Faculty of Engineering & Technology

NORTH MAHARASHTRA UNIVERSITY, JALGAON.

Syllabus For

M. Tech.
Nano Science and Technology
(W.E.F.2009-2010)

UNIVERSITY DEPARTMENT OF CHEMICAL TECHNOLOGY
NORTH MAHARASHTRA UNIVERSITY, JALGAON

Syllabus – M. Tech. Programme- Nano Science and Technology

First Semester

Sub. No.	Paper	Teaching Scheme Hrs/ Week	Examination Scheme Hrs	Marks		Total	Credits
				Internal	External		
NT-1.1	Introduction to Nano Science & Technology	03	03	40	60	100	03
NT 1.2	Techniques for Synthesis of Nanoparticles	03	03	40	60	100	03
NT 1.3	Laboratory Course on Synthesis and Characterization of Nanoparticles	06	06	40	60	100	03
NT 1.4	Quantum Mechanics	03	03	40	60	100	03
CT 1.1	Modern Methods of Instrumental Analysis	03	03	40	60	100	03
Total						**500**	**15**

Second Semester

Sub. No.	Paper	Teaching Scheme Hrs/ Week	Examination Scheme Hrs	Marks		Total	Credits
				Internal	External		
NT 2.1	Applications of Nano Science & Technology in Material Technology	03	03	40	60	100	03
NT 2.2	Science and Technology of Nanomedicines	03	03	40	60	100	03
NT 2.3	Applications of Nano Science & Technology in Electronics	03	03	40	60	100	03
NT 2.4	Biological Nanostructures and Applications of Nanostructures in Biology	03	03	40	60	100	03

NT 2.5	Applied Colloid and Surface Chemistry	03	03	40	60	100	03
NT 2.6	Nanoparticles in Energy production	03	03	40	60	100	03
CH 2.2	Reaction Engineering and Nanocatalysis	03	03	40	60	100	03
PT 2.2	Science & Technology of Nanocomposites, and Nanopigments	03	03	40	60	100	03
Total						**500**	**15**

NT 2.1 and NT 2. 2 are compulsory. Select any three courses out of remaining Courses.

Third Semester

Sub. No.	Paper	Teaching Scheme, Hrs/ Week	Marks		Total Marks	Credits
			Internal	External		
NT:3.1	Seminar	10	-	100	100	05
NT:3.2	Project	20	80	120	200	10
Total					**300**	**15**

Fourth Semester

Sub. No.	Paper	Teaching Scheme, Hrs/ Week	Marks		Total Marks	Credits
			Internal	External		
NT: 4.1	Project	30	120	180	300	15

UNIVERSITY DEPARTMENT OF CHEMICAL TECHNOLOGY
NORTH MAHARASHTRA UNIVERSITY, JALGAON
M.Tech. – Nano Science and Technology

Admission

Candidates holding B. Tech. / B.E. degree in any Engineering Branch or M.Sc. in any Science Branch or equivalent with 55 % marks are eligible for admission. However those students who have not studied Mathematics course at either undergraduate or post-graduate level, will have to opt and qualify mathematics course-CHE 404 Mathematics-II (Old Course) or BSL201 Mathematics-II (New Course). Preference will be given to candidates holding valid GATE score.

Notes:-

1. The students of M. Tech. Course have to attend 80% of lectures, practical and any other term work as may be prescribed by the university. The conduct and behaviour of the student must satisfy the Head of the Department.

2. The head of the Department certifies that the student has attended the course as prescribed and has conducted himself satisfactorily. In absence of such certificate the student shall not be permitted to the University examination.

3. The University examinations for all the terms shall be conducted at the end of the term.

4. The student shall have to appear personally to all parts of the examination.

5.The Credit Structure is based on M. Tech. Credit Guidelines sanctioned by University Academic Council.

