M.Tech. Programme in 'Nanoscience and Technology'

Departments of Physics and Chemistry, IIT Patna

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1. About the programme :

Nanoscience and technology has emerged recently as a promising area in the knowledge bank with lots of scope for innovation to address the challenging problems faced by science, society and humanity. It is basically the study and manipulation of matter properties at sub-micron scale for technological applications in general and challenging applications in particular. It deals with fundamentals and applications of material systems/structures having at least one dimension in the size ranging from 1 nm – 100 nm (nanoscale). It is an interdisciplinary branch of knowledge representing confluence of conventional disciplines like Physics, Chemistry, Material Science, Biology, Medicine, etc. at the nanoscale. This in turn has tremendously impacted our approach towards science and technology in a fundamental way. Modern synthetic chemistry has made it possible to prepare molecules and molecular assemblies with desired morphologies. At the same time, developments in Physics and allied disciplines have provided tools to engineer, visualize and manipulate matter at nanoscale. New properties emerge at the nanoscale which acts as a drive for innovation and in turn holds a key to global economic vitality. The program is designed to provide in-depth knowledge in the fundamental aspects of nanoscience and technology with an emphasis on synthesis, visualization and manipulation at the nanoscale. It is expected to prepare students for careers in nanomaterials, nanobiotech, and nanoelectronics industries. The courses will be conducted by faculty from Physics and Chemistry Departments. Moreover, experts from industry and academia (both within India as well as abroad) will be frequently invited as guest lecturers for developing a broader perspective on the subject keeping in mind the latest industry requirements.

2. Course structure and Syllabus

2.1 Name of the courses:

- **Core Courses**
  1. NT501: Concepts of Nanomaterials (3-0-0-6)
  2. NT502: Analytical Techniques (3-0-0-6)
  3. NT503: Nanoscale Measurement and Analysis Laboratory (0-0-6-6)
  4. NT504: Topical Seminar I (0-0-4-4)
  5. NT511: Design and Synthesis of Nanomaterials (3-0-0-6)
  6. NT512: Nanoscale Devices (3-0-0-6)
  7. NT513: Nanomaterial Synthesis and Device Fabrication Laboratory (0-0-6-6)
  8. NT514: Topical Seminar II (0-0-4-4)
  9. NT601: Project I (0-0-40-40)
  10. NT602: Comprehensive (0-0-0-10)
  11. NT611: Project II (0-0-45-45)

- **Elective Courses (Elective I –III)**
    1. PH501: Thin Film Technology (3-0-0-6)
    2. PH502: Nanomaterials for Solar Energy and Photovoltaics (3-0-0-6)
    3. PH503: Nanophotonics (3-0-0-6)
    4. PH504: Computational Nanoscience (3-0-0-6)
    5. CH501: Nanobiotechnology (3-0-0-6)
    6. CH502: Supramolecular Chemistry (3-0-0-6)
- **Elective Courses (Elective IV –VI)**
    1. CH511: Theory and Modelling in Nanoscience (3-0-0-6)
    2. CH512: Nanotechnology for Medical Diagnostics and Therapy (3-0-0-6)
    3. PH511: Nanoelectronics (3-0-0-6)
    4. PH512: Nanoionics: Concepts and Technological Applications (3-0-0-6)
    5. PH513: Magnetism at Nanoscale (3-0-0-6)
    6. PH514: Nanoscopic Dielectric and Ferroelectric Phenomena (3-0-0-6)

2.2 Course Curriculum :

1ST SEMESTER

Sl. no.	**Course Number**	**Course Title**	**L**	**T**	**P**	**C**
1	NT501	Concepts of Nanomaterials	**3**	**0**	**0**	**6**
2	NT502	Analytical Techniques	**3**	**0**	**0**	**6**
3		Elective I	**3**	**0**	**0**	**6**
4		Elective II	**3**	**0**	**0**	**6**
5		Elective III	**3**	**0**	**0**	**6**
6	NT503	Nanoscale Measurement and Analysis Laboratory	**0**	**0**	**6**	**6**
7	NT504	Topical Seminar–I	**0**	**0**	**4**	**4**
		TOTAL	**15**	**0**	**10**	**40**

2ND SEMESTER

Sl. No	**Course Number**	**Course Title**	**L**	**T**	**P**	**C**

1	NT511	Design and Synthesis of Nanomaterials	**3**	**0**	**0**	**6**
2	NT512	Nanoscale Devices	**3**	**0**	**0**	**6**
3		Elective IV	**3**	**0**	**0**	**6**
4		Elective V	**3**	**0**	**0**	**6**
5		Elective VI	**3**	**0**	**0**	**6**
6	NT513	Nanomaterial Synthesis and Device Fabrication Laboratory	**0**	**0**	**6**	**6**
7	NT514	Topical Seminar–II	**0**	**0**	**4**	**4**
		TOTAL	**15**	**0**	**10**	**40**

3RD SEMESTER

Sl. No	**Course Number**	**Course Title**	**L**	**T**	**P**	**C**
1	NT601	Project I				**40**
2	NT602	Comprehensive Viva				**10**
		TOTAL				**50**

