFM and DFT Issues, Board Materials, Circuit Design and Board Layout, Simulation, Standards.

Hybrid Assemblies: Introduction, Ceramic Substrates, Thick Film, Thin Film, Chip Resistors and Multilayer Ceramic Capacitors, Component and Assembly Packages, Buried Passive Circuit Elements,

Module-4

Interconnects: General Considerations, Wires for Interconnection, Single-Point Interconnects, Connectors,

Board Interconnects, Component Sockets, Fiber- OpticInterconnects and Connections, Coaxial Cable and

Interconnects, Microwave Guides and Couplers.

Thermal Management: Fundamentals of Heat, Engineering Data, Heat Transfer, Heat Removal/Cooling

Module-5

Inspection: General Inspection Criteria, Solder Paste Deposition Volume, Solder Joint Inspection Criteria, Visual Inspection, Automated Optical Inspection, Laser Inspection, X-Ray Inspection. Package/Enclosure: Introduction, Ergonomic Considerations, User Interfaces, Environmental Issues, Maintenance, Safety.

Electronics Package Reliability and Failure Analysis: Reliability, Micro-mechanisms of Failure in Electronic, Packaging Materials, Package Components, Failure Analyses of Electronic Packages, Thermal

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbooks: 1. The electronic packaging handbook edited by Glenn R. Blackwell, CRC Press LLC, 2000. 2. Fundamentals of microsystem packaging by Rao R. Tummala, McGraw-Hill, 2004.
Reference Books: 1. Micro- and Opto-Electronic Materials and Structures: Physics, Mechanics, Design, Reliability, Packaging by E. Suhir, Y.C. Lee, and C.P. Wong, Springer Science, 2007. 2. Nanopackaging: Nanotechnologies and Electronics Packaging by James E. Morris, Springer Science, 2008.

01	**16INT24**	**Group-2**	**Characterization Techniques**
Exam Hours: 3 hours			**Exam Marks(Maximum):100**
Module-1			
X-Ray based characterization: Principles and applications of X-ray diffraction, powder (polycrystalline) and single crystalline XRD techniques; Debye-Scherrer equation to treat line broadening and strain induced in nanoparticles and ultra-thin films. Basics ofstructure refinement (Reitveld).Rotating anode and synchrotron based X-ray diffraction for probing structure.X-ray photoelectron spectroscopy– basic principle, instrumentation, X-ray absorption techniques: XANES, EXAFS.			
Module-2			
Electron microscopy techniques: Introduction, Principles and applications of Electron beam, Electronbeam interaction with matter. Scanning electron microscopy (SEM/FESEM), transmission electron microscopy (TEM/HRTEM), Electron-diffraction, SAED. Scanning Probe Microscopy: Principles and applications,			
Module-3			
Spectroscopic techniques: UV-VISS pectrophoto meters, IR/FTIR Spectrophotometers, Principles, operation and application for band gap measurements. Raman spectroscopy principles and applications. Optical microscope: Nanoparticle size measurement by Dynamic light scattering methods zeta potential.			
Module-4			
Magnetic characterization: Types of magnetic materials, Magnetic susceptibility, Curie-Weis plot for paramagnetic materials, Neel temperature, Curie temperature VSM and SQUID magnetometers – M vsH, M vs T, MH-loops.			
Module-5			

Electrical measurements: Cyclic Voltameter, Impedence Measurement, IV, AC and DC electric measurements, impedance spectral information.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbooks:

1. Characterization of Nanostructure materials by XZ.L.Wang
2. Instrumental Methods of Analysis, 7 th edition- Willard, Merritt, Dean, Settle
3. Scanning Probe Microscopy: Analytical Methods (NanoScience and Technology)-Roland Wiesendanger

Reference Books:

1. X-Ray Diffraction Procedures: For Polycrystalline and Amorphous Materials, 2nd Edition
2. - Harold P. Klug, Leroy E. Alexander
3. Transmission Electron Microscopy: A Textbook for Materials Science (4-Vol Set)- David B. Williams and C. Barry Carter
4. Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM - Ray F. Egerton.

02	16INT22	Group-2	Nanoelectronics
Exam Hours: 3 hours			Exam Marks(Maximum):100

Module-1

Introduction to nanoelectronics: Technology roadmap of nano-electronics, Scaling of devices and technology jump, Challenge of the CMOS technologies, More-Moore and More-than-Moore. Review of semiconductor devices, Quantum statistical mechanics, Energy bands in silicon, Metal Oxide Semiconductor Field Effect Transistors (MOSFET), MOSFET Operation, Threshold Voltage and Subthreshold Slope, Current/voltage

characteristics, Finite Element Modeling of MOS, CMOS technology, Challenges of the CMOS technologies, High-k dielectrics and Gate stack, Future interconnect.

Module-2

Nanoscale MOSFETs: MOSFET as digital switch, Propagation delay, Dynamic and static power dissipation Moore's law, Transistor scaling, Constant field scaling theory, Constant Voltage Scaling, Generalized scaling, Short channel effects, Reverse short channel effect, Narrow width effect, Subthreshold conduction leakage, Subthreshold slope, Drain Induced Barrier Lowering, Gate Induced Drain Leakage, Design of NanoMOSFET, Halo implants, Retrograde channel profile, Shallow source/drain extensions, Twin well CMOS process flow, Gate Tunneling : Fowler Nordheim and Direct Tunneling, High k gate dielectrics,

Module-3

Designing with FINFETs: Evolution of FinFET, Principle of FinFET, Finfet Technology, FinFET Schematic, Compact Drain-Current equation, Small Signal Model of Si- Based FinFET, FinFET Fabrication Flow, Power dissipation in FinFETs, Leakage power reduction techniques, Power gating, Dual sleep, Dual stack, Sleepy stack, Basic gate design using FinFET's, combinational logic, sequential logic, Adders, Multiplier, SRAM cell design

Module-4

Designing with CNTFETs: Introduction to CNTs, CNT structure, metallic and semiconductor CNTs, energy bands in CNTs, types of CNTs: Single walled and multiwalled, physical, electrical and thermal properties of CNTs, fabrication of CNTs. CNTFETs, structure and model, small signal model, predictive

technology models, N-Channel and P-Channel CNTFET,smodel files of CNTFETs, basic gates using CNTFET, VI characteristics of CNTFET based inverter, designing of sub systems using CNTFETs,

Module-5

Advances in Nanoelectronics: Molecular Nanoelectronics: Electronic and optoelectronic properties of molecular materials, TFTs- OLEDs- OTFTs – logic switches, SPINTRONICS: Spin tunneling devices - Magnetic tunnel junctions- Tunneling spin polarization, -spin diodes - Magnetic tunnel transistor - Memory devices and sensors - ferroelectric random access memory- MRAMS

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.

- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbooks:

1. Yuan Taur and Tak H. Ning, Fundamentals of Modern VLSI Devices, Cambridge

2. Karl Goser, Peter Glosekotter, Jan Dienstuhl, ―Nanoelectronics and Nanosystems‖, Springer (2004)

3. Cyril Prasanna Raj P., Designing with FINFETs and CNTFETs, MSEC E-Publication (2016)

4. SadamichiMaekawa, ―Concepts in Spin Electronics‖, Oxford University Press (2006)

Reference Books:

1. V. Mitin, V. Kochelap, M. Stroscio, Introduction to Nanoelectronics, Cambridge University Press (2008)

2. Edward L. Wolf, ―Nanophysics and Nanotechnology: An Introduction to Modern Concepts in Nanoscience‖, Wiley-VCH (2006)

3. Streetman and Banerjee, Solid State Electronic Devices, Prentice-Hall

4. Rainer Waser, ―Nanoelectronics and Information Technology: Advanced Electronic Materials and Novel Devices, Wiley-VCH

03	16INT252	Group-2	MEMS and NEMS
Exam Hours: 3 hours			**Exam Marks(Maximum):100**

Module-1

Introduction to MEMS: Historical background of Micro Electro Mechanical Systems, Feynman' s vision, Nano Technology and its Applications Multi-disciplinary aspects, Basic Technologies, Applications areas, Scaling Laws in miniaturization, scaling in geometry, electrostatics, electromagnetic, electricity and heat transfer.

Module-2

Micro and Smart Devices and Systems: Principles Transduction Principles in MEMS Sensors: Micro sensors-thermal radiation, mechanical and bio-sensors, Actuators: Different actuation mechanisms - silicon capacitive accelerometer, piezo-resistive pressure sensor, blood

analyzer, conductometric gas sensor, silicon micro-mirror arrays, piezo-electric based inkjet print head,

Module-3

Materials and Micro manufacturing: Semiconducting Materials., Silicon, Silicon dioxide, Silicon Nitride, Quartz, Poly Silicon, Polymers, Materials for wafer processing, Packaging Materials Silicon wafer processing,

Module-4

Electrical and Electronics aspects: Electrostatics, Coupled Electro mechanics, stability and Pull- in phenomenon, Practical signal conditioning Circuits for Microsystems. Characterization of pressure sensors, RF MEMS. Switches varactors, tuned filters. Micromirror array for control and switching in optical communication,

Application circuits based on microcontrollers for pressure sensor Accelerometer Modeling using CAD

Module-5

Integration and Packaging of Microelectro mechanical Systems: Integration of microelectronics and micro devices at wafer and chip levels. Microelectronic packaging: wire and ball bonding, flip-chip. Micro system packaging examples, Testing of Micro sensors, Qualification of Mems devices

Question paper pattern:

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- Each full question is for 20 marks.
- There will be 2full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbooks:

1. G. K. Ananthasuresh, K. J. Vinoy, S. Gopalakrishnan, K. N. Bhat, V. K. Aatre, "Micro and Smart Systems", Wiley India, 2010.

2. T R Hsu, "MEMS and Microsystems Design and Manufacturing", Tata McGraw Hill, 2nd Edition, 2008

Reference Books:

1. Chang Liu, “Foundations of MEMS”, Pearson International Edition, 2006.

2. S. D. Senturia, “Micro System Design”, Springer International Edition, 2001.

04	16INT152	Group-2	Thin Film Technology
Exam Hours: 3 hours		Exam Marks(Maximum):100	

Module-1

Deposition Technologies: Introduction to thin films, background, definition, scope of studies, coating materials, applications in various fields; classification of deposition technologies – evaporative, glow discharge, gas phase, and liquid phase; application based deposition technique selection; contamination control and defect - material purity and selection, sources of contamination, substrate preparation techniques, defect measurement techniques.

Module-2

Vacuum and sputter technology: Vacuum technique kinetics of gases - speed, gas equation, collisions and interactions; Nucleation – gas/liquid/solid phases, homogenous, heterogeneous, and nucleation rate; Transport and pumping of gases; Pumping systems. Sputtering technology: Introduction, physical sputtering theory – energy dependence of sputtering, energy, and direction of sputtered atoms; Reactive sputtering; Plasma and sputtering systems: Deposition rates and efficiencies

Module-3

Plasma and thermal spraying technology: surface properties of plasma and thermal spray, process parameters

Module-4

Thin film deposition techniques: Physical vapor deposition (PVD) – process parameters, thermal and ebeam evaporation, evaporation of alloys and compounds films, reactive evaporation and safety features; Chemical vapor deposition (CVD) – conventional CVD methods: process adjustment, gas control system, leak testing,

gas and dopant flow control, and safety; metal-organic CVD (MOCVD): Physical and chemical properties of materials, organometallic source packaging, growth control features in MOCVD, leak control and cleanliness, advanced safety feature used in MOCVD; Ion beam deposition – introduction,

operational overview, and applications; Electrochemical methods – electroplating and electroless process;

Module-5

Metrology and polishing in thin-films: Typical metrology and inspection parameters -process steps,

measured attribute and metrology system; Film thickness measurement systems, resistivity measurement systems, stress measurement systems, defect inspections system in thin-films. Chemical mechanical

Question paper pattern:

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- Each full question is for 20 marks.
- There will be 2full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbooks:

1. Handbook of Thin-film deposition processes and techniques by Krishna Seshan, ISBN 0-8115-1442-5, Noyes Publication/William Andrew Publishing Company NY USA, 2002

2. Thin-Film Deposition: Principles and Practice by Donald L. Smith, ISBN-10: 0070585024 and ISBN-13: 978-0070585027, Publisher: McGraw-Hill Education, 1995.

3. Thin film Phenomena by K. L. Chopra, McGraw-Hill, New York, 1969.

4. Thermal Spray Fundamentals by P. Fauchais, J. Heberlein, and M. Boulos, Springer, New York, 2014).

01	16INT254	Group-3	Nanophtonics
Exam Hours: 3 hours			Exam Marks(Maximum):100

Module-1

Introduction to Nanophotonics: Nano photonics at a Glance, Multidisciplinary approach, Photons and Electrons: Similarities and Differences, Propagation, Nanoscale Optical Interaction, Free-Space Propagation, Confinement of Photons and Electrons, Nanoscale Confinement of Electronic Interactions.