UNIVERSITY DEPARTMENT OF CHEMICAL TECHNOLOGY
NORTH MAHARASHTRA UNIVERSITY, JALGAON
M.Tech. – Nano Science and Technology
Semester I

NT 1.1 Introduction to Nano Science & Technology (3hrs/ week – 03 Credits)

Introduction, Properties of materials & nanomaterials, role of dimensions in nanomaterials. Electronic Properties, Classification of materials: Metal, Semiconductor, Insulator, Band structures, Brillouin zones, Mobility, Resistivity, Relaxation time, Recombination centers, Hall effects, Confinement and transport in nanostructure Current, reservoirs, and electron channels, conductance formula for nanostructures, quantized conductance. Local density of states. Ballistic transport, Coulomb blockade, Diffusive transport, Fock space. Dielectric Properties, Polarization, ferroelectric behaviour. Magnetic Properties, Fundamentals of magnetism, Different kind of magnetism in nature: Dia, Para, Ferro, Antiferro, Ferri, Superpara. Important properties in relation to nanomagnetism. Optical Properties, Photoconductivity, Optical absorption & transmission, Photoluminescence, Fluorescence, Phosphorescence, Electroluminescence. Thermal Properties Concept of phonon, Thermal conductivity, Specific heat, Exothermic & endothermic processes. Mechanical Properties, Young's modulus, Bulk Modulus, Modulus of rigidity. Tensile Testing and Tensile Strength, Yield Strength, Breaking Strength, Plastic Deformation, True Stress and Strain Bend Testing – Flexural Strength and Modulus, Brinnell Testing – Hardness, Impact Testing – Toughness, Resilience, Scratch Test.

References

• Nanoscale Materials in Chemistry
• Novel Nanocrystalline Alloys and Magnetic Nanomaterials- Brian Cantor
• Nanomaterials Handbook- Yury Gogotsi
• Encyclopedia of Nanotechnology- Hari Singh Nalwa
• Introduction to Nanotechnology - Charles P. Poole Jr. and Franks. J. Qwens
• Microwave Properties of Magnetic Films - Carmine Vittoria.
• Physics of Magnetism - S. Chikazumi and S.H. Charap
• Physical Theory of Magnetic Domains - C. Kittel
• Magnetostriction and Magnetomechanical Effects - E.W. Lee
• Springer Handbook of Nanotechnology - Bharat Bhusan
• Electronic transport in mesoscopic systems, Supriyo Datta

NT 1.2 Techniques for Synthesis of Nanoparticles (3 hrs/week – 03 Credits)
Physical Methods- Inert gas condensation, Arc discharge, RF-plasma, Plasma arc technique, Ion sputtering, Laser ablation, Laser pyrolysis, Ball Milling, Molecular beam epitaxy, Chemical vapour deposition method and other variants, Electrodeposition.
Chemical Methods- Metal nanocrystals by reduction, Solvothermal synthesis, Photochemical synthesis, Electrochemical synthesis, Nanocrystals of semiconductors and other materials by arrested precipitation, Thermolysis routes, Sonochemical routes, Liquid-liquid interface, Hybrid methods, Solvated metal atom dispersion, Post-synthetic size-selective processing. Sol- gel, Micelles and microemulsions, Cluster compounds.
Biological Methods of Synthesis- 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; Synthesis process and application, Role of plants in nanoparticle synthesis. Lithographic Techniques- AFM based nanolithography and nanomanipulation, E beam lithography and SEM based nanolithography and nanomanipulation, Ion beam lithography, oxidation and metallization. Mask and its application. Deep UV lithography, X-ray based lithography.
Template assisted growth of an-isotropic nanoparticles.

References:

• Hari Singh Nalwa - Encyclopedia of Nanotechnology.
• Introduction to Nanotechnology - Charles P. Poole Jr. and Franks. J. Qwens
• Novel Nanocrystalline Alloys and Magnetic Nanomaterials- Brian Cantor
• Nanomaterials Handbook- Yury Gogotsi
• Springer Handbook of Nanotechnology - Bharat Bhusan
• Processing & properties of structural naonmaterials by Leon L. Shaw (editor)
• Chemistry of nanomaterials : Synthesis, properties and applications by CNR Rao et.al.