4TH SEMESTER

Sl. No	**Course Number**	**Course Title**	**L**	**T**	**P**	**C**
1	NT611	Project II				**45**
		TOTAL				**45**

TOTAL CREDITS: 40+40+50+45 = 175

2.3 Detailed syllabus:

Course Name	**Concepts of Nanomaterials**
Course Number	NT501 (Core)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

PROPOSED CONTENTS

Nanomaterials in daily life with examples (GMR read heads, NEMS goniometers, health care, energy materials, etc); Foundations of Quantum and Statistical Mechanics for nanomaterials, idea of tunneling, bound state and scattering, notion of quasiparticles, Light matter interaction; DOS, Bose-Einstein and Fermi-Dirac Statistics; Properties of individual nanostructures; Bulk nanostructured materials; Selection rules and spectroscopic techniques; Size and dimensionality effects; Quantum confinement; Properties dependent on density of states; Single electron tunneling; current-induced forces, current-induced heating and electromigration in nanowires; nanotribology; carbon based nanomaterials; biological materials and biomimetic strategies for nanosynthesis; magnetic nanomaterials; nanodevices and nanomachines.

TEXT BOOKS:

1. Introductory Nanoscience, by Masuro Kuno, Garland Science (2011).
2. Introduction to Nanotechnology, by Poole and Owen, Wiley Indian Edition (2010).
3. Nanophysics and Nanotechnology, by Edward L. Wolf, Wiley-VCH (2006).

REFERENCE BOOKS:

1. Nanotechnology, By Lynn E. Foster, Pearson (2011).
2. Quantum Mechanics, by J. J. Sakurai.
3. Statistical Mechanics, by Kerson Huang.
4. Fundamentals and Applications of Nanomaterials, by Z. Guo and Li Tan
5. Nanoelectronics and Information technology, by Rainer Waser, Wiley-VCH (2005).

Course Name	**Analytical Techniques**
Course Number	NT502 (Core)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

PROPOSED CONTENTS

Ellipsometer; Surface profile analysis; Scanning Probe Microscope (AFM and STM); Auger Electron Spectroscopy; Scanning Electron Microscopy; Transmission Electron Microscopy; Energy Disperssive Spectrum; Confocal Microscope; Kerr Microscope; Ferromagnetic Resonance Microscope, X-ray Diffraction; Small Angle X-ray Scattering; High Power X-ray (Syncrotron) Diffraction; Neutron Diffraction, Microprobe station, Impendance measurement, Electrical transport measurement (ac and DC conductivity, TEP measurement), Magnetic transport properties characterization, Vibrating Sample Magnetometer, SQUID, Electron Spin Resonance, UV-VIS Spectrophotometer; FT-IR Spectrophotometer; Micro-raman Spectrometer; Thermal Gravimetric Analysis (TGA);

*Differential thermal analysis (*DTA); *Differential scanning calorimetry (DSC)*; BET surface area analyzer; Dynamic Light Scattering; Differential Mechanical Analysis (DMA); *Universal testing machine (*UTM).

Text Books:

1. Nanoscale Characterization of Surfaces and Interfaces, N. John DiNardo , Wiley, September 2008
2. A. D. Helfrick and W. D. Cooper, Modern Electronic Instrumentation and Measurement Techniques, PHI (1996).
3. Nanoscale Handbook of microscopy for Nanotechnology, Nan Yao (Princeton univ. USA) and ZHONG LIN WANG (Georgia Institute of tech. USA), Kluwer academic publisher (2005).
4. Transmission Electron Microscopy and Diffractometry of Materials by Brent Fultz and James M. Howe (Nov 1, 2009).
5. Modern Spectroscopy, J. Michael Hollas, Willey, 2004.
6. Elements Of X Ray Diffraction(Kindle Edition) by B. D Cullity, S.R. Stock, Prentice Hall; 3 edition (February 15, 2001)

Reference Books:

1. D. A. Skoog, F. J. Holler and T. A. Nieman, Principles of Instrumental Analysis, Saunders College Publishers (1998).
2. X- Ray and Neutron Diffraction in Nonideal Crystals, X- Ray and Neutron Diffraction in Nonideal Crystals, Springer-Verlag Telos, 2004
3. Neutron and X- Ray Spectroscopy (Paperback) By Francoise Hippert, Erik Geissler, Jean Louis Hodeau, Springer, 2001.
4. High-Resolution Electron Microscopy (Monographs on the Physics and Chemistry of Materials) [Paperback] John C. H. Spence. Oxford science publications, 2009.

5. Scanning Electron Microscopy and X-ray Microanalysis by Joseph Goldstein, Dale E. Newbury, David C. Joy and Charles E. Lyman (Feb 2003), Springer.

Course Name	**Design and Synthesis of Nanomaterials**
Course Number	NT511 (Core)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

PROPOSED CONTENTS

Chemical Routes for Synthesis of Nanomaterials: Chemical precipitation and co-precipitation; Sol-gel synthesis; Microemulsions or reverse micelles; Solvothermal synthesis; Thermolysis routes, Microwave heating synthesis; Sonochemical synthesis; Photochemical synthesis; Synthesis in supercritical fluids.