Module-2

Quantum-Confined Materials and Characterization: Inorganic Semiconductors, Quantum Wells, Wires Dots, Rings, Manifestations of Quantum Confinement Dielectric Confinement Effect, Super lattices, Core-Shell Quantum Dots and Quantum Dot-Quantum Wells Quantum-Confined Structures as Lasing Media, Organic Quantum-Confined Structures, Characterization of Nanomaterials, Different techniques- X Ray, Electron Microscopy

Module-3

Photonic Crystals: Basics Concepts, Theoretical Modeling of Photonic Crystals, Features of Photonic Crystals, Methods of Fabrication, Photonic Crystal Optical Circuitry, non-linear Photonic Crystals, Photonic Crystal Fibers (PCF), Photonic Crystals and Optical Communications, Photonic Crystal Sensors.

Module-4

Nanolithography: Two-Photon Lithography, Near-Field Lithography, Near-Field Phase-Mask Soft Lithography, Plasmon Printing, Nanosphere Lithography, Dip-Pen Nanolithography, Nanoimprint Lithography, Photonically Aligned Nanoarrays.

Module-5

Silicon Photonic Applications: Communications and Interconnects, Radio-over-fibre (RoF) RF Applications, Nonlinear Optical Effects in Silicon and Applications, Silicon Amplifiers and Lasers, Wavelength Conversion, Sensing - Physical Sensors, Chemical Sensors, Biochemical Sensors, Integrated Lab-on-a-chip, Power Generation and Conversion, Information Technology, Sensor Technology, Nanomedicine.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbooks:

1. Paras N Prasad, Nanophotonics, Wiley Interscience, 2004

2. Graham T Reed, Silicon Photonics, John Wiely and Sons, 2008

3. David G. Bucknall. Nanolithography and patterning techniques in microelectronics, CRC Press,

02	16INT41	Group-3	Nanomaterials and Energy Systems
Exam Hours: 3 hours			Exam Marks(Maximum):100

Module-1

Renewable energy Technology: Energy challenges, nanomaterials and nanostructures in energy harvesting, developments and implementation of nanotechnology based renewable energy technologies, solar cell structures: quantum well and quantum dot solar cells, photo-thermal cells for solar energy harvesting, thin film solar cells, CIGS solar cells, Dye sensitized solar cells. Organic PV cells, Concentrated solar power (CSP): Reflective materials, absorptive coatings, thermal storage.

Module-2

Energy storage: Introduction, Battery types, Li-ion Battery, Battery components materials, cathodes, anodes, effect of Nanosize on energy storage and electrode materials performance. LIB for automobiles application, EV's, HEV, PHEV and power grid. Li Air battery, Li-Sulphur battery, Next generation battery and materials such as Na ion battery, Mg ion battery.

Module-3

Super capacitors: Introduction, Electrochemical energy storage, Electrochemical capacitors, Electrochemical double layer capacitor, electrode materials supercapacitors, Hybrid Nanostructures for supercapacitors-metal oxides, conducting polymers, Electrolytes for super capacitors, types of electrolytes.

Module-4

Hydrogen storage technology: Hydrogen production methods, purification, hydrogen storage methods and materials: metal hydrides and metalorganic framework materials, volumetric and gravimetric storage capacities, hydriding and dehydriding kinetics, high enthalpy formations and thermal management during hydriding reaction, multiple catalytic- degradation of sorption properties, automotive applications. Catalyst of hydrogen production, steam reforming & Water splitting, Nanoporous membranes for hydrogen separation.

Module-5

Fuel cell technology: Fuel cell principles, types of fuel cells (Alkaline Electrolyte, phosphoric acid, Molten carbonate, solid oxide and direct methanol and proton exchange fuel cells), Principle and operation of proton exchange membrane (PEM) fuel cell, materials and fabrication methods for fuel cell technology, micro fuel cell power sources, biofuels.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbooks:

1. D. Linden, Handbook of Batteries and Fuel Cells, Mcgraw-Hill, Noew York,1984

2. W. A. van Schalkwijk and B. Scrosati, Advances in Lithium- Ion Batteries, Kluwer Academic Publishers, Newyork, 2002

3. Linden , D. and Reddy , T.B. (2002) Handbook of Batteries , 3rd edn , McGraw - Hill , New York.

ReferenceBooks:

1. Crompton, T.R. (2000) Battery Reference Book, 3rd Edn, Newnes , Oxford .

2. K. E. Aifantis and S. A. Hackney and R. Vasant Kumar, High Energy Density Lithium Batteries, Wiley-VCH Verlag, 2009.

3. University of Cambridge (2005) DoITPoMS Teaching and Learning Packages,

http://www.doitpoms.ac.uk/tlplib/batteries/index.php

03	16INT421	Group-3	Advances in Nanodevices
Exam Hours: 3 hours		Exam Marks(Maximum):100	

Module-1

Nanoelectronic Devices: Nano-CMOS modelling, Nano-CMOS Predictive Technology Model, Mobility and Dopant Number Fluctuation Model, Random interface traps, Nano-CMOS Technology, Bottom-

Up approach for CMOS scaling, Low power adders.

Module-2

Nano Capacitors and Terahertz systems: Package-compatible high density nanoscale capacitors, Carbon nanostructures for display and energy, Nano antennas for energy conversion, Ballistic transistor logic for

Module-3

Memristors, Resistive switches and memory: Nanodevices: functions and Lienard equation, Sensing and writing operations of nanocross bar memory arrays, Complementary resistive switches, Memory cell using

memristor. Thermally actuated nanoelectromechanical memory

Module-4

CNT and Nanowire: Fabrication of single walled CNT, CNT for TFT, Yield improvement techniques for CNTFET, GaAs nanowires on Si Substrates, Tin Oxide Nanowires for Gas sensing, Cu Silicide Nanowires for Li-Ion Batteries, Zinc Oxide Nanowires for bio sensing, ZnO thin film transistors.