• Synthesis of Nanostructured Materials –Cao
• Handbook of Nanoscience, Engineering- Goddard et al

NT 1.3 Laboratory Course on Synthesis and Characterization of Nanoparticles (6hrs/week – 03 Credits)

Minimum of eight practical based on Theory Courses - **1. 2** & **1. 3**.

I. Preparation and testing of CaCo3 by Situ matrix deposition.
II. Preparation and testing of silver nanoparticles by chemical route.
III. Synthesis of ZnS nanoparticles by chemical route and determination of band structure through UV-Vis spectroscopy.
IV. Synthesis and testing of Cadmium Selenide Quantum dots.
V. Crystalline phase of analysis of Nanoparticles by DSC at ambient & low Temp condition.
VI. Preparation and testing of Iron oxide by Flame Pyrolysis
VII. Micellar route to Nano rod synthesis.
VIII. Synthesis and testing of Antimary oxychloride by matrix mediated growth
IX. Thermal degradation characteristics by TGA
X. Rheology of dispersion of Nanoparticles by Relaxation Viscometer
XI. Functional analysis by IR
XII. $CaCO_3$ preparation and testing by electrolysis
XIII. Preparation and testing of polymer & rubber Nan composites
XIV. Pharmaceutical Nanoparticles- Preparation and testing
XV. Surface & pore volume determination of Nano particles.
XVI. Contact Angle Measurement

Demonstration on safety aspects of handling of nanoparticles

NT 1.4 Quantum Mechanics Syllabus (3 hrs/week – 03 Credits)

1. Origin of Quantum Theory

1.1 The work of Planck: Blackbody radiation
1.2 The work of Einstein: The photoelectric effect
1.3 The work of Bohr: A quantum theory of atomic states (Bohr Model of hydrogen atom)
1.4 The Stern – Gerlach Experiment: Angular Momentum and spin
1.5 The De Broglie hypothesis and Davission – Germer Experiment

2. The Wave Function and the Uncertainty Principle (BJ)

2.1 Wave- particle duality
2.2 Interpretation of wave function (Probability & Super position principle
2.3 Wave function for particles having a definite momentum
2.4 Wave packet
2.5 The Heisenberg uncertainty principle

3. The Schrodinger Equation

3.1 Schrodinger equation in one dimension
3.2 Schrodinger in three dimensions
3.3 Probability current density

4. The Postulates of Quantum Mechanics

4.1 Obervables & operators
4.2 Measurements in quantum mechanics
4.3 The state function & Expectation values

5. One Dimensional Examples

5.1 General Formulae
5.2 The free particle
5.3 Potential step
5.4 The Rectangular potential barrier
5.5 The Deep potential well
5.6 Square well potential
5.7 The linear harmonic oscillator
5.8 Periodic potential

6. Several & Many-Particle System
6.1 System of identical particles
6.2 Two electron atoms
6.3 Many electron atoms
6.4 Molecules

7. Nanoscale Materials and Quantum Mechanics
7.1 Quantum Confinement,
7.2 Size Quantization,
7.3 Three Dimensional System (Bulk),
7.4 Two Dimensional System (Nanostructured Plane),
7.5 One Dimensional System (Quantum Wire),
7.6 Zero Dimensional System (Quantum Dots),
7.7 Varieties of Quantum Dots.

References:

1. Introductory Quantum Mechanics(Fourth Edition): Richard L. Liboff
2. Quantum Mechanics(Second Edition):B.H.Bransden & C.J.Joachain
3. Quantum Mechanics: Powell and Craseman
4. Advanced Quantum Mechanics: Satya Prakash . Kedarnath Ram Nath, Meerut.
5. Quantum Mechanics: Gupta, Kumar, Sharma.. Sultan Chand & Sons
6. Quantum Mechanics: Chatwal and Anand.. Himalaya Publishing Co.
7. Quantum Mechanics: L. I. Schiff

