M.Sc. DEGREE

IN

MATERIALS SCIENCE AND NANOTECHNOLOGY

CHOICE BASED CREDIT SYSTEM

(Effective from the Academic Year 2017-2018)

DEPARTMENT OF MATERIALS SCIENCE AND NANOTECHNOLOGY

YOGIVEMANA UNIVERSITY,

KADAPA – 516 005, ANDHRA PRADESH, INDIA

September - 2018

COURSE STRUCTURE AND EXAMINATION SCHEME

Semester	Course code	Title of the Course	No. of credits	No. of hours per week	Max. Marks 100	
					Internal Assessment	End Exams
SEMESTER I	MSNT 101	Classical and Statistical Mechanics	04	04	25	75
	MSNT 102	Concepts in Materials Science	04	04	25	75
	MSNT 103	Fundamentals of Chemistry	04	04	25	75
	MSNT 104	Polymeric Materials	04	04	25	75
	MSNT 105	Practical - I Physical Chemistry	04	12	25	75
	MSNT 106	Practical-II Inorganic Chemistry	04	12	25	75
SEMESTER II	MSNT 201	Quantum Mechanics	04	04	25	75
	MSNT 202	Properties of Bulk and Nanomaterials - I	04	04	25	75
	MSNT 203	Polymeric Processing, Composites and Heat Resistance Polymers	04	04	25	75
	MSNT 204	Introduction to Nanoscience and Synthesis of Nanomaterials	04	04	25	75
	MSNT 205	Practical - I Polymer Material Lab	04	12	25	75
	MSNT 206	Practical-II Study of Properties of Materials	04	12	25	75
	MSNT 207	***Non-Core: Concepts of Nanomaterials***	***04***	***04***	***25***	***75***
SEMESTER III	MSNT 301	Characterization Techniques	04	04	25	75
	MSNT 302	Semiconductors and Devices	04	04	25	75
	MSNT 303	Alloys and Paints	04	04	25	75
	MSNT 304	Nanocatalysis and its Applications	04	04	25	75
	MSNT 305	Practical - I Nanocatalysis Lab	04	12	25	75
	MSNT 306	Practical- II Semiconductors Lab	04	12	25	75
	MSNT 307	***Non-Core: Characterization Techniques and Applications of Nanomaterials***	***04***	***04***	***25***	***75***
SEMESTER IV	MSNT 401	Advanced Characterization Techniques	04	04	25	75
	MSNT 402	Properties of Bulk and Nanomaterials – II	04	04	25	75
	MSNT 403	Applications of Nanomaterials and Nanotechnology	04	04	25	75
	MSNT 404	Energy Conversion Technologies	04	04	25	75
	MSNT 405	Practical – I Nanomaterials Synthesis Lb	04	12	25	75
	MSNT 406	Project Work – I	04	12	--	100
Total for Core Papers			96			
Total for Non-CorePapers			08			
Grand Total			104			

NON CORE COURSES(FOR THE STUDENTS OF OTHER DEPARTMENTS)

COURSE CODE	TITLE
MSNT207	Concepts of Nanomaterials
MSNT307	Characterization Techniques and Applications of Nanomaterials

Note: The Department will offer both External Elective Courses depending on the student's strength opted for that course, which will be intimated at the beginning of the semester.

MSNT101: Classical and Statistical Mechanics

Unit-I: Lagrangian Mechanics and Hamiltonian Mechanics 15 h

Newtonian Mechanics of one and many particle systems; Conservation laws ; Constraints and their classification; Principle of virtual work ; D' Alembert's principle; Generalized coordinates; Lagrange's equations of motion; Hamiltonian principle ; Lagrange's equation from Hamilton's principle ; Hamilton's equation of motion ; Some applications of Lagrange's and Hamilton's formulation.

Unit-II : Canonical Transformations and Hamilton – Jacobi Theory 15 h

Canonical transformations ; generating function ; properties: Condition for transformation to be canonical ; Illustration of canonical transformation ; Poisson; brackets ; canonical equations in terms of Poisson – bracket notation ; Lagrangian; brackets and their properties ; The Hamiltonian; Jacobi equation ; one dimensional harmonic oscillator ; action Angle variables ; Kepler problem in action angle variables.

Unit-III: Ensembles & Partition functions 15 h

Foundations of statistical mechanics, specification of states of systems, relation between statistics and thermodynamics, phase space, concept of ensembles, ensemble average, Liouville's theorem.

Canonical, molecular, translational, rotational, vibrational, electronic and nuclear partition function, applications of rotational and vibrational partition functions to solids.

Unit-IV: Maxwell-Boltzman, Bose-Einestein and Fermi-Dirac Statistics 15 h

Maxwell-Boltzman statistics: Distribution of velocities, calculation of mean values, equipartition of energy, Bose-Einestein distribution; Bose-Einestein condensation, thermodynamic properties of an idea Bose-Einestein gas; Ideal Fermi-Dirac Gas, Fermi-Dirac Distribution, degeneracy.

Text Books:

1. Classical Mechanics by N.C. Rana and P.S. Joag (Tata Mc;graw Hill) 1991
2. Classical Mechanics by H. Goldstein (Addi Wesly) 1980
3. Introduction to Classical Mechanics by R. G. Takwale and P.S. Puranic
4. Classical Mechanics by J.C. Upadhyaya, Himalaya Pub.house, Mumbai
5. Introduction to IR & Raman Spectroscopy, N.B. Calthrup, L.N. Daly & S.E. Wiberlay, Academic Press, New York 1964.
6. B.K. Agarwal, Statistical Mechanics, Melvin Einser
7. ESR Gopal, Statistical Mechanics and Properties of Matter
8. F. Reif, Statistical and thermal physics
9. C. Kittel, Elementary Statistical Mechanics

MSNT102: Concepts in Materials Science

Unit-I: Crystal Systems **15 h**

Translational vectors; Lattice and Basis; Unit cell; Bravais lattices; Lattice constants, Crystal planes; Miller indices; Symmetric operations; Packing fraction; Simple cubic structures; Body centered cubic structure, Face centered cubic structure; Hexagonal close packed structure; NaCl, CsCl, Diamond and ZnS structures

Unit-II: Imperfections in Crystals **15 h**

Point defects: Impurities; Vacancies - Frenkel and Schottky intrinsic vacancies; Equilibrium concentration of defects; Ionic conductivity in alkali halides; Color centers: Classification-F,F', V centers-Production of color centers

Line defects: Edge and Screw dislocations; Burger vector; Stress field around dislocations; Dislocation energy - Estimation of dislocation densities, Expression for strain energy of dislocation; Role of dislocations in crystal growth;

Plane defects: Stacking faults; Grain boundaries – Low angle grain boundaries

Unit-III: Lattice Vibrations **15 h**

Lattice vibrations: Elastic vibrations of one dimensional homogeneous line; One dimensional line of atoms; Normal modes of vibrations in a finite length of lattice; The linear diatomic lattice; Phonons; Scattering of phonons by neutrons & photons

Unit IV: Band Theory of Solids **15 h**

Motion of electron in periodic potential – Bloch function – Kroning – penny model- formation of energy bands in solids, Concept of effective mass, Brillouin zones- different schemes of representation of E vs K curves, Distinction between metals, insulators and semiconductors.