Module-5

Microfluidics and Lab-on-a-chip: Microfluidic Devices - Microchannels, Microfilters, Microvalves, Micropumps, Microneedles, Microreserviors, Micro-reaction chambers. Concepts and Advantages of Microfluidic Devices - Fluidic Transport - Stacking and Scaling – Materials for The Manufacture (Silicon, Glass, Polymers) - Fluidic Structures - Fabrication Methods - Surface Modifications - Spotting - Detection Mechanisms. Microcontact printing of Proteins-Strategies- printing types- methods and characterization-

Cell nanostructure interactions networks for neuronal cells. Applications in Automatic DNA sequencing. DNA

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbooks:

1. James E. Morris, Krzysztof Iniewski, Nanoelectronic Device Applications Handbook, CRC Press, Taylor& Francis Group, ISBN 9781138072596, 2017 (Selected Chapters)

2. Jun Li, Nianqiang Wu, Biosensors Based on Nanomaterials and Nanodevices, CRC Press, Taylog& Francis Group, 2014

Reference Book:

Challa S. S. R. Kumar, Nanodevices for the Life Sciences, Wiley-VCH Verlag GmbH, 2006

04	16INT14	Group-3	Nanobiotechnology
Exam Hours: 3 hours			**Exam Marks(Maximum):100**

Module-1

Fundamentals of Biotechnology: Basic terms in biotechnology, recombinant DNA technology, genetic engineering, gene cloning. Development of nanobiotechnology, timelines and progress. Basics of cell orgenells. Biomacromolecules- carbohydrates, lipids, proteins and nucleic acids, PHA, cyanophcin inclusion, magnetosome, alginates, bacteriophages, S-layer protein, bacteriorhodpsin. Biological building blocks; Sizes of building blocks and comparison with nanostructures.

Module-2

Nanostructures: DNA and protein based nanostructures, DNA origami, DNA nanotubes, polypeptide nanowire and protein nanoparticles, SAM, biological nanomotor. Nanoconjugates: DNA-gold nanoconjugates. DNA based nanoelectronics: immobilization of DNA on substrates, probing the electronic properties of single DNA molecules. Manipulation of DNA on metal surfaces.

Module-3

Interaction between biomolecules and nanoparticle surface: Different types of inorganic materials used for the synthesis of hybrid nano-bio assemblies, Application of nano in biology, nanoprobes for Analytical Applications - A new methodology in medical diagnostics and Biotechnology, Current status of Nanobiotechnology, Future perspectives of Nanobiology.

Module-4

Applications of nanomaterials: Drug delivery and gene delivery, Nanobiochips, biosensors.Nanomaterials in bone substitutes and dentistry. Polymeric nanofibres-tissue engineering, smart capsules, microemulsions, nano based cancer therapy, nanorobotics. Lotus leaf as a model self-cleansing system. Diatoms as example for silicon biomineralization. Biomechanical strength properties of Spider silk.

Module-5

Photoinduced Electron Transport in DNA: Electronic Devices Based on DNA Architecture, DNA

Nanowires, Charge Transport, DNA-Based Nanoelectronics, Electrical Manipulation of DNA on Metal

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbooks:

1. Nanobiotechnology: Bioinspired devices and materials of the future by OdedShoseyov, Ilan Levy. Humana Press 2010.

2. Bionanotechnology - Global Prospects by David E. Reisner, Taylor & Francis Group, LLC, 2009.

3. Nanotechnology in Drug Delivery by MelgardtM.deVilliers, PornanongAramwit, Glen S. Kwon, Springer-American Association of Pharmaceutical Scientists Press 2009.

Reference Books:

1. T. Pradeep , "NANO The Essential , understanding Nanoscience and Nanotechnology". Tata McGraw-Hill Publishing Company Limited, 2007.

2. Nancy A. Monteiro-Riviere, C. Lang Tran Nanotoxicology: Characterization, Dosing and Health Effects Published:July 25, 2007 by CRC Press

01	16INT13	Group-4	Synthesis and Processing Techniques
Exam Hours: 3 hours			**Exam Marks(Maximum):100**

Module-1

Physical Methods: Bottom-Up versus Top-Down; Top-down approach with examples. Ball milling synthesis, Arc discharge, RF-plasma, Plasma arch technique, Inert gas condensation, electric explosion of wires, Ion sputtering method, Laser pyrolysis, Molecular beam epitaxy and electrodeposition. Electro spinning, Physicalvapor Deposition (PVD) – Chemcial vapour Deposition (CVD) - Atomic layer Deposition (ALD) – Self Assembly- LB (Langmuir-Blodgett) technique.

Module-2

Chemical methods: Chemical precipitation methods- co-precipitation, arrested precipitation, sol-gel method, chemical reduction, photochemical synthesis, electrochemical synthesis, Microemulsions or reverse micelles, Sonochemical synthesis, Hydrothermal solvothermal, supercritical fluid process.

Module-3

Combustion and Solution Methods: Solution combustion process, spray pyrolysis method, flame spray pyrolysis, gas phase synthesis, gas condensation process, chemical vapor condensation. Fundamental aspects of VLS (Vapor-Liquid-Solid) and SLS (Solution-Liquid-Solid) processes – VLS growth of Nanowires – Control of the size of the nanowires – Precursors and catalysts – SLS growth – Stress induced recrystallization**.**

Module-4

Biological methods: Use of bacteria, fungi, Actinomycetes for nanoparticle synthesis, Magnetotactic bacteria for natural synthesis of magnetic nanoparticles; Mechanism of formation; Viruses as components for the formation of nanostructured materials; Natural and artificial synthesis of nanoparticles in microorganisms; Use of microorganisms for nanostructure formation, Role of plants in nanoparticle synthesis, synthesis of nanoparticles using proteins and DNA templates.

Module-5

Surface Modification of Nanoparticles: 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 - Development of new cosmetics based on nanoparticles - Development of functional skincare cosmetics using biodegradable PLGA

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbooks:

1. Guozhong Cao, "Nanostructures and Nanomaterials, synthesis, properties and applications", Imperial College Press, 2004

2. M.S. Ramachandra Rao, Shubra Singh, Nanoscience and Nanotechnology: fundamentals to Frontiers, Wiley 2013.

3. Introduction to Nanotechnology - Charles P. Poole Jr. and Franks. J. Qwens.

Reference Books:

1. Nanomaterials – A. K. Bandyopadhyay, New Age International Publishers, 2nd Edition, 2010

2. T. Pradeep , "NANO The Essential , understanding Nanoscience and Nanotechnology". Tata McGraw-Hill Publishing Company Limited, 2007.

3. C.A. Mirkin and C.M. Niemeyer, Nanobiotechnology- II, More Concepts and Applications, WILEY-VCH, VerlagGmb H&Co, 2007.

