M.Sc. II Year Materials Science (MS)

Semester-III

MS- 301: ATOMIC AND MOLECULAR PHYSICS

1. STRUCTURE OF ATOM (PERIODS-5 HOURS)

Various atomic models- survey-brief ideas with assumptions, postulates and shortcomings, Quantum states of an electron in an atom, Quantum numbers, Electron spin, Stern-Gerlach experiment, Vector atom model- its need/important.

Atom model for two valance electron (10 Hours)

Various coupling schemes: LL, SS, LS and jj, Pauli exclusive principle, Coupling principle, factors for LS coupling , Lande interval rule, JJ branching rule, selection rules, magnetic moment of atom, Lande g factor, Zeeman effect, intensity rules, calculation of Zeeman pattern, Paschen Back effect-LS and jj coupling and Paschen Back effect, Breits scheme for derivation of spectral terms, Pauli's exclusive principle

2. COMPLEX SPECTRA (PERIODS-5 HOURS)

Displacement law, alternation law of multiplicities, vector model for more valance electrons, Lande interval rule, inverted terms, Hund's rule, Zeeman effect and magnetic quantum numbers in complex spectra, magnetic energy and Lande g factor

Hyperfine structure (5 Hours)

Introduction, hyperfine structure and Lande interval rule, nuclear interaction with one valance electron, hyperfine structure of two or more electron, Zeeman effect in hyperfine structure, Back Gouldsmit effect in hyperfine structure.

3. PURE ROTATIONAL STRUCTURE (8 HOURS)

Rotation of linear system (classical and quantum mechanical), rigid rotator, rotational energy levels and their populations, interaction of rotation with rotating molecules, rotational spectra of rigid rotators, selection rules for linear molecules, determination of moment of inertia and bond length from rotational spectra, isotope effect on rotataional spectra, relative intensities of spectral lines

4. PURE VIBRATIONAL SPECTRA (PERIODS-6 HOURS)

Vibrations of two particles connected by spring (classical), Harmonic oscillators, vibrational energies of diatomic molecules, interaction of radiation with vibrating molecules, anharmonic oscillator, deduction of molecular properties from vibrational spectra of diatomic molecules.

Rotation and vibration spectra (4 Hours)

Diatomic vibrating rotator coupling of rotation and vibration , rotation-vibration spectra , selection rules and transition for vibrating rotator, intensities in rotation and vibration spectrum, parallel and perpendicular bands of linear molecules, Isotope effect-vibration , rotation.

5. ELECTRONIC SPECTRA OF DIATOMIC MOLECULES (PERIODS-8 HOURS)

Electronic energy curves, potential energy curves stable and unstable molecular states, vibration structure of electronic transitions, general formula, graphical representation, isotopes effect, rotational structure of electronic spectar, the branches of band , band head formation, shading of bands: Fortrat diagram, intensities in electronic bands-Vibrational structure-Frank Condon principle, absorption and emission, rotational structure , transition.

References:

1. Introduction to atomic and nuclear physics (Van Norstrand Reinhold (east-West

Press) by H. E. White)

2. Introduction to atomic spectra (Mc. Graw hill, International Edition) by H. E.

White)

3. Atoms and Molecules: An introduction for students of Physical chemistry (W. A.

Benjamin Inc. New York) by Martin Karplus and Richard N. Porter)

4. Atomic physics, (Oxford Master Series in atomic, optical and laser physics) by

Christopher J. Foot.

5. Introduction to atomic spectra (Mc. Graw hill, International Edition) by H. E. White

6. Molecular structure and spectroscopy , 2 nd edition (PHI learning Pvt. Ltd. New

Delhi) by G. Aruldhas

7. Fundamentals of Molecular Spectroscopy (McGraw-Hill Publishing Company by

Colin Banwell)

MS -302: CONDENSED MATTER PHYSICS

1. SPECIFIC HEAT AND LATTICE VIBRATIONS (PERIODS-7 HOURS)

Classical theory of specific heat and it's drawbacks, Einstein theory of specific heat, vibrational modes of a continuous medium, Debye approximation, The Born cut-off procedure, Vibrational modes of a finite one-dimentional lattice of identical and diatomic lattice.

2. FREE ELECTRON THEORY OF METALS (PERIODS-7 HOURS)

The free electron theory of metals, electronic specific heat, Response and relaxation phenomena, Drude model of electrical and thermal conductivity, the Fermi surface, electrical conductivity; effects of the Fermi surface, Fermi surfaces: its characteristics.