Text Books:

1. R. L. Singhal, Solid State Physics, Kedarnath Ramnath - Publisher
2. M.A.Wahab, Solid State Physics: Structure and Properties of Materials, Alpha Science International Ltd., (2005)
3. S.O. Pillai, Solid State Physics, Wiley Easter Ltd.(1994)
4. C.Kittle, Introduction to Solid State Physics, Wiley, 7th Edition (1995)
5. Gupta, Kumar, Sharma, Solid State Physics
6. Stephen Elliott and S.R. Elliot, The Physics and Chemistry of Solids, Wiley, 1st Edn (1998)
7. Malik Wahid U. Et. Al, Selected topics in inorganic chemistry, S. Chand & Co., Ltd. (2009)

MSNT 103: Fundamentals of Chemistry

UNIT-I: Chemical bonding and Shapes of Molecules 15 h

Ionic or electrovalent, covalent and vander walls bonds; Inert pair effect; Lattice energy of ionic crystals; Ion deformation or polarization of ions; Hydrogen bond, Odd electron bonds; Bonding in metals-Metallic bond.
Molecular orbital theory (MOT): Molecular orbital configuration of some homonuclear diatomic species; Bond order or bond multiplicity; Molecular orbital configuration of some hetro-nuclear diatomic species; Hybridization of atomic orbital's - Types of hybridization and shapes of some common molecules with σ-or σ+ π bonds; Structure and bonding of diborane

UNIT-II: Coordination Chemistry 15 h

IUPAC nomenclature; Bonding theories – review of Werner's theory and Sidgwick's concept of coordination, Valence bond theory; Geometries of coordination numbers 4-tetrahedral and square planar and 6-octahedral and its limitations;
Crystal filed theory: Splitting of d-orbitals in octahedral, tetrahedral and square-planar complexes, low spin and high spin complexes; Factors affecting crystal-field splitting energy; Merits and demerits of crystal-field theory; Isomerism in coordination compounds – Structural isomerism and stereo isomerism; Stereochemistry of complexes with 4 and 6 coordination numbers.

UNIT-III: Reaction Mechanisms in complexes 15 h

Reactivity of metal complexes- inert and labile complexes- kinetics and Mechanisims of substitution reactions- Substitution reactions in octahedral complexes- Acid hydrolysis- factors affecting Acid Hydrolysis-Base hydrolysis- conjugate base mechanisms- Anation reactions-substitution reaction in square plannar complexes- trans effect- Mechanisms of trans effect-Electron transfer reaction- Inner sphere and outer sphere mechanisms-Marcus theory

UNIT-IV: Halogen compounds 15 h

Nomenclature and classification of alkyl (into primary, secondary, tertiary), aryl, aralkyl, allyl, vinyl, benzyl halides; Chemical reactivity; Formation of RMgX; Nucleophilic aliphatic substitution reaction - Classification into S_N1 and S_N2.

Energy profile diagram of S_N1 and S_N2 reactions; Stereochemistry of S_N2 (Walden Inversion) S_N1 (Racemisation); Explanation of both by taking the example of optically active alkyl halide – 2 bromobutane; Ease of hydrolysis – comparision of alkyl, benzyl, alkyl, vinyl and aryl halides.

Text Books:

1. Concise Inorganic Chemistry, (5^{th} Ed.), J. D. Lee (Blackwell)
2. Modern Inorganic Chemistry, W. L. Jolly (McGraw-Hill)
3. Coordination Compounds, S. F. A. Kettle (ELBS)
4. Inorganic Chemistry, Gary Wulfsberg (Viva Books)
5. Mechanism and theory in organic chemistry, Thomas H Lowry, Addison Wesly Longman

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MSNT 104: Polymeric Materials

Unit-I: Basic Concepts in Polymers 15 h

Definition of monomer & polymer; Classification of polymers; Mechanism of polymerization - Addition (Free radical) and Condensation polymerization; Polymerization techniques - Bulk, Solution, Suspension and Emulsion; Definition of Copolymer (Random, Alternate, Block and Graft) and blends

Unit-II: Molecular Weight and its Determination 15 h

Concept of average molecular weight, Number, weight, viscosity and Z-average molecular weights; Molecular weight and degree of polymerization; Polydispersity and molecular weight distribution in polymers; Significance of molecular weight; Determination of molecular weight by membrane osmometry, viscosity and end group analysis.

Unit-III: Physical Properties 15 h

Glass transition temperature: Definition, determination of t_g and factors influencing t_g , relation between t_g and t_m and t_g of blends and copolymers

Crystallinity: Degree of crystallinity and polymer crystallization behaviour

Rheology of polymer materials: Hooke's equation; Newton's equation; Maxwell and Voigt models for visco-eleasticity; Deformation behaviour of polymer

Unit IV: Polymer Solutions 15 h

Process of dissolution; Thermodynamics of polymer dissolution; Flory-Huggins theory of polymer solutions; Nature of polymer molecules in solution; Size and shape of macromolecules in solution; viscosity of dilute polymer solutions

References:

1. Text Book of polymer science by Gowarikar, Sreedhar and Viswanathan, Wiley-Eastern Publications. India
2. Introduction to polymers – by R.J.Young, Chapman and Hall, U.K.
3. Organic polymer chemistry by K.J.saunders, 2nd Ed., Chapmann Hall Publications, U.K.,1988
4. Plastic materials by J. Brydson, 7th ed., Butterworth-Heineman, Elsevier (2005)
5. Industrial Polymers – by Ulrich

MSNT 105 Practical – I: Physical Chemistry

1. Determination of rate constant of acid hydrolysis of an ester and investigate the effect of catalyst concentration, reactant concentration and temperature.
2. Conductometry.
3. Potentiometry
4. Estimation of monomer, and other functional groups

5. Identification of plastics by simple test

6. Synthesis of polymer by bulk and solution techniques

MSNT 106 Practical – II: Inorganic Chemistry

1. Semi-micro qualitative analysis of a mixture containing four cations of rare elements and insolubles:

   Rare elements: Te, W, Se, Mo, Zr, Ce, Th, V, and U.