Metal Nanoparticles: Size and shape control of metal Nanoparticles and their characterization; Study of their properties: Optical, electronic, magnetic; Surface plasmon band and its application; Role in catalysis, Alloy Nanoparticles,

Semiconductor Nanoparticles: Size and shape control of semiconductor Nanoparticles and their characterization; Study of their properties: optical and electronic and its application; Synthesis and application of Core-Shell structured semicoductor nanoparticles (Type I and Type II).

Organic nanoparticles: Size and shape control of nanoparticles and their characterization; inorganic-organic hybrid nanoparticles**;** Nanopolymers: Preparation and characterization of diblock Copolymer based nanocomposites; Applications of Nanopolymers in Catalysis

Top-down techniques: photolithography, other optical lithography (EUV, X-Ray, LIL), particle-beam lithographies (e-beam, FIB, shadow mask evaporation), scanning probe lithographies.

TEXT BOOKS:

1. Nanochemistry: A Chemical Approach to Nanomaterials, Geoffrey A. Ozin, Andre C. Arsenault, Royal Society of Chemistry, Cambridge, UK, 2005.
2. Chemistry of nanomaterials : Synthesis, properties and applications C. N. R. Rao, Achim Muller, A. K Cheetham, Wiely-VCH, 2004
3. Metal Nanoparticles: Synthesis Characterization & Applications, Daniel L. Fedlheim, Colby A. Foss, Marcel Dekker, 2002
4. Nanostructures and Nanomaterials - Synthesis, Properties and Applications - Cao, Guozhong, ying Wang, World Scientific, 2011

Course Name	**Nanoscale Devices**
Course Number	NT512 (Core)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

PROPOSED CONTENTS

Challenges in Nanoscience & Nanotechnology, Quantum mechanical, Physical and Biological aspects of Nanoscience & Technology, Nanodefects, Nanolayers and Nanostructuring, Growth and Fabrication of Nanostructures, Electron transport in nanostructures, Nanostructured electronic devices, Nano tunneling devices, Self organization phenomena at nanocrystal surfaces, Engineering of complex nanostructures, Quantum dot nanostructures for single electron devices, Carbon nanotubes and carbon electronics, Quantum electronic devices (QEDs), Organic electronics, Complex integrated systems and information processing at nanoscale, Limits of integrated systems and nanodevices, Concept of heterostructure devices (e.g.; oxide heterostructures, photovoltaics, sensors, actuators, quantum dot heterostructure lasers etc.), Nano-MEMS, Introduction to quantum computation and soft computing.

TEXT BOOKS

1. Nanoscience and Nanotechnology in Engineering, V. K. Vardan et. al., World Scientific, 2010.

2. Introduction to Nanotechnology & Nanoelectronics: Materials, Devices and Measurement Techniques, W. R. Fahrner, Springer, 2005.
3. Introduction to Nanoelectronics : Science, Technology, Engineering & Applications, V. V. Mitin, V. A. Kochelap, M. A. Satroscio, Cambridge University Press, 2008.
4. Nanoelectronics and Nanosystems, K. Goser, P. Glosekotter, J. Dienstuhi, Springer, 2005.
5. Nanostructures, V. A. Shchukin, N. N. Ledentsov, D. Bimberg, Springer, 2007.
6. Semiconductor LASERS I & II: Fundamentals, E. Kapon, Academic Press (Indian edition), 2006.

REFERENCE BOOKS

1. Optical Materials, John H. Simmons and Kelly S. Potter, Academic Press (Indian edition), 2006.
2. Electronic Properties of Materials, Rolf E. Hummel, Springer (3rd edition)
3. Energy Storage, R. A. Huggins, Springer, 2010.
4. Fundamentals of Photovoltaic Modules and their Applications, G. N. Tiwari, S. Dubey & Julian C. R. Hunt, RSC Energy Series, 2009.

Course Name	**Thin Film Technology**
Course Number	PH501 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

PROPOSED CONTENTS

Introduction to thin films, Technology as a drive and vice versa; Structure, defects, thermodynamics of materials, mechanical kinetics and nucleation; grain growth and thin film morphology; Basics of Vacuum Science and Technology, Kinetic theory of gases; gas transport and pumping; vacuum pumps and systems; vacuum gauges; oil free pumping; aspects of chamber design from thin film growth perspectives; various Thin film growth techniques with examples and limitations; Spin and dip coating; Langmuir Blodgett technique; Metal organic chemical vapor deposition; Electron Beam Deposition; Pulsed Laser deposition; DC, RF and Reactive Sputtering; Molecular beam epitaxy; Characterization of Thin films and surfaces; Thin Film processing from Devices and other applications perspective.

TEXT BOOKS:

1. Materials Science of Thin Films Deposition and Structure, Milton Ohring.
2. Thin Film Solar Cells, Chopra and Das
3. Thin Film Deposition: Principles and Practice, Donald Smith.