3. DIELECTRIC AND OPTICAL PROPERTIES OF INSULATORS

(PERIODS-12 HOURS)

Static fields: Macroscopic description of the static dielectric constant, The static electronic and ionic polarizabilities of molecules, Oriental polarization, The internal field according to Lorentz and the Clausius-Mosotti formula. Alternating fields: The complex dielectric constant and dielectric losses, dielectric losses and relaxation time, The Classical theory of electronic polarization and optical absorption. Ferroelectricity: General properties of ferroelectric materials, classification, ferroelectric domains.

4. MAGNETISM (12 HOURS)

Magnetic materials and their properties, Quantum theory of paramagnetism, Diamagnetism, Ferromagnetism: The Weiss molecular field and its interpretation, Temperature dependence of spontaneous magnetization. Antiferromagnetism: Molecular field theory, two sub lattice model.

5. SUPERCONDUCTIVITY (10 HOURS)

Introduction, Meissner effect, The critical field, Thermodynamics of superconducting transition: The heat capacity and stability of superconducting state, Electrodynamics of superconductors: The London equation, coherence length and penetration depth, BCS theory of superconductivity, the condensate, The Josephson Tunneling: DC and AC effect, Introduction to high Temperature superconductivity.

References:

1. A. J. Dekker, Solid State Physics, Macmillan India Limited, 1991.

2. Charles Kittel, Introduction to Solid State Physics, , John Wiley and Sons.

3. H. P. Myers, Viva Books Private Limited, Second Edition.

4. N. W. Ashcroft and N. D. Mermin, Solid State Physics, CBS publishing Asia Ltd.

5. M. Ali Omar, Elementary Solid State Physics, Pearson Education.

MS 303: ELEMENTS OF MATERIALS SCIENCE:

UNIT-1: CLASSIFICATION OF MATERIALS (PERIODS-3 HOURS)

Classification of materials, Selection of materials, the structure of Materials, selecting an optimal material, Modern material needs, structure-property relationship in materials.

(Reference books:

1. Material Sciences and Process, S. K. Hajara-Chaudhari, Indian Book Distributing Co.

2. Material Science and Engineering, W.D. Callister, Jr. W, Wiley Internatinal Editions, 2003.)

UNIT-2: PROPERTIES OF MATERIALS (10 HOURS)

Mechanical properties: Mechanical fundamentals, isotropy and anisotropy, stress and strain, hooks law and modulus of materials, stress-strain relation, Important properties: strength, ductility, toughness, stiffness, malleability, plasticity, hardness, brittleness.

Electrical properties: Resistivity, conductivity, Ionic conductivity, factors affecting conductivity.

Thermal properties: Heat capacity, expansion, conductivity and stresses

Optical properties: Electromagnetic radiation, refraction, reflection, absorption,

transmission, color.

Magnetic properties: Diamagnetism, paramagnetism, ferromagnetism, ferrimagnetism, susceptibility and curie temperature, hysteresis loss.

(Reference books:

1. Material Sciences and Process, S. K. Hajara-Chaudhari, Indian Book Distributing Co.

2. Material Science and Engineering, W.D. Callister, Jr. W, Wiley Internatinal Editions, 2003.)

UNIT-3: PHASE DIAGRAM (PERIODS-8 HOURS)

Structure of solid solutions, factors governing the solid solubility (Hume Rothery rules for primary solid solution), inter-metallic compounds.

Phase diagrams : basic concept, Construction of phase diagrams, Phase rule and applications, Lever rule and applications, interpretation of phase diagram, single component system, study of phase diagram for complete solid solution, eutectic diagram with no solid solution, eutectoid, peritectic diagram, micro structural diagram developments: Study of Pb-Sn, Fe-C, Cu-Ni phase diagram

Reference books:

1. Material Sciences and Process, S. K. Hajara-Chaudhari, Indian Book Distributing Co.

2. Material Science and Engineering, W.D. Callister, Jr. W, Wiley Internatinal Editions, 2003.

3. Material Science and Engineering , V. Raghavan, Prentice Hall of India Pvt. Ltd.,

New Delhi.

UNIT-4: METALLURGICAL THERMODYNAMICS AND PHASE TRANSFORMATION:

(5 HOURS)

Thermodynamic origin of phase diagram, Solidification and crystallization, nucleation and growth, surface and volume energies, nucleation and critical radius in heterogeneous and homogenous nucleation, growth rate and nucleation rate, phase transformation in alloys crystal growth, rate of crystal growth, Facets.