   Insolubles: $PbSO_4$, $SrSO_4$, Al_2O_3, Cr_2O_3, Fe_2O_3, SnO_2, TiO_2, ThO_2, WO_3.

2. Quantitative separation and determination of the following pairs of metal ions using complexometric methods

   a) Cu^{2+} and Ni^{2+}

   b) Ca^{2+} and Mg^{2+}

   c) Fe^{3+} and Ti^{3+}

   d) Cu^{2+} and Zn^{2+}

MSNT 201: Quantum Mechanics

Unit-I:Postulates of Quantum Mechanics 15 h

Postulates of quantum mchanics; Eigen values and Eigen functions for finite well and barrier; Simple harmonic oscillator; Schroedinger equation and operator method.

Liner vector space-Ket and Bra notations; Observables as Hermitian operators; Properties of Hermitian operators; Matrix representation of and operator-Unitary transformation

Unit-II Angular Momentum 15 h

Orbital angular momentum – L_x, L_y,L_z, L^2, L_+, L_-operators; Commutation operators, Eigen functions and Eigen values of L^2 and L_z; Spin angular momentum and matrices,; Addition of angular momenta; Clebsch-Gordon coefficients for J_1=J_2 = ½.

UNIT-III: Approximate Methods 15 h

Time independent nongenerate perturbation- Anhormonic oscillator; Degenerate; Linear stark effect in H atom; Variation method; He atom and harmonic WKB approximation; Connecting formulae; Application to potential well barrier; Quantization and tunnelling; Time dependent perturbation; Transition - Harmonic perturbation and Fermi Golden rule.

UNIT-IV: Relativistic Quantum Theory 15 h

Klein – Gorden equation; Probability current density; Inadequacy of K. G. equation; Dirac's linear equation-plane wave solution; Negative energy states and spin of electrons.

Reference Books:

1. Arul Das, Quatntum Mechanics
2. S.L. Kakani and H.M. Chandalia, Quantum Mechanics
3. B.S. Rajput and Pragatiprakasan, Advanced quantum Mechanics
4. V.K. Thankappan, Quantum Mechanic, Wiley Eastern Limited
5. P.M. Methews and K. Venkatesan, A Textbook of Quantum Mechanics, Tata McGraw Hill Publishing Company.
6. S. L. Gupta, V. Kumar, H.V. Sharma and R. C. Sharma Jai, Quantum Mechanics, RakashNath and Company.
7. P.T. Mathews, An Introduction to Quantum Mechanics, McGraw Hill Publishing Company

MSNT 202: Properties of Bulk and Nanomaterials - I

Unit-I: Dielectric and Ferroelectric Properties **15 h**

Dielectric properties: Dielectric polarization; Dielectric constant and displacement vector; Atomic or molecular polarizability; ClausiusMossotti relation; Types of polarizability - Dipolar polarizability, Frequency dependence of dipolar polarizability; Ionic polarizability; Electronic polarizability

Ferroelectric properties: Classification and properties of ferroelectrics; Ferroelectric domains; Dipole theory of ferroelectricity; Theory of $BaTiO_3$; Dielectric behaviour of $BaTiO_3$ and determination of transition constants; Titanium and oxygen ion displacement theories; Anti-ferroelectricity and piezoelectricity; Effect of particle size on ferroelectrics

Unit-II: Magnetic Properties **15 h**

Classification; Weiss filed theory; Temperature dependence of spontaneous magnetization; Heisenberg model; Exchange; Exchange interaction; Exchange integral; Concept of ferromagnetic domains;

Antiferromagnetism: Molecular field theory of Antiferromagnetism; Ferrimagnetism – Introduction; Structure of ferrites; Curie temperature and susceptibility of ferromagnets; Garnets; Occurrence of super paramagnetism; Effect of nano size particles on domain structures and other magnetic properties

Unit-III: Mechanical Properties **15 h**

Concept of stress and strain; Hook's law; Stress strain behaviour; Anelasticity; Elastic properties of materials -Young's modulus, bulk modulus, shear modulus and Poissson's ratio; Plastic deformation - Yielding and yield strength, tensile strength, ductility, resilience, toughness, true stress and strain and hardness; Creep of soft materials;

Effect of nanodimensions on mechanical properties- Elastic properties, hardness and strength, tensile ductility and strain hardness, creep and super-plastic behaviour, fracture and toughness

Unit-IV: Thermal Properties **15 h**

Specific heat of solids – The classical model, the Einstein model, the Density of states; The Debye's model; Thermal conductivity of solids; Conductivity due to electrons and phonons; Thermal expansion of solids; Thermal properties of nonmaterials

Text Books:

1. R. L. Singhal, Solid State Physics, KedarNath Ram Nath& Co.;, India
2. Material science and engineering An introduction by W.D. Callister, Jr, John wiley and Sons
3. Wahab, Solid State Physics
4. Kittle, Introduction to Solid State Physics
5. Gupta, Kumar, Sharma, Solid State Physics
6. S.O.Pillai, Solid-State-Physics
7. Nanostructures and Nanomaterials by Guozhong Cao, Imperial college Press
8. Textbook of Nanoscience and Nanotechnology by B.s. Murthy, P. Shankar, Baldev Raj, B.B. Rath and J. Murday, Universities Press InidaPvt Ltd.

MSNT 203: Polymer Processing, Composites and Heat Resistant Polymers

Unit-I: Plastic Additives, Degradation and Stabilization 15 h

Additives: Type of plastic additives - fillers, plasticizers and softeners, lubricants and flow promoters' anti aging additives, flame retardants, colourants, blowing agents' cross linking agents, photo stabilizers, Nucleating agents; Equipment used for compounding-the fabricator, raw material forms and mixing.