Additional Readings:

1. Hari Singh Nalwa - Encyclopedia of Nanotechnology.

2. Processing & properties of structural Naonmaterials by Leon L. Shaw (editor)

3. Chemistry of Nanomaterials : Synthesis, properties and applications by CNR Rao et.al.

4. Nanochemistry: A chemical approach to Nanomaterials Roayal Society of Chemistry, Ozin and Arsenault, Cambridge UK 2005,

5. Nanoparticles: From Theory to Applications, G.Schmidt, WileyWeinheim 2004.

02	16INT151	Group-4	Micro and Nano Fluidics

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Introduction: Fundamentals of kinetic theory-molecular models, micro and macroscopic properties, binary collisions, distribution functions, Boltzmann equation and Maxwellian distribution functions-Wall slip effects and accommodation coefficients, flow and heat transfer analysis of microscaleCouette flows, Pressure driven gas micro-flows with wall slip effects, heat transfer in micro-Poiseuille flows, effects of compressibility.

Pressure Driven Liquid Microflow: Apparent slip effects, physics of near-wall microscale liquid flows, capillary flows, electro-kinetically driven liquid micro - flows and electric double layer (EDL) effects, concepts of electroosmosis, electrophoresis and dielectro-phoresis.

Module-2

Laminar flow: Hagen-Poiseullieeqn, basic fluid ideas, Special considerations of flow in small channels, mixing, microvalves&micropumps, Approaches toward combining living cells, microfluidics and 'the body' on a chip, Chemotaxis, cell motility. Case Studies in Microfluidic Devices.

Ionic transport: Polymer transport – microtubule transport in nanotuble channels driven by Electric Fields and by KinesinBiomolecular Motors - Electrophoresis of individual nanotubules in microfluidic

Module-3

Fabrication techniques for NanofluidicChannels:Biomolecules separation using Nanochannels - Biomolecules Concentration using Nanochannels – Confinement of Biomolecules using Nanochannels.

Hydrodynamics: Particle moving in flow fields – Potential Functions in Low Renoylds Number Flow –

Module-4

Microfluidics and Lab-on-a-chip: Microfluidic Devices - Microchannels, Microfilters,Microvalves, Micropumps, Microneedles, Microreserviors, Micro-reaction chambers. Concepts and Advantages of

Microfluidic Devices - Fluidic Transport - Stacking and Scaling – Materials for The Manufacture (Silicon, Glass, Polymers) - Fluidic Structures - Fabrication Methods - Surface Modifications - Spotting - Detection Mechanisms. Microcontact printing of Proteins-Strategies- printing types- methods and characterization. Cell-nanostructure interactions networks for neuronal cells. Applications in Automatic DNA

Module-5

BioMEMS: Introduction and Overview, Bio-signal Transduction Mechanisms: Electromagnetic Transducers Mechanical Transducers, Chemical Transducers, Optical Transducers – Sensing and Actuating mechanisms (for all types). Case Studies in Biomagnetic Sensors, Applications of optical and chemical transducers. Ultimate Limits of Fabrication and Measurement, Recent Developments in BioMEMS and BioNEMS - An alternative approach to traditional surgery, Specific targeting of tumors and other organs for drug delivery, Micro-visualization and manipulation, Implantation of microsensors, microactuators and other components

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbooks:

1. Joshua Edel "Nanofluidics" RCS publishing, 2009.
2. PatricTabeling "Introduction to Microfluids" Oxford U. Press, New York 2005.
3. K. Sarit "Nano Fluids; Science and Technology", RCS Publishing, 2007.

Reference Books:

03	16INT422	Group-4	Nanobioelectronics and Applications
Exam Hours: 3 hours			Exam Marks(Maximum):100

Module-1

Bionanoelectronics: Introduction,Photoinduced Electron transport in DNA: Toward Electronic Devices Based on DNA Architecture, Effective Models for charge Transport in DNA Nanowires, Optimizing Photoactive Proteins for Optoelectronic, DNA Based Nanoelectronics, Electrical Manipulation of DNA on Metal Surfaces.

Module-2

Microfluidics Meets Nano: Introduction, Overview, Definition and History, Advantages of Microfluidic Devices, Concepts for Microfluidic Devices, Fluid Transport, Stacking and Sealing, Methods, Materials for the Manufacture of Microfluidic Components, Silicon, Glass, Polymers, Fluidic Structures, Fabrication Methods, Surface Modifications, Spotting, Detection Mechanisms.

Module-3

Nanoparticle-Biomaterial hybrid systems for Bioelectronic Devices and Circuitry: Introduction, Biomaterial- Nanoparticles Systems for Bio-electtronic and Biosensing Applications, Bioelectronic systems based on nanoparticle-Enzyme Hybrids, Bioelectronic Systems for sensing of biorecognition events on Nanoparticles, Biomaterial based Nanocircuitry, Protein based Nanocircuitry, DNA as Functional Template for Nanocircuitry

Module-4

DNA based Nanostructures : Overview, Introduction, Oligonucleotide-Enzyme Conjugates, DNA Conjugates of binding proteins, Noncovalent DNA Streptavidin Conjugates, Multifunctional Protein Assemblies, DNA Protein Conjugates in Microarray Technologies, Methods, Conjugation of Nucleic Acids and Protein, Immuno PCR, Supramolecular Assembly, DNA directed Immobilization, DNA template Electronics Sequence Specific Molecular Lithography

Module-5

Nanoparticle Molecular labels: Introduction, Immunogold Silver staining, Combined Fluroscent and Gold probes, Methodology, Choice of Gold and AMG Type , Iodization, Sensitivity, Applications for the microscopical detection of Nucleic acids, guidelines and laboratary protocols, Gold derivatives of other biomolecules, protein labeling, gold Cluster of conjugates of other small molecules, gold lipids: metallasomes, Larger Covalent particle labels, Gold Targeted to His Tags, Enzymes Metallography, Gold Cluster Nanocrystals, Gold Cluster Oligonucleotide Conjugate: Nanotechnology applications, DNA Nanowires, 3-D Nanostructured Mineralized Biomaterials, Gold Quenched molecular beacons, Other Metal

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Reference Books:

1. "Nanobiotechnology". Edited by C Niemeyer, Chad Mirkin, WILEY-VCH , ISBN 3-527-30658-7.

2. "Nanobiotechnology". Edited byOdedShoseyov, Ilan Levy, Humana Press Inc., ISBN 978-61737-830-0.