CT 1.1 Modern Methods of Instrumental Analysis (3 hrs/week – 03 Credits)
Detail study of following sophisticated instruments with reference to construction, operation principle, applications and merits and demerits:
Gas Liquid Chromatography
High Performance Liquid Chromatography
Infra Red & FTIR Spectroscopy
NMR Spectroscopy
UV Visible Spectroscopy
Mass Spectroscopy
Differential Scanning Calorimeter
Thermo gravimetric Analysis
Scanning Electron Microscope
Transform Electron Microscope & Atomic Force Microscopy
XRD – crystalline phase analysis
Surface area determination by BET- method, Particle size by light scattering method, Zeta potential
Colour Matching and Lovibond Tintometer

References:

• Scanning Probe Microscopy: Analytical Methods (NanoScience and Technology)- Roland Wiesendanger
• Advanced X-ray Techniques in Research and Industries - A. K. Singh (Editor)
• X-Ray Diffraction Procedures: For Polycrystalline and Amorphous Materials, 2nd Edition - Harold P. Klug, Leroy E. Alexander
• Transmission Electron Microscopy: A Textbook for Materials Science (4-Vol Set)- David B. Williams and C. Barry Carter
• Introduction of X-ray Crystallography- M.M. Woolfson
• Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM - Ray F. Egerton
• Fabrication of fine pitch gratings by holography, electron beam lithography and nanoimprint lithography (Proceedings Paper) Author(s): Darren Goodchild; Alexei Bogdanov; Simon Wingar; Bill Benyon; Nak Kim; Frank Shepherd
• Microfabrication and Nanomanufacturing- Mark James Jackson
• A Three Beam Approach to TEM Preparation Using In-situ Low Voltage Argon Ion

Final Milling in a FIB-SEM Instrument E L Principe, P Gnauck and P Hoffrogge,
Microscopy and Microanalysis (2005), 11: 830-831 Cambridge University Press
• Instrumental Methods of Analysis, 7th edition- Willard, Merritt, Dean, Settle
• Transmission Eletron Micoscopy of Materials – Gareth Thomas
• Poole, C. P.; Owens, F. J. Introducyion to Nanotechnology John Wiley and Sons Inc: 2006.
• Kulkarni, S. K. Nanotechnology: Principles and Practices Capital Publishers,2007.

Semester II

NT 2.1 and NT 2.2 are compulsory. Select any three courses out of remaining Courses.

NT 2.1 Applications of Nano Science & Technology in Material Technology (3 hrs/week – 03 Credits)

Structure of Matter- Amorphous, crystalline, crystals, polycrystals, symmetry, Unit Cells, Crystal Structures (Bravais Lattices), , Crystallographic Directions, Crystallographic Planes, Miller Indices, Chemical Bonding- Atomic Bonding in solids, Types of bond: Mettalic,Ionic, Covalent and Venderwaals bond; Hybridisation; H-bonding Molecular orbital theory for simple molecules such as diatomic molecule etc.

Present status of Material Technology Magnetic Phenomena : Fundamentals of Magnetism, Antisymmetrization, Concept of Singlet and Triplet States, Diamagnetism and Paramagnetism, Magnetic fluids, Magnetopolymer (ferrofluid conducting polymer composites), Magnetic nanoparticles Band Structure in Solids:. The Bloch Function, The Bloch Theorem, Band Structure in 3-Dimensions, modification of dielectric properties with nanoparticles, Metals and Semiconductors

Optical Properties, Electrical Properties, Mechanical Properties, Thermochromisam.

Sensors:- Fundamentals of sensors, biosensor, micro fluids, MEMS and NEMS, Packaging and characterization of sensors. Sensors for aerospace and defense: Accelerometer, Pressure Sensor, Night Vision System, Nano tweezers, nano-cutting tools, Integration of sensor with actuators and electronic circuitry, Sensor for bio-medical applications: Cardiology, Neurology and as diagnostic tool, For other civil applications: metrology, bridges etc. Biosensors. Clinical Diagnostics, generation of biosensors,

References:

• Introduction to Solid State Physics -C. Kittel
• Introduction to Solid State Chemistry – A. R. West.
• Solid State Physics- A.J. Dekker
• Solid State Physics -R.K Puri and V.K.Babar
• Elements materials science -Van Vlack
• The Physics and Chemistry of Solids - Stephen Elliott & S. R. Elliott
• Physics and Chemistry of Interfaces- Hans-Jürgen Butt, Karlheinz Graf, Michael Kappl
• Materials Science & Engineering: An Introduction, 5th edition- William D. Callister, Jr
• Phase Transformation- Jena & Chaurbedi
• Diffusion in Solids- Shewmon
• Sensors: Micro & Nanosensors, Sensor Market trends (Part 1&2) by H. Meixner.
• Between Technology & Science : Exploring an emerging field knowledge flows & networking on the nanoscale by Martin S. Meyer.
• Nanoscience & Technology: Novel structure and phenomea by Ping Sheng (Editor)
• Nano Engineering in Science & Technology : An introduction to the world of nano design by Michael Rieth.
• Enabling Technology for MEMS and nano devices -Balles, Brand, Fedder, Hierold.
• Optimal Synthesis Methods for MEMS- G. K. Ananthasuresh
• MEMS & MOEMS Technology and Applications- P. Rai Choudhury
• Processing Technologies- Gandhi
• From Atom to Transistor- Supriyo Datta

NT 2.2 Science and Technology of Nanomedicines (3 hrs/week – 03 Credits)

Present status of pharmaceuticals and fine chemicals, Concept of nanomedicines, physical properties of molecules and super molecular complexes within cell.

Molecular machinery and manufacturing with due stress on programmable medical micro machines, tiny supercomputers through molecular computing, concept of nanorobots/ molecular robotics smaller than a cell and their role in elimination of cancer, infections, clogged articles etc., retardation of aging phenomenon.

Role of nanotechnology in biotechnology, engineered enzymes, coated colloids in cosmetics and pharmaceuticals, encapsulated drugs for sustained release(Concept of Drug delivery), Sunscreen and UV

protective cosmetics, Biomedical tagging and bio magnetic separation, Diagnostic content agent, biomedical implants. Drug Delivery, Therapeutic
action of nanoparticles and nanodevices- Targeted, non-targeted delivery; controlled drug release; exploiting novel delivery routes using nanoparticles; gene therapy using nanoparticles; Nanostructures for use as antibiotics; Diseased tissue destruction using nanoparticles; Diagnostics using nanomaterial, Nanoparticles for bioanalytical applications- Nanodevices for sensing and therapy. Use of nanoparticles for MRI, X Ray, Ultrasonography, Gamma ray imaging. Nanoparticles as molecular labels; biological labeling using quantum dots as molecular labels.

References:

• Nanomedicine, Vol. IIA: Biocompatibility by Robert A. Freitas
• Nanosystems: Molecular Machinery, Manufacturing, and Computation - K. Eric Drexler
• Nanofabrication towards biomedical application: Techniques, tools, Application and impact – Ed. Challa S., S. R. Kumar, J. H. Carola.
• Nanomedicine, Vol. I: Basic Capabilities
• Nanomedicine, Vol. IIA: Biocompatibility - Robert A. Freitas

NT 2.3 Applications of Nano Science & Technology in Electronics (3 hrs/week – 03 Credits)

Introduction. Recent past, the present and its challenges, Future, Overview of basic Nanoelectronics. Technologies, Single Electron Devices, Quantum Mechanical Tunnel. Devices, Quantum Dots & Quantum wires. Nanoelectronic & Nanocomputer architectures and nanotechnology. Manufacture of Nanowires, Nonosheets, Nanoribbons, Nanobelts, etc.
Detail applications of nanoparticles in following areas :
X-ray lithography, carbon nanotubes, microspeakers, tiny hearing aids, laptop computer seals, DWDM filter, Optical fibres, photon Detectors, Superconductive wires etc. Generation of Spin Polarization. Theories of spin Injection, spin relaxation and spin dephasing,
Spintronic devices and applications, spin filters, spin diodes, spin transistors.