Degradation and Stabilization: Types of degradation – Physical (thermal, photo and mechanical degradation and stabilization) and Chemical degradation (solvolytic, hydrolysis, oxidative and bio degradation)

Unit – II: Polymer Processing 15 h

Extrusion: Extrusion line; Extruder screw-single and twin screw; Mixing zones

Injection moulding: Process details of plunger and reciprocating screw type injection moulding, Components of a basic mould.

Blow moulding: Basics of extrusion and injection blow moulding.

Fibre spinning: Spinning process; Spinnerets; Melt, dry and wet spinning

Unit-III Composites and its fabrication 15 h

Need of composites; Classification; Components of composites; Matrix Materials – Preparation and properties of epoxy, polyesters; Reinforcements - glass, carbon and Kevlar; Fabrication of composites – Hand layup, Spry dry, reaction injection moulding, compression moulding and Pultrusion

Unit-IV: Heat Resistant Polymers 15 h

Preparation, properties and uses of (i) Polyphenylene sulfide; (ii) Poly sulfones; (iii) Poly benzimidazole (PBI) and (v) poly(ether ether Ketone) (PEEK); Aromatic polyamides- Poly(meta Phenyleneisophthalamide)-Poly(paraphenyleneterephthalamide; Polyimides- Poly(amide-imides), Polyesterimides, Polyetherimides-Poly bismaleimides.

Text Books:

1. Text Book of polymer science by Gowarikar, Sreedhar and Viswanathan, Wiley-Eastern Publications. India
2. Organic polymer chemistry by K.J.saunders, 2nd Ed., Chapmann Hall Publications, U.K.,1988
3. Plastic materials by J. Brydson, 7th ed., Butterworth-Heineman, Elsevier (2005)
4. Polymer processing by D.H. Morton Jones, Chapman and Hall, UK.
5. Polymer mixing Technology: George Mathews,applied science Publishers.
6. An introduction to composite materials by Derek Hull, Cambridge University Press, Cambridge, U.K. ((1981)

MSNT 204: Introduction to Nanoscience and Synthesis of Nanomaterials

Unit 1: Basic Concepts in Nanoscience and Carbon Nanostructures 15 h

Scientific Revolution - Feynman's Vision – Nanoscience – Nanotechnology - Nanomaterials definitions - Classification of Nanomaterials - dimensions, confinement - Surface to volume ratio - Energy at bulk and nano scale - Nature Nanophenomena – Size dependent variation in Physical- Chemical- Catalytic properties - Allotropes of carbon and carbon nanostructures.

UNIT – II: Synthesis of Nanomaterials: Chemical Methods 15 h

Colloidal precipitation - Sol-Gel process - Reduction method - Hydrothermal - Solvothermal - Templated - Combustion route and photochemical method.

UNIT – III: Synthesis of Nanomaterials: Physical and Mechanical Methods 15 h

Arc discharge – Lithography – Chemical Vapor Deposition - High Energy Ball milling – Mechano-chemical reactions - Special Nanostructures - Quantum dots - Magnetic NPs - Nanocomposites- ZnO- TiO_2.

UNIT-IV: Synthesis of Nanomaterials: Biological Methods and applications 15 h

Advantages of biogenic synthesis of nanoparticles – Bio-Nanoparticles using bacteria, fungi andalgae – Purification and characterization of bio-nanoparticles- Bioremediation using microorganism – Gold Nanoparticles in Catalysis and Biomedical applications – Application of Biogenic silver nanoparticles in fabrics and antibacterial properties - Application of Nanomaterials for self-cleaning surfaces.

Text books:

1. Nanomaterials, Nanotechnologies and Design - M.F.Ashby, P.J.Ferreira, D.L.Schodek, Elsevier (2009).
2. Text book of Nanoscience and Nanotechnology - B S Murthy, P Shankar, Baldev Raj, B BRath and James Murday, Universities Press (2012).
3. NANO: The Essentials – T.Pradeep, TATA McGraw Hill (2007).
4. Springer Handbook of Nanotechnology- Ed. by B. Bhushan, Springer-Verlag(2004)
5. Vacuum Technology, A. Roth, North- Holland Pub., 2nd Edition (1982)
6. The Chemistry of Nanomaterials: Synthesis, Properties and Applications, C.N.R. Rao, A. Muller, A. K. Cheetham (Eds), Wiley-VCH Verlag (2004)
7. B.S. Murty and S. Ranganathan, International Materials Reviews (1998) Vol. 43(3), 101

MSNT 205 Practical – III: Polymer Material Lab

1. Determination molecular weight of a polymer by viscometer and end group analysis methods
2. To study the effect of solvents on viscosity of polymer using viscometer.
3. Size of the molecule: To determine the intrinsic viscosity, Huggins and Kramer's constants, viscosity average molecular weight and hence root mean square end to end length and expansion coefficient of the given polymer using viscometer
4. Synthesis of polystyrene/PMMA
5. Study the miscibility of the polymer blend using refractometer and viscometry.
6. Degradation studies of poly (vinyl alcohol) by Viscosity method.

MSNT 206 Practical – IV: Study of Properties of Materials

1. Determination of lattice constant of a mono-atomic and di-atomic lattices
2. Creep behaviour
3. Hysteresis behavior of magnetic materials
4. Di-electric behavior of ferroelectric materials
5. Thermal expansion of materials
6. Initial permeability of magnetic materials
7. Determination of specific heat of a graphite with a change in temperature

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MSNT 207: Introduction to Nanoscience and Synthesis of Nanomaterials

Unit 1: Basic Concepts in Nanoscience and Carbon Nanostructures 15 h

Scientific Revolution - Feynman's Vision – Nanoscience – Nanotechnology - Nanomaterials definitions - Classification of Nanomaterials - dimensions, confinement - Surface to volume ratio - Energy at bulk and nano scale - Nature Nanophenomena – Size dependent variation in Physical- Chemical- Catalytic properties - Allotropes of carbon and carbon nanostructures.

UNIT – II: Synthesis of Nanomaterials: Chemical Methods 15 h

Colloidal precipitation - Sol-Gel process - Reduction method - Hydrothermal - Solvothermal - Templated - Combustion route and photochemical method.

UNIT – III: Synthesis of Nanomaterials: Physical and Mechanical Methods 15 h

Arc discharge – Lithography – Chemical Vapor Deposition - High Energy Ball milling – Mechano-chemical reactions - Special Nanostructures - Quantum dots - Magnetic NPs - Nanocomposites- ZnO- TiO_2.