Reference books:

1. Physical Metallurgy Part I and II, Edited by R. W. Cahn and H_Haasan, North Holland, 1983.

2. Phase transformation in metals and allys, david A. Porter and K.E. Easterling, (Van Nostarnd Rcinhold Co., Newyork).

3. Material Sciences and Process, S. K. Hajara-Chaudhari, Indian Book Distributing Co.

UNIT-5: POLYMERIC MATERIALS (PERIOD-8 HOURS)

Basic concepts of polymer, Chemistry of polymers, size of polymer, molecular weight, molecular shape, structure, configuration, crystallanity, mechanisms of polymerization, mechanical, optical and thermal properties of polymers, electrical properties - conducting polymers.

Reference books:

1. Material Sciences and Process, S. K. Hajara-Chaudhari, Indian Book Distributing Co.

2. Material Science and Engineering, W.D. Callister, Jr. W, Wiley Internatinal Editions, 2003.

3. Material Science and Engineering , V. Raghavan, Prentice Hall of India Pvt. Ltd., New Delhi.

UNIT-6. CERAMICS: (PERIOD-4 HOURS)

Classification of ceramics, structure of ceramics, silicates structure, mechanical, thermal and electrical properties of ceramic phases, applications.

Reference books:

1. Material Sciences and Process, S. K. Hajara-Chaudhari, Indian Book Distributing Co.

2. Material Science and Engineering, W.D. Callister, Jr. W, Wiley Internatinal Editions, 2003.

UNIT-7: ADVANCED MATERIALS (PERIOD-10 HOURS)

a) Nanomaterials: Concepts of nanomaterials- electron confinement in infinitely deep square well, confinement in two and one dimensional well, idea of quantum well structure, quantum dots, mechanical, electrical, thermal, magnetic and optical properties of nanomaterials.

b) Composite materials:

Concepts of composites, Types of composites, particulate composites and Fiber Composites, Theories of hardening of composites.

c) Solar energy materials: (or Solar Cell materials)

Photovoltaic conversion materials, silicon, GaAs, CdS, CuInSe2, Black Ni, Black Cr, selective coatings its properties

Reference books:

1. Material Sciences and Process, S. K. Hajara-Chaudhari, Indian Book Distributing Co.

2. Material Science and Engineering, W.D. Callister, Jr. W, Wiley Internatinal Editions, 2003.

3. Nano: The essentials – Understanding Nanoscience and Nanotechnology, T. Pradip, Tata Mac Graw Hills

4. Nanotechnology, Booker and Boysen, Wiley.

Semester-IV

MS-401 NUCLEAR PHYSICS

UNIT-1: NUCLEAR PROPERTIES (PERIOD-04 HOURS)

The nuclear radius, mass and abundance of nuclides, energy of nucleons in the nucleus, nuclear binding energy, nuclear angular momentum and parity, nuclear electromagnetic moments, nuclear excited states.

UNIT-2: NUCLEAR MODELS (PERIOD-08 HOURS)

Constitution of the nucleus; neutron-proton hypothesis, Nature of nuclear force, Inventory of stable nuclides, Liquid drop model: Semi-empirical mass formula, applications of semi-empirical mass formula, limitations of liquid drop model, Nuclear Shell model: Shell model and it's evidence, limitations of shell theory.

UNIT-3: RADIOACTIVITY (PERIOD-10 HOURS)

Radioactive disintegration and displacement law, Nuclear decay laws, half life, successive disintegrations, radioactivity equilibrium, radioactive dating methods. Alpha–decay: kinematics of alpha decay: alpha particle energy, penetration through the Coulomb barrier (Geiger-Nutall law) Beta-decay: The old beta decay theory and the neutrino hypothesis, Energy relations and Q-values in beta-decay, The Fermi theory of beta-decay, selection rule. Gamma decay: passage of gamma rays through matter, gamma ray spectra and nuclear energy levels, radiative transitions in nuclei.

UNIT-4: DETECTION OF NUCLEAR RADIATION AND THEIR MEASUREMENT

(PERIOD-06 HOURS)

Interaction of radiations with matter, gas filled counters, scintillation detectors, semiconductor detectors, counting statistics, energy measurements, coincidence measurement and time resolution, measurement of nuclear lifetimes.