01	16INT251	Group-5	Sensors and Actuators
Exam Hours: 3 hours			**Exam Marks(Maximum):100**

Module-1

Fundamentals of sensors: Micro and nano-sensors, biosensor, packaging and characterization of sensors, method of packaging at zero level, and first level. Thermal energy sensors: temperature sensors, heat sensors, electromagnetic sensors, electrical resistance sensors, electrical current sensors, electrical voltage sensors, electrical power sensors, magnetic sensors, Mechanical sensors, pressure sensors, gas and liquid flow sensors, position sensors, chemical sensors, optical and radiation sensors- gas sensor.

Module-2

Sensor Characteristics and Physical Effects: Active and Passive sensors – Static characteristic: Accuracy, offset and linearity – Dynamic characteristic: First and second order sensors, Physical effects involved in Signal

Transduction: Photoelectric effect – Photodielectric effect, Photoluminescence Effect – electroluminescence effect – chemiluminescence effect, Doppler effect, Barkhausen effect, Hal effect – nernst / Ettinshausen effect, Thermoelectric effect – Peizoresistive effect – piezoelectric effect, pyroelectric effect, magneto-

Module-3

Sensor Architecture and Classification: Sensor characteristics: linearity, repeatability, hysteresis and drift. Sensor models in the time & frequency domains. Sensors for physical measurands: strain, force, pressure,

acceleration, flow, volume, temperature and biopotentials. Nano based Inorganic Sensors: One dimensional gas sensors: - gas sensing with nanostructured thin films, absorption on surfaces, metal oxide modifications by additives, surface modifications, Nano optical sensors, nanomechanical sensors, plasmon

Module-4

Actuators: What is an actuator, Transducing materials as a basis for actuator design, Energy domains and transduction phenomena, Transducer basics, The role of the actuator in a control system: sensing, processing and Actuation-Impedance matching. Emerging versus traditional actuator, Other actuator technologies - Electrostatic actuators, Thermal, Magnetic shape memory actuators, Piezoelectric actuators.

Module-5

Biological Sensors-2: Noninvasive Biosensors in Clinical Analysis. Applications of Biosensor-based instruments for the bioprocess industry. Application of Biosensors for environmental samples. Introduction to Biochips and their application to genomics. BIAcore, an optical Biosensor. Photo induced Electron Transport in DNA: Electronic Devices Based on DNA Architecture, DNA Nanowires, Charge Transport, DNA-Based Nanoelectronics, Electrical Manipulatio of DNA on Metal Surfaces, Nanostructured Biocompartments, DNA-Gold nanoconjugates.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2full questions (with a maximum of four sub questions in one full question) from each module.

- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbooks:

1. Nanotechnology enabled sensors by KouroushKalantar – Zadeh, Benjamin Fry, Springer Verlag New York, (2007)

2. Biosensing: International Research and Development, Jerome Schultz, MilarMrksich, Sangeeta N. Bhatia, David J. Brady, Antionio J. Ricco, David R. Walt, Charles L. Wilkins, Springer 2006

3. Sensors and signal conditioning, 2nd edition Ramon Pallas-Areny, John G. Webster John Wiley & Sons (2001).

Reference Books:

1. Handbook of Biosensors and Electronic Noses: Medicine, Food and the Environment: CRC-Press; 1 edition;1996.

2. D. L. Wise, Biosensors: Theory and Applications, CRC Press,1993.

3. Rao &Guha, Principles of Medical Electronics & Biomedical Instrumentation, Orient Longman.2001.

02	16INT23	Group-5	Advanced Materials
Exam Hours: 3 hours			Exam Marks(Maximum):100

Module-1

Crystal structure: Crystal systems, Crystal classes, Bravais lattice. Unit cell: Wigner-Seitz cell, equivalent positions in a unit cell. Notations of planes and directions. Atomic packing: packing fraction, Co-ordination number. Examples of simple crystal structures: NaCl, ZnS and diamond. Symmetry operations, point groups and space groups.

Module-2

Crystal bonding: Types of bonding. Van der Waals-London interaction,Repulsive interaction. Modelung constant. Born's theory for lattice energy in ionic crystals and comparison with experimental results. Ideas of metallic binding, Hydrogen bonded crystals. Vibrations of monoatomic lattices. First Brillouin zone. Quantization of lattice vibrations - Concept of Phonon, Phonon momentum. Specific heat of lattice (qualitative)

Module-3

Photonic Materials: Need for New Photonic Materials, composite materials for nonlinear optics, nanostructured waveguides for nonlinear optics quantum and nonlinear optics for advanced imaging applications. Spintronics Materials:Modeling the growth of Mn on semiconductor substrates, Dilute magnetic semiconductor nanocrystals, Advances in wide bandgap materials for semiconductor spintronics

Module-4

Smart Materials and Systems: Thermoresponsive materials, piezoelectric materials, electrostrictive and magnetostrictive materials, Magnetic materials, superparamagntism in metallic nanoparticles, Giant and colossal magnetic materials, ferrofluids, ER and MR fluids, biomimetic materials, smart gel, shape memory

Module-5

Advanced Materials in Catalysis: Bimetallic Catalysts, Supported Bimetallic Catalysts, Graphite Intercalation Compounds as catalysts, Carbides, Nitrides, and Borides for Catalysis, Synthetic Layered Silicates and

Alumino silicates; Complex Catalysts on Inorganic Supports.

Advanced materials in Biomedical Application: Zeolite Structures as Drug Delivery Systems,

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbooks:

1. Introduction to Solid State Physics, C. Kittel, Wiley Eastern
2. A practical approach to X-Ray diffraction analysis by C.Suryanarayana
3. Semiconductor Physics, P. S. Kireev, MIR Publishers.

Reference Books:

1. Solid State Physics, A. J. Dekkar, Prentice Hall Inc.
2. Introduction to Superconductivity, M. Tinkham, McGraw-Hill, International Editions
3. Elementary Solid State Physics: Principles and applications, M. A. Omar, Addison-Wesley.
4. Advanced Materials in Catalysis, Frank Bolz, Academic Press, 1977
5. Advanced Healthcare Materials Tiwari, A. (ed) (2014), John Wiley & Sons, Inc., Hoboken, NJ, USA.

03	16INT253	Group-5	Nanotechnology and Drug Delivery Systems
Exam Hours: 3 hours			**Exam Marks(Maximum):100**

Module-1

Principles of drug delivery systems (DDS): Design of drug delivery systems, Aims of DDS, Modes of drug delivery, ADME hypothesis – controlled drug delivery, site specific drugs , barriers for drug targeting, passive and active targeting, Strategies for site specific, time and rate controlled delivery of drugs, antibody based and metabolism-based targeting.