UNIT-IV: Synthesis of Nanomaterials: Biological Methods and applications 15 h

Advantages of biogenic synthesis of nanoparticles – Bio-Nanoparticles using bacteria, fungi andalgae – Purification and characterization of bio-nanoparticles- Bioremediation using microorganism – Gold Nanoparticles in Catalysis and Biomedical applications – Application of Biogenic silver nanoparticles in fabrics and antibacterial properties - Application of Nanomaterials for self-cleaning surfaces.

Text books:

1. Nanomaterials, Nanotechnologies and Design - M.F.Ashby, P.J.Ferreira, D.L.Schodek, Elsevier (2009).
2. Text book of Nanoscience and Nanotechnology - B S Murthy, P Shankar, Baldev Raj, B BRath and James Murday, Universities Press (2012).
3. NANO: The Essentials – T.Pradeep, TATA McGraw Hill (2007).
4. Springer Handbook of Nanotechnology- Ed. by B. Bhushan, Springer-Verlag(2004)
5. Vacuum Technology, A. Roth, North- Holland Pub., 2nd Edition (1982)
6. The Chemistry of Nanomaterials: Synthesis, Properties and Applications, C.N.R. Rao, A. Muller, A. K. Cheetham (Eds), Wiley-VCH Verlag (2004)
7. B.S. Murty and S. Ranganathan, International Materials Reviews (1998) Vol. 43(3), 101

MSNT 301: Characterization Techniques

Unit-I: UV-Visible and Atomic absorption spectroscopy 15 h

UV-Visible spectroscopy: Introduction, Types of electronic transisitons, Effect of conjugation, Concept of chromophore and Auxochrome, Bathochromic, Hyperchromic and Hypsochromic shifts, Theory, Instrumentation, Double beam spectroscopy; Sources of radiation, Detectors, Monochromators, Applications to organic compounds and Chemical kinetics and disadvantages.

Atomic Absorption spectrophotometer: Theory, Instrumentation, resonance line sources, hollow cathode lamp, chemical and spectral applications with special reference to analysis of trace metals in oils, alloys and toxic metals in drinking water and effluents**.**

Unit-II: IR Spectroscopy 15 h

Vibrational energies of diatomic molecule, Infrared selection rules, Asymmetry of rotation, Hydrogen bonding, Rotational vibration spectra of polyatomic molecules, Interpretation of vibrational spectra, Instrumentation, Fourier transform infrared spectroscopy.

UNIT-III: Raman Spectroscopy 15 h

Classical and quantum theory of Raman effect. Stokes and anti-Stokes Raman lines, Pure rotational Raman spectra, Linear symmetric, top and spherical top molecules, vibrational Raman spectra, Complementary nature of IR and Raman spectra. Structure determination using Raman spectra, Experimental techniques and instrumentation.

UNIT-III: X-ray Diffraction 15 h

Bragg's law, Laue transmission and back reflection methods, Powder Methods: Principle of powder diffraction, Interpretation of powder photographs by analytical and graphical methods, Rotating crystal Methods: Oscillation and rotation methods, Weisenberg and Burger's precession methods, Reciprocal Lattice: Geometrical construction, relation between direct- reciprocal Lattice, Reciprocal of simple cubic, BCC, FCC lattices.

Text Books:

1. M.H.Willard, Instrumental Methods of Analysis, CBS publishers, (1986)
2. G.R. Chatwal and S. Anand, Spectroscopy Atomic and Molecular, Himalaya Pub. House (2004)
3. M. Bersohn and J.C. Baird, An Introduction to Electron Paramagnetic Resonance, Benjamin Inc., London (1967)
4. BK Sharma, Spectroscopy, Goel Publishers House, Meerut (2007)
5. B.D. Cullity, Elements of X-ray Diffraction,
6. L.V. Azarkoff, Elements of X-ray Crystallography,
7. L.V. azarkoff and M.J. Buerger, The Powder Method in X- ray Crystallography
8. Atomic and Molecular spectroscopy-C,L Arora ,S Chand Publishing Company,3rd Edition (2001)
9. Molecular Spectroscopy- Raman Gopalan and Raghavan, Thomson Learning Publishers(2004)

MSNT 302: Semiconductors and Devices

UNIT-I: Basic Aspects of Semiconductors **15 h**

Intrinsic and extrinsic semiconductors, Expression for position of Fermi levels and carrier concentrations, Variation of Fermi levels with temperature, np product, Carrier mobility, Conductivity and their variation with temperature, Direct and indirect band gap semiconductor, Hall effect, Continuity equation, Drift and Diffusion, Einstein relation,

Unit-II: Transport Phenomenon **15 h**

Concept of electrical and thermal resistivity, Different scattering mechanisms, Matheissens rule, Formulation of Boltzmann transport equation, Relaxation time approximation, Distribution function, Expression for thermal and electrical conductivities for metals, Lorenz number.
Somerfield model: its consequences, Electron-Lattice interaction (Quantitative only),

Unit-III: Junctions and Interfaces **15 h**

p-n Junctions: Description of p-n Junction action, Junction in equilibrium, Application of bias- energy band diagrams, The abrupt junction- Calculation of the built-in voltage, Electric field and potential distributions, Expression for Depletion layer capacitance
Static-I-V characteristics of p-n junction diodes: The ideal diode model, Derivation of ideal diode equation, Real diodes- Carrier generation, recombination in the junction depletion region, I-V characteristics of Real Diodes.
Electrical breakdown in p-n junctions: Zener and Avalanche breakdown in p-n junctions, Distinction between the Zeber abd avalanche breakdown, Applications of breakdown diodes.

Unit-IV: Junction Transistors: **15 h**

Bipolar junction transistors: Principle of operation, Ebers Moill Equations- Four regions of operation of a bipolar transistor. Real transistors – carrier recombination in the Emitter- Base junction depletion region- effect of collector bias variation, avalanche multiplication in the collector- base junction and base resistance.
Junction field – effect transistors: JFET principle of operation, Static I-V Characteristics of the idealized model.
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Text Books:

1. M. S. Tyagi, Introduction to Semiconductor Materials and Devices, John Wiley & Sons, 2004.
2. S. M. Sze, Semiconductor Devices Physics and Technology, 2nd Edition, John Wiley & Sons, 2005.
3. Kannan Kano, Semiconductor Devices, PHI, 2005.
4. Robert F Pierret, Semiconductor Device Fundamentals, Pearson Education, 2006.
5. J. L. Moll, Physics of Semiconductors**,** McGraw-Hill.
6. Ben G. Streetman and Sanjay Banerjee, Solid State Electronic Devices, VI ed, Pearson Ed, 2007.