References:

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

NT 2.4 Biological Nanostructures and Applications of Nanostructures in Biology
(3 hrs/week – 03 Credits)

Microorganisms for synthesis of nanomaterials and for toxicity detection- Natural and artificial synthesis of nanoparticles in microorganisms; Use of microorganisms for nanostructure formation, Testing of environmental toxic effect of nanoparticles using microorganisms; Nanocomposite biomaterials, teeth and bone substitution- Natural nanocomposite systems as spider silk, bones, shells; organic-inorganic nanocomposite formation through self-assembly. Biomimetic synthesis of nanocomposite material; Use of synthetic nanocomposites for bone, teeth replacement. Nanobio Systems-Nanoparticle-biomaterial hybrid systems for bioelectronic devices, Bioelectronic systems based on nanoparticle-enzyme hybrids; nanoparticle based bioelectronic biorecognition events. Biomaterial based metallic nanowires, networks and circuitry. DNA as functional template for nanocircuitry; Protein based nanocircuitry; Neurons for network formation. DNA nanostructures for mechanics and computing and DNA based computation; DNA based nanomechanical devices. Biosensor and Biochips. Major physiologic systems of current interest to biomedical engineers: cardiovascular, endocrine, nervous, visual, auditory, gastrointestinal, and respiratory. Useful definitions, The status of tissue engineering of specific organs, including bone marrow, skeletal muscle, and cartilage. Cell biological fundamentals of tissue engineering
Integrating and Tagging Biological Structures with Nanoscale Semiconducting Quantum Dot Structure, Biomedical Applications of Semiconductor and Magnetic Quantum Dots Potential Applications of Carbon Nanotubes In Bioengineering, Nanophysical Properties of Living Cells: The Cytoskeleton, Hairpin Formation in Polynucleotides

References:
• Bionanotechnology: Lessons from Nature by David S. Goodsell
• Nanomedicine, Vol. IIA: Biocompatibility by Robert A. Freitas
• Handbook of Nanostructured Biomaterials and Their Applications in Nanobiotechnology - Hari Singh Nalwa
• Nanobiotechnology; ed. C.M.Niemeyer, C.A. Mirkin.
• Nanocomposite Science & Technology Ajayan, Schadler & Braun
• BioMEMS (Microsystems) - Gerald A. Urban
• Introduction to Nanoscale Science and Technology (Nanostructure Science and Technology) -Massimiliano Di Ventra
• Nanosystems: Molecular Machinery, Manufacturing, and Computation - K. Eric Drexler
• Springer Handbook of Nanotechnology - Bharat Bhushan
• Nanobiotechnology; ed. C.M.Niemeyer, C.A. Mirkin.
• Nanofabrication towards biomedical application: Techniques, tools, Application and impact – Ed. Challa S., S. R. Kumar, J. H. Carola.
• Nanomedicine, Vol. I: Basic Capabilities
• Nanomedicine, Vol. IIA: Biocompatibility - Robert A. Freitas
• Dendrimers I, II, III, Ed. F. Vogtle
• Tissue Engineering-Bernhard O. Palsson , Sangeeta N. Bhatia
• Principles of Tissue Engineering - Robert Lanza, Robert Langer, and Joseph P

NT 2.5 Applied Colloid and Surface Chemistry (3 hrs/week – 03 Credits)
Introduction to the nature of colloidal solutions
Surface Tension, Wetting, Solubilisation, Dispersion, Detergency
Thermodynamics of Adsorption
Surfactants and Self-assembly
Emulsions and Microemulsions
Charged Colloids
Van der Waals forces and Colloid Stability
Bubble coalescence, Foams and Thin Surfactant Films
Role of surfactants in synthesis of nanoparticles.

NT 2.6 Nanoparticles in Energy production. (3 hrs/week – 03 Credits)
Alternatives for the power production,
Fuel cell: Types of fuel cells, detailed of mechanism, role of nanomaterials in enhancement in functioning, Merits and demerits of fuel cells.
Batteries: Types of battries, operating mechanism of batteries, role of nanomaterials in improving their performance.
Capacitors and Super capacitors: Importance of capacitors, Functioning of capacitor, role of nanomaterials in enhancement in functioning.
Role of nanocatalysts in energy production in petrochemical refinery (Hydrotreating, Fischer Trops, etc.)