Module-2

Nano sized Drug Carriers: Structure and Preparation- Liposomes, Cubosomes andHexosomes, Solid Lipid Nanoparticles (SLP). Lipid based colloidal system, Liposomal Drug Carriers, Dendrimer (PAMAM), Polymer Micelle, Ceramic and Magnetic nanoparticle, Polymer drug conjugates. Nanotubes, Nanowires, Nanocage, Nanorods, Nanofibers, and Fullerenes, Carbon nanotubes biocompatibility. Smart drug delivery systems, Multifunctional Drug carriers, organic and inorganic composites. Problems with DDS, Drug loading efficiency in nanovehicles, complexity of Nanocarriers, interface between synthetic materials and biological

Module-3

Drug Discovery & Cancer therapy: Drug Discovery Using Nanocrystals, Drug Discovery Using Resonance Light Scattering (RLS) Technology. Nanosensors in Drug Discovery, Drug Delivery Applications, Nanorobots, Benefits of Nano-Drug Delivery. Use of microneedles and nanoparticles for local highly controlled drug delivery. Metal nanoparticles in drugs discovery. Nanotechnology for Cancer therapy-Nanobodies, Nanoparticles, nanoshells, Nanobombs, pebbles for brain tumor therapy, Targeting through angiogenesis and Folate Receptors Liposomal formulation in cancer therapy, application of liposomes in pharmaceutical

Module-4

Nanomedicines: Introduction, Applications of nanobiotechnology in medicine, Role of nanotechnology in methods of treatment, Nanomedicines for Nervous system, Developing Nanomedicines, Protocols for nanodrug Administration, Nanotechnology in Diagnostics applications, materials used in Diagnostics and Therapeutic applications - Molecular Nanomechanics, Molecular devices, Nanomedicines for Skin disorders, wound healing, eye diseases, infections Nanotubes for detection and destruction of bacteria

Module-5

Nanoanalytics: Nanoparticles for biological labelling, Nano-Imaging Agents, Nano particles molecular labels, Immunogold-silver staining, combined fluorescent and gold probes, Protein Labeling, gold cluster labelled peptides, gold cluster conjugates of other small molecules, gold-lipids metallosomes, Larger covalent particles labels, gold targeted to His Tabs, gold cluster nanoscrystals.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbooks:

1. Nanotechnology in Drug Delivery: Melgardt M. de Villiers, PornanongAramwit, glen s. Kwon, Springer, 2009

2. NanoBiotechnology: BionInspired Devices and Materials for the Future: OdedShoweyov, Ilan Levy, Humana Press, New Jersey 2010

3. Nanobiotechnology, Concepts applications and Perspectives: C. M. Niemeyer and Chad A.Mirkin, Wiley VCH, 2009

Reference Books:

1. Bionanotechnology Global prospects II: david E Reisner, CRC Press 2012

2. Nanoparticulate Drug Delivery Systems Deepak Thassu, Michel Deleers (Editor),Yashwant Pathak

3. Drug Delivery and Targeting, A.M.Hillery, CRC Press, 2002.

4. Bio-Applications of Nanoparticles Warren C.W. Chan

5. Lisa Brannon-Peppas, James O. Blanchette Nanoparticle and targeted systems for cancer therapy Advanced Drug Delivery Reviews 56 (2004) 1649– 1659

01	16INT11	Group-6	Quantum Mechanics and Mathematical Modelling

Exam Hours: 3 hours	Exam Marks(Maximum):100

Module-1

Introduction: Milestones in nanoscience and nanotechnology, Nanostructures and quantum physics, Layered nanostructures and superlattices, Nanoparticles andnanoclusters, Carbon-based nanomaterials. Wave-particle duality: Blackbody radiation, interaction of radiation with matter, photoelectric effect, Compton effect, wave-particle duality, De-Broglie's hypothesis, uncertainty relations, wave function, Schrodinger equation, Operators.

Module-2

Solutions of Schrodinger Equations: One-dimensional potential: Free electron in vacuum,electron in a potential well with infinite barriers, finite barriers and propagation of an electron above the potential well, Tunneling: propagation of an electron in the region of a potential barrier. Three-dimensional potential: Electron in a rectangular potential well (quantum box) and spherically-symmetric potential well, Quantum harmonic oscillators. Phonons

Module-3

Approximate methods and Quantum states in atoms and molecules: Stationary perturbation theory for a system with non-degenerate states and degenerate states. Non-stationary perturbation theory, quasi-classical approximation.Quantum states in hydrogen atom, emission spectrum, spin of an electron. Many-electron atoms: wave function of a system of identical particles, hydrogen molecule.

Module-4

Quantization in nanostructures: Number and density of quantum states, low-dimensional structures, Quantum states of an electron in low-dimensional structures, density of states for nanostructures, Double-quantum-dot structures (artificial molecules), electron in a periodic one-dimensional potential, one-dimensional superlattice of quantum dots, three-dimensional superlattice of quantum dots.

Module-5

Computational Modeling of Nanoparticles: Introduction, Benefits of Computer Science for

nanotechnology, modeling at different scales – electronic, atomistic, meso and continuum. Concept of computational modeling of nanostructures, computational control of matter through modeling – empirical and Abinitio potentials, molecular dynamics simulation, Monte Carlo simulation, advantages and limitations of MDS and MCS. Modeling of nanoparticles - electronic transport, mechanical properties, optical properties. Bionanoparticles and polymer nanocomposites. Opportunities and challenges in computer modeling of

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbooks:

1. Quantum Mechanics for Nanostructures, Vladimir V. Mitin, Dmitry I. Sementsov, Nizami Z. Vagidov. Cambridge University Press 2010.

2. Quantum Mechanics with applications to nanotechnology and information science. Yehuda B. Band, YshaiAvishai. Elsevier 2013.

3. Handbook of theoretical and computational Nanotechnology" eds. Michael Rieth and wolfram schommers, 2006.

4. Computational physics, R. C. Verma, K. C. Sharma & P. K. Ahluwalia.

02	16INT12	Group-6	Nanomaterials and Properties
Exam Hours: 3 hours			**Exam Marks(Maximum):100**

Module-1

Introduction to nanoscience and nanotechnology: History, background scope and interdisciplinary nature of nanoscience and nanotechnology, scientific revolutions. Definition of Nanometer, Nanomaterials, and

Nanotechnology. Concepts of nanotechnology - size dependent phenomena, surface to volume ratio, atomic structure, molecules and phases, energy at the nanoscale molecular and atomic size.