MSNT303: Alloys and Paints

Unit-I: Alloys **15 h**

Introduction to Alloys; Solid solution - substitutional and interstitial; Hume Rother's rules for primary substitution sold solubility; Intermediate phase – interstitial compounds, defect phase and electro valence compounds;

Shape memory alloys: General Characteristics; Nickel-titanium shape memory alloy, Cu-Zn-Al; Cu-Al-Ni alloy systems; Applications of shape memory alloys

Unit-II: Phase diagrams **15 h**

Introduction; Phase rules; Unary phase diagrams – pure iron phase diagrams; Binary Phase diagrams – Ni-Cu system; Lever rule; Bi-Cd; Fe-C; Pb-Sn system; Uses of Phase diagrams; Limitations of phase diagrams

Unit-III: Fundamentals of Paints **15 h**

Definition; Ingredients of paints –binders, pigments, additives, solvent and plasticizers; Classification of paints by curing mechanism (air dried and baked), solvent (aqueous and non-aqueous), functions of system ingredients (primers, sealers, under coats and finishing/top coats), solid content (high and low) and resin components; Film formers – synthetic resins (alkyd, acrylic and urethane coatings); Methods of film formation; Fundamentals of film formation; Factors affecting coating properties – film thickness (mechanical and optical methods), film density and pigment volume concentration

Unit-IV: Properties and Evaluations of Paints: **15 h**

Optical properties of coatings (basics of color, gloss and hiding power); mechanical properties of coatings [structure-mechanical correlations and measurement and performance (hardness and bending tests)]; Ageing properties (accelerated outdoor and laboratory tests); Adhesion properties of coatings (factors affecting the establishment of adhesion bond, measurement sof surface coating adhesion (Destructive methods film detachment by normal (direct pull off and topple method), by lateral stress (scratch and peel test) Non-destructive tests; Scratch, mar and wear resistance test; Ani-condensation paint test; Water and chemical resistance of paint films; Tautening test; Fire resistance; Resistance to yellowing; Bleeding.

References:

1. Physical Metallurgy by Vijendra Singh, Standard Publishing distributors
2. Material Science & Engineering by V. Raghavan, Prentice Hall of India
3. Physical Metallurgy- Principles, Practise by V. Raghavan, Prentice Hall of India
4. Introduction to Paint Chemistry by G.P.A. Turner, Oxford & IBH Publishing Company, India
5. Text Book of polymer science by Gowarikar, Sreedhar and Viswanathan, Wiley-Eastern Publications. India
6. Surface coatings by Swaraj Paul, John Wiley & Sons (1985)
7. Testing of paints by CJA Taylor and S. Mark)

MSNT 304 Nanocatalysis and its Application

Unit I: Fundamentals in Catalysis

Homogeneous and Heterogeneous Catalysis – Characteristics of Catalytic Reactions - Promotors – Catalytic Poisoning – Activation Energy and Catalysis – Intermediate compound formation theory – Adsorption theory – Acid-base Catalysis and its mechanism - Enzyme Catalysis and its mechanism - Requirements for Successful Catalysts - Surface Area determination of non-porous and porous materials using BET method.

Unit II: Synthesis of Nanoporous Catalysts

Microporous materials: Zeolites- Zeotypes – Overall steps in zeolite crystallization- Zeolite synthesis via.- dry gel route- Zeolite Y- determination of surface acidity- shape-selectivity; Mesoporous aluminosilicates: Synthesis of Mesoporous Silica- MCM-41- SBA-15; Mesoporous Carbon - Sulfated Zirconia - Ag/SiO_2 composite nanocatalysts.

Unit III: Nanophotocatalysis and Catalysis of Gold nanocrystals

Introduction to photocatalysis: Principle- Band energy engineering- Degradation of dye - Hydrogen generation- Organic synthesis. Gold catalysts: Uniqueness- particle size- Metal-support interaction; Preparative methods: Co-precipitation – Deposition – Precipitation - Impregnation- Photodeposition- bimetallic catalysts; Properties- Selective oxidation & reduction reactions.

Unit IV: Applications of Nanocatalysts

Environmental protection; Energy processing: Processes involved in crude oil refinery- Gasoline production- Cracking- Fuel cell- Biomass gasification- Biodiesel- Naphtha reforming; Energy conversion & storage; Synthesis of fine chemicals- Hydrogenation/dehydrogenation- Synthetic fuels- Selective oxidation reactions- Polymerization.

References

1. Essentials of Physical Chemistry, Arun Bahl, B.S. Bahl, G.D. Tuli, S.Chand, Revised Edition 2012.
2. Nanoporous Materials: Synthesis and Applications, Edited by Qiang Xu, CRC Press, 2013
3. Catalysis: Principles and Applications, Edited by B. Viswanathan, S. Sivasanker, A.V. Ramaswamy, Narosa Publishing House, 2011
4. Photocatalysis, Edited by Masao Kaneko, Ichiro Okura, Springer, 2003.
5. New and Future Developments in Catalysis, Edited by Steven L. Suib, Elsevier, 2013.
6. Catalysis by Gold, Geoffrey C. Bond, Catherine Louis, David T. Thompson, Imperial College Press, 2006.

MSNT 305 Practical III: Nano Catalysis Lab

1. Study on Adsorption Properties of porous and non-porous materials
2. Solar Photocatalytic degradation of Methyl Orange dye in aqueous solution using TiO_2 photocatalyst
3. Semiconductor Band Gap Engineering – Synthesis of N-doped ZnO
4. Photochemical deposition of Silver nanoparticles on anatase TiO_2 photocatalyst under solar light irradiation.
5. Hydrothermal Synthesis of Zeolite (Microporous Materials)
6. Synthesis of Mesoporous material by template assisted method
7. Synthesis of $H_2Ti_3O_7$ nanostructure using alkaline hydrothermal method and its post-synthesis process for conversion into anatase TiO_2
8. Preparation of Fe-ZSM-5 Zeolite by ion-exchange method
9. Synthesis of CdS nanoparticles Chemical kinetics, Optical absorption spectra, Band gap estimation from the band edge using UV-VIS spectrophotometer

MSNT 306 Practical IV: Semiconductors Lab

1. Determination of energy gap of semiconductors
2. Hall effect
3. Field emission transmitter characteristics
4. Bipolar junction transistor
5. MOSFET characteristics
6. Characteristics of zenaer-diode
7. Analysis of powder diffraction pattern
8. Lave diffraction pattern
9. Silicon solar cells

MSNT-307 Non-core: Characterization Techniques and Applications of Nanomaterials

Unit 1: X-ray diffraction and UV-Visible spectroscopy 15 h

Bragg's law - Powder Methods: Principle of powder diffraction, Interpretation of powder photographs by analytical and graphical methods, Rotating crystal Methods: Oscillation and rotation methods – Estimation of particle sizes by X-ray diffraction pattern.