REFERENCE BOOKS:

1. Handbook of Thin Film Deposition (Materials and Processing Technology), Krishna Seshan.
2. Handbook of Physical Vapor Deposition, D. M. Mattox.

Course Name	**Nanomaterials for Solar Energy & Photovoltaics**
Course Number	PH502 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

PROPOSED CONTENTS

Solar radiations as a source of energy and mechanism for its entrapment; Measurements and limits of solar energy entrapment; Flat plate collectors and solar concentrators; Solar energy for industrial process heat (IHP) and design of solar green house; Solar refrigeration and conditioning; Solar thermo-mechanical power;

Introduction of energy storage/conversion devices, State-of-the art status of portable power sources, Solar/photovoltaic (PV) cells as a source of green energy; Fundamentals, Materials, Design and Implementation aspects of PV energy generation and consumption; Solar cell technologies (Si-wafer based, Thin film, GaAs based, dye-sensitized, PESC and organic solar cells), Efficiency of solar cells and PV array analysis, Photovoltaic system design (stand alone and grid connected) and applications; Balance of system (BOS) with emphasis on role of storage batteries; Cost analysis, Case study for performance evaluation and problem identification in wide-spread commercialization of the technology.

TEXT BOOKS

1. Solar Energy: Fundamentals & Applications; H. P. Garg and J. Prakash; Tata McGraw Hill, 1997.
2. Fundamentals of Photovoltaic Modules and their Applications, G. N. Tiwari, S. Dubey & Julian C. R. Hunt, RSC Energy Series, 2009.
3. Solar Photovoltaics: Fundamentals, Technologies and Applications (2nd ed.), C. S. Solanki, Prentice Hall of India, 2011 (ISBN: 978-81-203-4386-6)
4. Solar Cell Device Physics, Stephen Fonash (2nd ed.), Academic Press, 2010 (ISBN: 978-0-12-374774-7).

REFERENCE BOOKS

1. Energy Storage, R. A. Huggins, Springer, 2010.
2. Handbook of Advanced Electronic and Photonic Materials and Devices: Ferroelectrics & Dielectrics, Vol. 10, H. S. Nalwa (ed.), Academic Press, 2001.
3. Electrochemical Nanotechnology, T. Osaka, M. Dutta, Y. S. Diamand (eds.), Springer, 2010, (ISBN: 978-1-4419-1423-1).
4. Encyclopedia of Nanoscience & Nanotechnology, Vol. 10, H. S. Nalwa (ed.), American Scientific Publishers, 2004.

Course Name	**Nanophotonics**
Course Number	PH503 (Elective)
Course Credit	3 – 0 – 0 – 6

Prerequisite	None

PROPOSED CONTENTS

- Foundations of nanophotonics
- Near-field interaction and microscopy
- Quantum confined materials (quantum wells)
- Sub-wavelength phenomena and plasmonic excitations (plasmonic waveguiding)
- Nanocontrol of excitation dynamics (nanostructure and excited states)
- Photonic crystals (theoretical modeling, features, methods of fabrication, photonic crystal sensors, photonic crystal fibers)
- Meta-materials
- Nanophotonics for Biotechnology & Biomedicine

TEXT/REFERENCE BOOKS:

1. Paras N. Prasad, *Nanophotonics*, John-Wiley-Interscience, 2004.
2. Sergey V. Gaponenko, *Introduction to Nanophotonics*, Cambridge University Press, 2010.
3. Hiroshi Masuhara and Satoshi Kawata, *Nanophotonics; Integrating Photochemistry, Optics and Nano/Bio Materials Studies*, Elsevier, 2004.
4. Mark L. Brongersma and Pieter G. Kik, Eds., *Surface Plasmon Nanophotonics*, Springer, 2007.
5. Motoichi Ohtsu, Ed., *Progress in Nanophotonics*, Springer, 2011.

Course Name	**Computational Nanoscience**
Course Number	PH504 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

Programming fundamentals, Flow Chart, plotting, fitting data, building new functions, and making iterations and loops.

Application on elementary numerical methods (e.g., Taylor-series summations, roots of equations, roots of polynomials, systems of linear and nonlinear algebraic equations, integration). Applications in nanotechnology engineering.

Ordinary differential equations with constant coefficients. Boundary value problems and applications to quantum mechanics. Numerical solution of ordinary differential equations. Numerical solution of partial differential equations.

Finite Difference Time-Domain Method: Optical Responses, advantage & disadvantage, Practical implementation, Numerical examples.

Finite element method: Introduction, Matrix form of the problem, Various types of finite element methods, Approximation of elliptic problems, Piecewise polynomial approach, One dimensional model problem.

Numerical schemes for nonlinear systems. Basic modelling and simulation. Relevant applications: optical, thermal, mechanical, and fluidic, and nanoscale devices.