Module-2

Classification of Nanostructures: Zero dimensional, one-dimensional and two dimensional nanostructure materials. Clusters of metals, semiconductors, ceramics and nanocomposites. Size effect on shapes, Quantum dots, Nanorods, nanowires, nanotubes, nanosheets, nanocones, Nanotetrapods, Nanoflowers, nanobrushes, nano and mesopores, Core-Shell nanoparticles, misnomers and misconception of nanotechnology, importance of nanoscale materials and their devices

Module-3

Properties of Nanomaterials: Mechanical properties, Nano size effect on strength, fracture toughness and fatigue behaviour. Bulk Properties ofMaterials, electrical conductivity, Dielectric properties, Thermal properties, thermal conductivity, heat capacity. Magnetic properties, Magnetic materials, domains inMagnetic

Module-4

Electronic and Optical Properties: Electronic structure of Nanomaterials, magic numbers, Fermi surface, Size effect on Electron-Phonon Coupling, Size effect on physical properties. Optical properties,Optoelectronic properties of bulk and nanostructures, relation between optical properties and electronic structure of nanomaterials – Catalytic property Catalysis by Gold Nanoparticles.

Module-5

Types of Nanomaterial: Metal nanoparticles, Ceramics nanomaterials, Semiconductor nanoparticles, Metal oxides nanoparticles, Carbon based nanostructures, Graphene, Carbon Nanotubes, Fullerenes, Importance of these nanomaterials and their applications.

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbooks:

1. Edward L. Wolf, "Nanophysics and Nanotechnology - An Introduction to Modern Concepts in Nanoscience" Second Edition, John Wiley & Sons, 2006.

2. M.S. Ramachandra Rao, Shubra Singh, Nanoscience and Nanotechnology: fundamentals to Frontiers, Wiley 2013

3. Nanostructures and Nanomaterials synthesis, properties and applications, g. Cao, Imperial College press 2004.

Reference Books:

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

2. Nanotechnology – Basic Science & Emerging Technologies, Chapman & Hall/CRC 2002

3. Nanomaterials – A. K. Bandyopadhyay, New Age International Publishers, 2nd Edition, 2010

03	16INT423	Group-6	Nanotechnology and Environment
Exam Hours: 3 hours			**Exam Marks(Maximum):100**

Module-1

Environmental Application of Nanomaterials: Metal oxide nanoparticles organic contamination remediation, Nanoactive materials, Advanced photocatalyst, removal organic contamination from waste water using Nanomaterials based photocatalyst. Nanostructure electrode for Electrochemical oxidation.

Module-2

Nanostructure catalytic materials: Nanostructured metals like Pt, Pd and Fe, nanostructured ceramics like silica, silicate and alumina, pillared clays, colloids and porous materials. Nanomaterials as catalyst for exhaust gas treatment such as CO 2 , H 2 S, Pb, NO.

Module-3

Nanomaterials as Adsorbents: Meosoporous materials-synthesis and characterization, properties and application with suitable examples, unipore size, bimodal pore size. Nanoporous materials- synthesis and application. Adsorption at the Oxide Nanoparticles/Solution Interface, Nanomaterial-Based Removal of nanoparticles-Principle of particle removal - Removal of nanoparticles suspended in gas - Removal of nanoparticles in liquid. Adsorption of hazardous chemicals by metal oxide nanoparticles, Adsorption of chemical warfare agents by metal oxide nanoparticles. Nanomaterials as adsorbents for Heavy metal removal from water and Wastewater Treatment, Nanomaterials for GroundwaterRemediation- Reactivity, Fate, and Lifetime, Delivery, and Transport Issues

Module-4

Nanotoxicology: Health effects on nanoparticles - Inhalation of nanomaterials–overview, Nanoparticle exposure and systematic cardiovascular effects. Respiratory particulate matter exposure and cardiovascular toxicity, Toxicity of different nanomaterials, Toxicological assessment of nanoparticles: Toxicity of polymeric nanoparticles.Ecotoxicological Impacts of Nanomaterials. Nanoparticles in atmospheric environment, Ground water environments,Waste water and in exhaust gases - Industrial processes and nanoparticles. Safety of nanoparticles- Problems caused by nanoparticles - Safety assessment for the nanoparticles.

Module-5

Cleanroom basics, hazards, and safety: Basics of cleanroom classification and ISO standards, sources of particulate contamination, clean air devices, special construction materials for cleanroom, and surface

finishes. The HEPA filters and filtration process in the clean rooms. Parameters control in cleanrooms: temperature, RH, air volume and velocity, pressurization, and differential pressure. Potential hazards in cleanrooms: Fire, explosions, toxicity, and physical hazards. Cleanroom operational and behavioural requirement. Material handling issues: DI water, solvents, cleaners, ion implantation sources, diffusion sources, photoresists, developers, metals, dielectrics, toxic gases, flammable, corrosive, and packaging materials. Types

Question paper pattern:

- The question paper will have ten questions.
- Each full question is for 20 marks.
- There will be 2full questions (with a maximum of four sub questions in one full question) from each module.
- Each full question with sub questions will cover the contents under a module.
- Students will have to answer 5 full questions, selecting one full question from each module. ■

Textbooks:

1. Glen E. Fryxell, Guozhong Cao, Environmental Applications of Nanomaterials: Synthesis, Sorbents and Sensors.

2. Mark R. Wiesner, Jean-Yves Bottero, Environmental Nanotechnology: Applications and Impacts of Nanomaterials

3. J. B Park, "Biomaterials Science and Engineering", Plenum Press, New York, 1984.

4. P.P. Simeonova, N. Opopol and M.I. Luster, "Nanotechnology - Toxicological Issues and Environmental Safety", Springer 2006.

Reference Books:

1. J.J. Davis, Dekker, "Encyclopedia of Nanoscience and nanotechnology".

2. Dracy J. Gentleman, Nano and Environment: Boon or Bane? Environmental Science and technology, 43 (5), P1239, 2009

3. VinodLabhasetwar and Diandra L. Leslie, "Biomedical Applications of nanotechnology", A John Willy & Son Inc, N.J, USA, 2007.

4. Cleanroom Technology: Fundamentals of Design, Testing, and Operation by William White, Print ISBN 0-471-86842-6, John Wiley & Sons Ltd, 2001

5. Hazardous Waste Management by Michael D. LaGrega, Reissue edition, ISBN-13: 978-1577666936, Waveland Press Inc., 2010