Introduction - Types of electronic transitions, Effect of conjugation, Concept of chromophore and Auxochrome, Bathochromic, Hyperchromic and Hypsochromic shifts, Theory, Instrumentation, Double beam spectroscopy; Sources of radiation, Detectors, Monochromators, Applications to organic compounds and Chemical kinetics and disadvantages.

UNIT – II: Electron Microscope and Chromatography Techniques 15 h

Principle, Instrumentation and Applications of Scanning Electron Microscopy (SEM) – Transmission Electron Microscopy (TEM) – Dynamic Light Scattering (DLS) – Gas Chromatograph – High Performance Liquid Chromatograph (HPLC).

UNIT – III: Nanotechnology enabled sensors 15 h

Sensors and Nanotechnology Enabled Sensors - Inorganic Nanotechnology Enabled Sensors – Gas Sensing with Nanostructured Thin Films - Nanotechnology enabled optical sensors - Organic Nanotechnology Enabled Sensors - Proteins in Nanotechnology Enabled Sensors - Nano-sensors based on Nucleotides and DNA.

Unit-IV: Drug Delivery Applications 15 h

Preparation of nanomaterials - Dispersion, Solvent Evaporation, Emulsification, Supercritical fluid technology, polymerization - Drug loading - Drug releases characteristics, surface properties - protein adsorption, characterization methods, surface modification (PEG, PEO coated) – Nanoparticles (Polysorbate) for blood brain barrier.

Text Books:

1. M.H.Willard, Instrumental Methods of Analysis, CBS publishers, (1986)
2. G.R. Chatwal and S. Anand, Spectroscopy Atomic and Molecular, Himalaya Pub. House (2004)
3. B.D. Cullity, Elements of X-ray Diffraction,
4. John J. Bozzola and Lonnie D. Russel, "Electron Microscopy", Jones and Bartlett Publishers Inc., USA, 1999.
5. Sivasankar, Instrumental Methods of Chemical Analysis, Oxford University Press, New Delhi (2012)
6. K.Kalantar-zadeh and B. Fry, Nanotechnology-Enabled Sensors, Springer, USA (2008).
7. Biodegradable Polymeric nanoparticles as drug delivery devices, K.S.Soppimath et al., *Journal of Control Release*, 70 (2001) 1 - 20.

MSNT 401: Advanced Characterization Techniques

Unit-I: Microscopic Techniques **15 h**

Surface topography, Principle, Instrumentation and applications of Electron microscopy, Scanning electron microscopy (SEM),Transmission electron microscopy (TEM), Scanning Probe Microscopy (SPM), Scanning tunnelling electron microscopy (STM), Atomic force microscopy (AFM).

UNIT-II: Thermal Analysis **15 h**

Principles, Instrumentation and applications of ThermogravimetricAnalalysis (TGA), Differential Thermal Analysis (DTA), Differential Scanning Calorimetry (DSC), Thermo-mechanical Analysis (TMA); Understanding of curing kinetics and thermal decomposition reactionto ceramics and polymers.

Unit-III: Chromatographic Techniques **15 h**

Chromatographic Parameters - Paper Chromatography (PC), Thin Layer Chromatography (TLC), Column Chromatography (CC), Ion Exchange Chromatography (IEC). High Performance Liquid Chromatography (HPLC): Principle, Instrumentation, pumps, columns, Detectors and Applications of HPLC. Gas Chromatography (GC): Principle, Instrumentation, columns, Detectors and Applications of GC.

UNIT-IV: Chemical and Particle size Analysis Techniques **15 h**

Basic concepts – Energy dispersion Analysis of X-rays (EDAX) – X-ray photoelectron spectroscopy (XPS) – Auger Electron Spectroscopy (AES) – Dynamic Light Scattering (DLS).

Text Books:

1. M.H.Willard, Instrumental Methods of Analysis, CBS publishers, (1986)
2. M. Bersohn and J.C. Baird, An Introduction to Electron Paramagnetic Resonance, Benjamin Inc., London (1967)
3. Sivasankar, Instrumental Methods of Chemical Analysis, Oxford University Press, New Delhi (2012)
4. R. Haynes, Optical Microscopy of Materials, International Textbook Company, Glascow, 1984.
5. John J. Bozzola and Lonnie D. Russel, "Electron Microscopy", Jones and Bartlett Publishers Inc., USA, 1999.
6. H. W. Willard, L. L. Merritt and J. A. Dean, Instrumental Methods of Analysis, (Affiliated East-West)
7. D. A. Skoog and D. M. West (Holt, Rinehart and Wilson) Principles of Instrumental Analysis.
8. Nature (2000) Microscopy Techniques

MSNT 402: Properties of Bulk and Nanomaterials-II

Unit -I: Optical Properties: 15 h

Electromagnetic radiation; Light interaction with solids and Atomic and electron interactions; Optical properties of metal; Optical properties of non metals-refraction, refelction, absorption, transmission, color, opacity and translucency in insulators; Basic concepts of luminescence, photoconductivity, lasers, and optical fibers in communication;
Optical properties of nanomaterials –Surface Plasmon resonance and quantum size effects

Unit-II: Superconductivity 15 h

Concept of zero resistance, Magnetic behaviour, Distinction between a perfect conductor and superconductor,Meissner effect,Isotope effect, Specific heat behaviour, Thermal conductivity, Infrared absorption- First and second order transitions in superconductors, Londons equations,Penetration depth, BCS theory(Qualitative aspects only), Applications of superconductors, High T_c superconductors.