Text & References:

1. Nanoscience, Hans-Eckhardt Schaefer
2. Introduction to Nanotechnology, Poole and Owen.
3. Introduction to Nanoelectronics and Information technology, Rainer Waser.
4. Mathematical Methods in the Physical Sciences, Mary L. Boas.
5. Finite Element Methods for Partial Differential Equations, Endre Suli.
6. Introduction to the Finite Element Method, J. N. Reddy.
7. Handbook of Theoretical and Computational Nanotechnology, M. Rieth and W. Schommers

Course Name	**Nanobiotechnology**
Course Number	CH501 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

PROPOSED CONTENTS

Module 1: Generic Methodologies for Nanobiotechnology

Introduction to Nanobiotechnology; challenges and opportunities associated with biology on the Nanoscale; nanobiotechnology systems; introduction to bioelectronics; Biologically relevant molecular nanostructures-Carbon nanotubes, quantum dots, metal based nanostructures, naowires, polymer based nanostructures, protein and DNA based nanostructures; Characterisation techniques for biological molecular nanostructures.

Module 2: Biosensors

Introduction to biosensors; the biological component; the sensor surface; Immobilisation of the sensor molecule; Transduction of the sensor signal -Optical sensors; Electrochemical sensors; Suppression or substraction of non-specific background interaction at sensor surfaces; Sensor stabilisation; Data analysis.

Module 3: Imaging of Bionanostructures

Practical and theoretical aspects of imaging biological systems, from the cellular level through to whole-body medical imaging, basic physical concepts in imaging. Major techniques using ionising and non-ionising radiation including fluorescence and multi-photon microscopy, spectroscopy, OCT, MRI, X-ray CT, PET, Confocal and SPECT imaging.

Module 4: Bionanomaterials

Biomolecules for designing nano-structures; nanoprinting of DNA, RNA and Proteins, use of these nano-structures in biological and medical applications. Principles of self-assembly, self-organisation and its application to biology.

DNA nanostructures, DNA robot, DNA microarrays, Bio-MEMS: biological and biomedical analysis and measurements and micro total analysis systems.

Module 5: Toxicological and Medical Applications of Nanobiotechnology

Environmental behaviour and speciation of nanoparticles; Introduction to Nanomaterials for toxicology; bioaccumulation of Nanomaterials, Nanoparticles cytotoxiciy, Applications of Nanostructures in Drug discovery, Delivery, and Controlled Release.

TEXT BOOKS

1. Nanodevices for the Life Sciences, Challa S. S. R. Kumar (Editor), John Wiley & Sons, Inc.
2. Bionanotechnology, by Elisabeth Papazoglou, Publisher: Morgan & Claypool

REFERENCE BOOKS

1. Bionanotechnology: Global Prospects
2. David E. Reisner (Editor), CRC Press (Taylor and Francis)

Course Name	**Supramolecular Nanoscience**
Course Number	CH 502 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

PROPOSED CONTENTS:

Introduction to core concepts of supramolecular chemistry: definitions, Cooperativity and Preorganization, Supramolecular interactions (including those in Chemomechanical Polymers)

Self-Assembly of nanoscalar supramolecular entities: definition, thermodynamics, types; self-assembly in biological systems; self-assembly in synthetic systems involving coordination and hydrogen bonding interactions; self-assembly of nanoscalar capsules and their applications.

Supramolecular chemistry in solid state: Zeolites, clathrates, crystal engineering and solid state reactivity, coordination polymers: applications as microreactors and energy storage materials

Supramolecular semiochemistry, colorimetric sensors and the indicator displacement assay, photophysical sensing and imaging, electrochemical sensors

Molecular nanomachines: based on cyclodextrin, based on metal ion translocation molecular gyroscopes, shuttles and muscles based on transition metals, Nanocar

Nanochemistry: Definition and description of transition metal nanoparticles and their application in catalysis.

Text Books:

1. Supramolecular Chemistry: Jonathan W. Steed and Jerry L. Atwood, Second Edition, John Wiley & Sons, Ltd., 2009
2. Core Concepts in Supramolecular Chemistry and Nanochemistry: Jonathan W. Steed, David R. Turner, Karl Wallace, John Wiley & Sons, Ltd., 2007

References:

1. Nanoparticles and Catalysis:: Didier Astruc (Editor), Wiley-VCH Verlag GmbH & Co. KGaA, 2008
2. Molecular Machines Special Issue: Acc. Chem. Res., 2001, 34 (6)
3. Various journal review articles/perspectives.
4.

Course Name	**Theory and Modeling in Nanoscience**
Course Number	CH511 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

PROPOSED CONTENTS

1. Molecular Dynamics;
2. Monte Carlo Methods;
3. Computations of Phase Transition under Confinement;
4. General Basis for predicting physical properties of nanocrystals and large clusters;
5. Quantum Confined Systems & computational techniques
6. Computational Electrodynamics Methods;
7. Large Scale Electronic Transport Calculations;
8. Density Functional Calculations in Carbon Nanotubes;
9. Time Dependent Density Functional Theory;
10. Computational Study of Nanotubes;
11. Excited State Properties (GW, BSE);
12. Computing Mechanical Properties and Modeling Growth;
13. How Well does Computation do with respect to Experiment
14. Present Day Scenario: regarding computation in the field.