CH 2.2 Reaction Engineering and Nanocatalysis (3 hrs/week – 03 Credits)
Review of techniques of interpretation of kinetic data, material and energy balance across reactors with reference to their design, Detail coverage of design of fixed, fluidized, trickle, moving bed reactors.
Nanocatalysis: Role of transition metals & metal oxides in homogeneous and heterogeneous catalysis and their mechanism of catalysis, manufacture of these catalysts in nano-form and their characterization.
Silica, alumina, carbon as high temperature carriers for catalysts. Use of nanocatalysts in automobile pollution control, photocatalysis of toxics in effluents, gas sensors.
Reactor design for manufacture of nanocatalysts and nanosupports: Design of flame aerosol reactors, diffusion and premixed flame reactors, co precipitation reactors, hot wall flow reactors; their mechanical features, modeling and simulations.
Catalytic vapour –liquid- solid growth mechanism for understanding particle formation and growth during chemical vapour deposition, particle dynamics and CFD simulations of flame process based on fundamental equations for flow, heat and mass transfer, aerosol dynamics in flames.

PT 2.2 Science & Technology of Nanocomposites, and Nanopigments (3 hrs/week – 03 Credits)
Nanocomposites: Comparison with conventional composites. Manufacture and Characteristics of thermoplastic and thermoset nanocomposite products: Fiber reinforced nanocomposites, copolymer / clay nanocomposites,

latex / ZnO nanocomposites, hybrid nanocomposites, PVC / $CaCO_3$ nanocomposites, etc. Effect of modifier concentration on structure, mechanical and viscoelastic properties of nanocomposites, Development and Optimization of Polymer melt process, Nanocomposite preparation by injection molding.

Applications of Nanocomposites : Flame retardant textiles, toughened plastics, automotive bodies, mirror housing on various vehicles, belts, vacuum cleaners, covers for mobile phones, power tools.

Nanoextenders and Transparent Pigments : Manufacture and properties of Alumina, Silica, Titanium Dioxide, Carbon Black, Iron Oxides, Zinc Oxides, $CaCO_3$ etc. on Nano scale; Bimodally porous nanoparticles (e.g. titanium tetraisopropexide), variables affecting particle size aggregation and crystal structure. Their use as spacing extenders / pigments in paints, reinforcing agent in polymers, heat & wear resistant materials etc.

Coating nanoparticles with layers of polymers.

References:

• Nanocomposites Science and Technology - P. M. Ajayan, L.S. Schadler, P. V. Braun
• Physical Properties of Carbon Nanotubes- R. Saito
• Carbon Nanotubes (Carbon , Vol 33) - M. Endo, S. Iijima, M.S. Dresselhaus
• The search for novel, superhard materials- Stan Vepr¡ek (Review Article) JVST A, 1999
• Electromagnetic and magnetic properties of multi component metal oxides, hetero
• Nanometer versus micrometer-sized particles-Christian Brosseau,Jamal Ben,
Youssef, Philippe Talbot, Anne-Marie Konn, (Review Article) J. Appl. Phys, Vol 93, 2003
• Diblock Copolymer, - Aviram (Review Article), Nature, 2002

Semester III

NT 3.1 Technical Seminar: Presentation on selected topics in nanotechnology with due emphasis on latest developments. (10 hrs/ week) (05 Credits)

NT 3.2 Project : finalization of particular research problem, thorough literature review, preliminary experimental work, Presentation of Project report and viva - voce based on project work.
(20 hrs/ week) (10 Credits)

Semester IV

NT 4.1 Project: (30 hrs/ week) (15 Credits)

The entire semester will be devoted for detail experimental work on a research problem selected in III semester. The student will present his/her findings in the form of neatly typed and bound thesis within one month after approval of his synopsis. He/ She will have to appear before panel of experts for defending his Thesis.

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