Unit-III Diffusion in Solids 15 h

Fick's laws; Diffusion mechanism; Study state diffusion; Non study state diffusion; Factors that influence diffusion; The Kirkendal effect; Diffusion in alkali halides; Ionic conductivity

Unit-IVElectrical Properties 15 h

Ohm's law; Electrical conductivity; Electronic and ionic conduction; conduction in terms of band and atomic bonding model; electron mobility; electrical resistivity of metals; conduction in ionic materials; Electrical conductivity of semiconductors with temperature; Electrical properties of polymers
Effect of particle size on electrical properties – surface scattering, change of electronic structure, quantum transport, effect of microstructure

Text Books:

1. R. L. Singhal, Solid State Physics, KedarNath Ram Nath& Co.;, India
2. Material science and enginerring An introduction by W.D. Callister, Jr, John wiley and Sons
3. Wahab, Solid State Physics
4. Gupta, Kumar, Sharma, Solid State Physics
5. S.O.Pillai, solid-state-physics
6. Nanostructures and Nanomaterials by Guozhong Cao, Imperial college Press
7. Textbook of Nanoscience and Nanotechnology by B.s. Murthy, P. Shankar, Baldev Raj, B.B. Rath and J. Murday, Universities Press InidaPvt Ltd.

MSNT 403: Applications of Nanomaterials and Nanotechnology

Unit-I: Introduction to MEMS, Photonics and spintronics: 15 h

MEMS: Introduction to MEMS; Materials for MEMS-si based; Processes for micro-machining – dry and wet etching; Substrate bonding; surface micromachining; Oxidation; Applications – pressure sensors.

Photonics: Photons and electrons – similarities and differences, free space propagation, confinement of photons and electrons, Propagation through classically forbidden region; Tunnelling applications; Photonic crystal.

Spintronics: why spin; Metallic magnetic multilayers – interlayer exchange coupling and giant magnetoresistance; Applications – magnetic hard drives

Unit-II: Inorganic Nanotechnology Enabled Sensors 15 h

Introduction - Sensors andNanotechnology Enabled Sensors; Inorganic Nanotechnology Enabled Sensors –Gas Sensing with Nanostructured Thin Films; Nanotechnology enabled optical sensors; Organic Nanotechnology Enabled Sensors - Proteins in Nanotechnology Enabled Sensors; Nano-sensors based on Nucleotides and DNA.

Unit-III: Environmental Applications: 15 h

Introduction; Nanomaterials for ground water remediation; Nanomaterials for membrane process - principles and membrane fabrication; Nanomaterials as adsorbents; Electrochemical sensors based on nanomaterials for environmental monitoring.

Unit-IV: Drug Delivery Applications 15 h

Introduction; Preparation of nanomaterials - Dispersion, Solvent Evaporation, Emulsification, Supercritical fluid technology, polymerization; Drug loading; Drug releases characteristics, surface properties - protein adsorption, characterization methods, surface modification (PEG, PEO coated) – Nanoparticles (Polysorbate) for blood brain barrier.

Text Books:

1. Nanostructures & Nanomaterials, Guozhong Cao, Imperial College Press (2003)
2. Introduction to Nanoscale Science & Technology, Massimiliano Di Ventra, StephaneEvoy, Randy Heflin, Kluwer Academic Publishers (2004)
3. Nanophotonics by Paras N Prasad, Wiley & sons Publications (2004)
4. Nanoelectronics& Photonics by AnatoliKorkin, Federico Rosei, Spinger publications
5. Biodegradable Polymeric nanoparticles as drug delivery devices, K.S.Soppimath et al., *Journal of Control Release*, 70 (2001) 1 - 20.
6. K.Kalantar-zadeh and B. Fry, Nanotechnology-Enabled Sensors, Springer, USA (2008).
7. Environmental Nanotechnology, Eds. M.R.Wiesner and J.Y.Bottero, McGrawHill (2007)
8. Environmental Applications of Nanomaterials, Eds.G.LFryxell, G.Cao, Imperial College Press (2007).

MSNT 404: Energy Conversion Technologies

UNIT - I Introduction **15 h**

Principles of renewable energy – Introduction, Energy and sustainable development, Fundamentals, Scientific principles of renewable energy, Societal implications; Nanotechnology for sustainable energy - Energy conversion process; indirect and direct energy conversion; Nanotechnology enabled renewable energy technologies -Energy transport, conversion and storage.

Unit-II: Batteries **15 h**

Principles of battery operation; Battery components; Types of batteries – Primary and secondary batteries; Lead acid, Nickel-cadmium and Lithium ion batteries

Unit-III: Fuel Cells **15 h**

Fuel Cell principles; Types of fuel cells - Alkaline Electrolyte, Phosphoric acid, Molten Carbonate, solid oxide and direct methanol fuel cells; Principle and operation of Proton Exchange Membrane (PEM) fuel cell -Construction of PEM fuel cell stack, efficiency characteristics of PEM fuel cells; Direct methanol fuel cells

Unit-IV: Solar Cells **15 h**

Importance of solar cells; Principle of operation; Current-voltage characteristics,; Comparison of inorganic and organic solar cells, silicone solar cells - manufacture of polycrystalline and nanocrystalline silicon; Conjugated polymer solar cells - Concept of heterojunction (dispersed and molecular heterojunctions); Function of dye sensitized solar cells (DSSC).

Reference Books:

1. J. Twidell and T. Weir, *Renewable Energy Resources*, Routledge, Taylor & Francis group, New York, Third Edition (2015).
2. Vielstich, Hand Book of Fuel Cells: Fuel Cell Technology and applications, Wiley CRC Press
3. C.Rayment, S.Sherwin. Introduction to fuel cell technology (2003)
4. D.M.Roundhil, John P.Facker, Optoelectronic properties of inorganic compounds, Plenum press, New York (2009).
5. A brief history of the development of organic and polymeric photovoltoics, H.Spanggaard and F.C. Krebs, Solar Energy Materials & Solar Cells 83 (2004) 125-146.

MSNT 405: Nanomaterial synthesis Lab

1. Nanocomposite (TiO_2/Fe_2O_3) preparation by wet-chemical method
2. Synthesis of SnO_2 nanoparticles by co-precipitation method
3. Synthesis of ZnO_2 nanoparticles by sol-gel method
4. Solid state synthesis of ZnO nanorods
5. Synthesis of Fe^o nanoparticles by chemical reduction method using $NaBH_4$ solution

MSNT 406: Project work