TEXT BOOKS

1. **Computational Nanoscience (RSC Theoretical and Computational Chemistry) yr. 2011.**
2. **Nano Structures: Theory & Modeling, yr 2004**

Course Name	**Nanotechnology for Medical Diagnostics & Therapy**
Course Number	CH 512 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

PROPOSED CONTENTS

Nanotechnology for Disease Diagnostics: Quantum dot conjugation strategies with DNA-aptamer, Protein and Antibody and FRET/BRET based assays for Cancer, AIDS, tuberculosis and other disease diagnostics; Nanoparticle assisted multiplexed diagnostic assays (Bio-barcode amplification *assay, Sandwich DNA assay, Eliza)* and point-of care diagnostics (Lateral flow assay).

Nanotechnology for Drug delivery: Lipid, polymeric, Hyaluronic acid and heparin functionalized core shell nanoparticle as drug delivery vehicles; Carbon nanotube-based vectors for delivering immunotherapeutics and drugs, Hydrogels for drug delivery, nanoparticle induced Gene delivery for gene therapy.

Nanotechnology for therapy: Nanodrugs for treatment of cancer (abraxane and other drugs); concept of nanodrug-encapsulation, self assembly, controlled release (targeted and triggered release), nanoparticle recovery; modified Ag-nanoparticle for Photodynamic Therapy of cancer; nanoparticle assisted vaccine development; nanoshells for surgical procedures.

<u>Text Books:</u>

1. The handbook of Nanomedicine by Kewal K. Jain, Humana Press,

ISBN: 978-1-60327-319-0.

2. Nanomaterials for Medical Diagnostics and Therapy By Challa Kumar (Editor), Wiley-VCH, ISBN-978-3-527-31390-7.

<u>Reference Books:</u>

1. Medical Nanotechnology and Nanomedicine by Harry F. Tibbals, CRC Press (Taylor & Francis, ISBN: 13-978-1-4398-0876-4.

Course Name	**Nanoelectronics**
Course Number	PH511 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

PROPOSED CONTENTS

Nanoelectronics: Why? Device scaling, Moore’s law, limitations, role of quantum mechanics, Feynmans nanobot; Nanostructures: Impact, technology and physical consideration; Mesoscopic observables: Ballistic transport, phase interference, universal conductance fluctuations, weak localization; Carrier heating; Novel molecules (Pentacene, carbon nanotube, Fullerenes and its derivatives etc.) and conjugated polymers (Polyacetylene, P3HT, PEDOT:PSS etc.); Preliminaries : Basic Quantum mechanics and Fermi statistics, Metals, Insulators and Semiconductor, Density of states (DOS) in 0D-3D, DOS in disordered materials, Physics of organic semiconductors: concept of HOMO and LUMO, band gap etc. ;Two terminal quantum dot and quantum wire devices: Equilibrium in two terminal devices, Current flow in the presence of a bias, numerical technique for self-consistent estimation of V-I ,Current flow, quantum of conductance, Landauer theory; Field Effect Transistors (FETs): Ballistic quantum wire FETs, conventional MOSFETs, CMOS, short channel and narrow width, hot electron effect, punch-through and thin gate oxide breakdown, OFET;

Spintronics: Spin, propagation, detection, spinFETs; Fluxtronics: Fluxon, ratchet effect, rectification, flux-QUBIT; Nano-fabrication techniques: Top-down and bottom-up strategies, advantages/disadvantages/ limitations, e-beam lithography, Focussed Ion beam milling, self-organized structures, laser nano-patterning, nano-imprint, electrochemical synthesis, Fabrication of OEDs etc.; Special topics: Graphene, return to Feynmann's nanobot, future prospects

TEXT BOOKS

1. David Ferry , Transport in Nanostructures Cambridge University Press (1995) (available on IITP library site as ebook).
2. M. Baldo, Introduction to Nanoelectronics (Lecture Notes; May 2011 MIT).

REFERENCE BOOKS

1. S. Datta, Electronic Transport in Mesocopic Systems; Cambridge University Press (1995).
2. S. Datta, Quantum Transport: Atom to Transistor; Cambridge University Press (2005).
3. M. Lundstrom and J. Guo, Nanoscale Transistors; Physics, Modeling, and Simulation, Springer (2006).
4. P.W. Atkins and R.S. Friedman, Molecular Quantum Mechanics; Oxford University Press, 3rd edition (1997).
5. M. Stepanova and S. Dew, Nanofabrication: Techniques and Principles; Springer-Verlag (2012).
6. Rainer Waser, Nanotechnology

Course Name	**Nanionics : Concepts & Technological Applications**
Course Number	PH512 (M. Tech. Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

PROPOSED CONTENTS

Introduction, solid state ionics vis-à-vis solid state electronics, Principles of ionic conduction in ordered and disordered nanostructures; Superionic materials classification – Crystalline anionic and cationic conductors, mixed ionic and electronic conductors, structural factors responsible for high ionic conductivity; Brief review on physical techniques for analysis of ion conducting solids; Transport properties and Ion dynamics; Ion transport in homogeneous and heterogeneous medium – Ion conducting glasses, ceramics, polymers and composites; Ion Transport Models - Phenomenological models, Free volume theory, Configurational entropy model, Jump relaxation and Ion hopping model, Bond percolation model and Effective medium theory; Concepts and feasibility of ion conducting polymer nanocomposites and nanocrystalline ceramics.

Material problems and processing techniques; Technological applications of ion conducting solids; Design, Fabrication and Evaluation of Solid State Lithium Batteries, Supercapacitors (EDLC and Redox), Fuel Cells (PEM Fuel cell, SOFC), Gas sensors and display devices. Thermodynamics and mass transport in solid sate batteries. Battery performance and electrode kinetics. Double layer and other polarization effects at solid /solid interface; Fuel Cells as micro-power houses, Power conditioning and control of fuel cell systems.

TEXTBOOKS

1. Superionic Solids : Principles and Applications, S. Chandra, North Holland, 1981
2. Solid State Ionics, T. Kudu and K. Fueki, Kodanasha-VCH, 1990
3. Lithium Batteries : Research, Technology & Applications, Greger R. Dahlin, Kalle E. Strøm, Nova Science Pub Inc, 2010
4. Energy Storage, R. A. Huggins, Springer, 2010.
5. Electrochemical Supercapacitors: Scientific Fundamentals & Technological Applications, B. E. Conway, Kluwer Academic, 1999.
6. Fuel Cell Technology, Nigel Sammes (ed.), 1st edition, Springer, 2006
7. Clean Energy, R. M. Dell & D. A. J. Rand, Royal Society Publications, 2004
8. Fuel Cell Engines, Matthew M. Mench, John Wiley & Sons, 2008.

REFERENCE BOOKS

1. Solid State Electrochemistry, P. G. Bruce (ed.), Cambridge University Press, 1995
2. The CRC Handbook of Solid State Electrochemistry, P. J. Gellings & H. J. M. Bauwmeester, CRC Press, 1997
3. Solid State Electrochemistry II : Electrodes, Interfaces and Ceramic Membranes, V. V. Kharton (ed.), Wiley-VCH, 2009
4. Fuel Cell Technology Handbook, G. Hoogers (ed.), CRC Press, 2003 (ISBN: 0-8493-0877-1).
5. Fuel Cell Technologies: State & perspectives; N. Sammes, A. Smirnova and O. Vasylyev (eds.), Springer, 2004.

Course Name	**Magnetism at nanoscale**
Course Number	PH513 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

PROPOSED CONTENTS

Why magnetism at nanoscale ? experimental methods; Magnetic anisotropy at nanoscale; Magnetostriction and the effect of stress; Domains and magnetization process; Fine particle and thin films; soft magnetic materials and hard magnetic materials, One-dimensional Heisenberg model; Two-dimensional XY model; Three-dimensional Heisenberg ferromagnet; Three-dimensional antiferromagnet; Magnetism of the electron gas; Stoner model; Spin excitations in Stoner model; RKKY interaction; Field models of magnetization; Exchange model in two dimensions; Magnetic domains and domain walls; Random anisotropy model of amorphous magnet; Landau-Lifshitz equation;

Spin waves; Magnetic resonance; Angular momentum and spin; Magnetism of atoms; Exchange interaction and magnetic anisotropy; Superparamagnetism; Quantum mechanics of a large spin; Quantum magnetization curve; Josephson effect; Spin-lattice relaxation of rigid atomic clusters; Spin transport at nanoscale; Magnetic materials in applications; Magnetoresistive Sensors Based on Magnetic Tunneling Junctions; Magnetoresistive Random Access Memory (MRAM); Emerging Spintronic Memories; GMR Spin-Valve Biosensors; Semiconductor Spin-Lasers; Spin Logic Devices and magnetic drug delivery; Magnetic materials in memory device.

Text Books:

1. Introduction to Magnetic Materials, 2nd Edition, L. C. Cullity and C. D. Graham, IEEE Press, Willey.
2. Handbook of Spin Transport and Materials and Magnetism, **Editors** - Evgeny Y.Tsymbal and Igor Źutić, CRC Press - Taylor & Francis Group
3. Magnetism: From Fundamentals to Nanoscale Dynamics [Hardcover] Joachim Stöhr (Author), Hans Christoph Siegmann (Author,Springer Verlac
4. Principles of Nanomagnetism, **Guimarães,** Alberto P., Springer, 2009.

Reference Books:

1. Handbook of Spin Transport and Magnetism, Edited by Evgeny Y. Tsymbal, Igor Zutic, **Tailor and Francis, 1st edition**
2. Advances in Nanoscale Magnetism, Proceedings of the International Conference on Nanoscale Magnetism ICNM-2007, June 25 -29, Istanbul, Turkey, Series: Springer Proceedings in Physics, Vol. 122
3. Lectures on Magnetism, Eugene Chudnovsky and Javier Tejada, Rinton Press, 1st edition.
4. Introduction to magnetism and magnetic materials, David Jiles, Chapman and Hall, 16-Jun-1998.

Course Name	**Nanoscopic Dielectric & Ferroelectric Phenomena**
Course Number	PH514 (Elective)
Course Credit	3 – 0 – 0 – 6
Prerequisite	None

PROPOSED CONTENTS

Introductory remarks on classical concepts of electrostatics and Maxwell e.m. field equations; Concept of dielectric constant for nanostructures; Quantum approach for carriers in dielectrics; Electric polarization and relaxation – frequency and temperature dependence; Optical properties and radiative process in dielectric heterostructures & nanostructures; Photoemission, Luminescence, Photoconduction, Quantum yield and quantum efficiency; Transport in nanostructure networks (e.g.; tunneling, hopping, coulomb blockade etc.), Transitions between electrical conductivity, Transient phenomena, Charge carrier injection from electrical contacts; Role of defects and impurities in transport properties; Dielectric properties of metals, semiconductors and insulators (with examples of polymer, ceramics and composites).

Spontaneous polarization and origin of Ferroelectricity; Phenomenology of Ferro, Antiferro, Pyro and Piezoelectric effects; Ferroelectric memory and its application for high density data storage; Charging of a dielectric nanostructure and mechanism of charge storage in it; Electrets and their applications; Ferroelectric-insulator-semiconductor junctions;

Non-radiative and relaxation processes – multi-phonon capture at point defects, hot carrier relaxation; Electro-optic processes – Electro-optic, Photo-refractive and Magneto-optic effects; Elementary idea of Magneto-dielectric effect and Multiferroicity, Magnetoelectricity and Magnetoelectric coupling; Applications of multiferroicity and magnetoelectricity; Dielectric breakdown phenomena.

TEXT BOOKS

1. Nanostructures: Theory & Modelling; C. Delerue, M. Lannoo, Springer, 2004.
2. Dielectric Phenomena in Solids, k. C. Kao, Academic Press, 2004
3. Broadband Dielectric Spectroscopy, F. Kremer and F. Nicholas. Springer, 2003.
4. Ferroelectric Devices, K. Uchino, Marcel Dekker, 2000.
5. Ferroelectric Thin Films, M. Okayama & Y. Ishibashi (eds.), Springer, 2004.

REFERENCE BOOKS

1. Handbook of Advanced Electronic and Photonic Materials and Devices: Ferroelectrics & Dielectrics, Vol.4, H. S. Nalwa (ed.), Academic Press, 2001.
2. Handbook of Advanced Electronic and Photonic Materials and Devices: Nonlinear Optical Materials, Vol. 9, H. S. Nalwa (ed.), Academic Press, 2001.
3. Encyclopedia of Nanoscience & Nanotechnology, Vol. 5, H. S. Nalwa (ed.), American Scientific Publishers, 2004.

Course Name	Nanoscale Measurement and Analysis Laboratory
Course Number	NT503(lab)
Course Credit	0 – 0 – 6 – 6
Prerequisite	None

PROPOSED CONTENTS

Pre Mid-Semester

1. Thermocouple and thermistor as temperature sensor (sensor calibration and PID control).
2. LVDT characteristics.
3. Strain gauge: Calibration and signal conditioning.
4. B-H loop of nanomaterials.
5. Magnetoresistance of thin films and nanocomposite, I-V characteristics and transient response.
6. Design of Ferrite core for transformer and its performance evaluation.

Post Mid-Semester

1. X-ray diffraction (XRD): Phase analysis of binary mixture; indexing of XRD peaks and lattice structure refinement.

2. Selective area electron diffraction: Software based structural analysis based on TEM based experimental data from published literature. (Note: Later experiment may be performed in the lab based on availability of TEM facility).
3. SEM: Comparative microstructural analysis using FESEM on (i) cleaved HOPG, (ii) cleaved Mica, (iii) Glass, (iv) Si and (v) oxide sample (e.g., $BaTiO_3$).
4. EDXA (SEM based): EDXA of a multicomponent sample.
5. Complex impedance spectroscopy for electronic property evaluation (e.g., on $BaTiO_3$).
6. Surface area and pore volume measurements of nanoparticles (a standard sample and a new sample (if available)).

Course Name	Nanomaterial Synthesis and Device-fabrication Laboratory
Course Number	NT513 (lab)
Course Credit	0 – 0 – 6 – 6
Prerequisite	None

PROPOSED CONTENTS

Pre Mid-Semester

1. A PCB based design of electronic circuit for various applications (e.g., a cell phone circuit).
2. Design and performance evaluation of a transformer.
3. Energy density, power density and cyclability of a rechargeable Li-ion battery and capacitor.
4. Fuel cell performance evaluation.
5. Solar cell performance evaluation.
6. Thin film deposition using coating (spin and dip) and deposition (Langmuir-Blodgett and electro-deposition) for gas sensor application.

Post Mid-Semester

1. Synthesis of colloidal nanoparticles by appropriate techniques (precipitation, sol-gel, microemulsion, solvothermal, sonochemical, etc).
2. Spectroscopic characterization of metallic, semiconducting and insulating nanoparticles.
3. Ball milling route for making nanoparticles and particle size distribution estimation.
4. Particle size and lifetime analysis using dynamic light scattering.
5. Physical vapor deposition and chemical vapor deposition techniques for thin film deposition.
6. Fabrication of suitable structures on thin films for device applications.