UNIT-5: THE ACCELERATION OF CHARGED PARTICLES (PERIOD-06 HOURS)

The van de Graff machine, cyclotron, frequency-modulated cyclotron, the betatron and the electron synchrotron, the proton synchrotron, Linear accelerators,

UNIT-6: NUCLEAR FISSION AND FUSION (PERIOD-06 HOURS)

Characteristics of fission, Energy in fission, energy distribution between the fission fragments, energetic of fission process, cross section of neutron induced fission, controlled fission reactions, Q- value calculations, fission reactor, fission explosives, Basic fusion process, cross section of fusion reaction, critical temperature, Lawson criterion.

UNIT-7: ELEMENTARY PARTICLES (PERIOD-08 HOURS)

Classification of elementary particles, conservation laws, fundamental interactions in nature. Elementaary idea of CP and CPT invariance. Quark hypothesis: Classification, Quark structure of mesons and baryons, Gellman-Okubo mass formula.

References:

1. Introductory nuclear Physics, Kenneth S. Krane, John Wiley and Sons, 1988.

2. Nuclear Physics, Irving Kaplan, Addison-wesley publishing company, Inc, 1962.

3. Introduction to Nuclear Physics, H. A. Enge, Addison-Wesley, 1975.

4. Concepts of Nuclear Physics, Bernard L Cohen, Tata McGraw-Hill publishing company limited, 1971.

5. Basic ideas and concepts in Nuclear Physics, K. Heyde, IOP publishing limited, 2005.

6. Nuclear Physics, S. N. Ghoshal, S. Chand and company limited, 1994.

7. Introduction to Atomic and nuclear Physics, Harvey E. White, Van Nostrand Reinhold company, 1964.

MS-402: MATERIAL SYNTHESIS METHODS

UNIT-1: MATERIAL SYNTHESIS (PERIOD-06 HOURS)

Importance of the materials and methods, formation of thin and thick films with application, Synthesis of Bulk (Powder form) Materials: Basic concept, process description, preparation, blending of powder, compacting and sintering, advantages and disadvantages, application of the bulk material and a case study

UNIT-2: CRYSTALS GROWTH (PERIOD-04 HOURS)

Importance of growing crystals and their applications, thermodynamic theory of crystal growth. Growth from solution methods: growth from water solution, gel method, flux method, hydrothermal method Growth from melt methods: Czocharalski crystal pulling (CZ), Bridgman-Stockbarger technique

UNIT-3: THICK FILM DEPOSITION (PERIOD-04 HOURS)

Screen Printing: Basic aspects of the process, experimental set-up, substrate materials, screen printing and firing process, advantages and disadvantages, a case study. Doctor blade: Basic aspects of the process, experimental set-up, substrate materials, need of annealing step, advantages and disadvantages, a case study

UNIT-4: THIN FILM DEPOSITION (PERIOD-01 HOUR)

Brief introduction regarding different methods for thin film formation (Physical and chemical), nucleation and growth mechanism

CHEMICAL METHODS: (PERIOD-06 HOURS)

Chemical bath deposition (CBD) method: Introduction, experimental set-up, basic requirements, basic mechanisms: ion-by-ion, hydroxide cluster and complex decomposition mechanism, deposition from acidic bath, effect of stirring, advantages and disadvantages, a case study of CdS deposition, size quantization in CD films. Brief idea about SILAR (Successive ionic layer adsorption and reaction) method, advantages over CBD

ELECTROCHEMICAL DEPOSITION (PERIOD-06 HOURS)

Introduction, principle, Faradays laws of electrolysis, experimental set-up, electrode, electrolyte, additives, power supply, substrate, Classification of elctrodeposition: potentiostatic, galvanostatic and cyclic voltametry, Steps involved in electrodeposition process, Over potential term, nucleation and growth mechanism, advantages and disadvantages, a case study

SPRAY PYROLYSIS: (PERIOD-05 HOURS)

Principle, experimental set-up, preparative parameters: influence of temperature, precursor's solution, Model for films deposition: Atomization of precursor's solution, Aerosol transport, decomposition of precursor, advantages and disadvantages, a case study of SnO_2 deposition

SPIN COATING: (PERIOD-02 HOURS)

Introduction, experimental set-up, Modeling spin coating, advantages and disadvantages, a case study.

UNIT-5:PHYSICAL METHODS (PERIOD-14 HOURS)

Introduction physical vapor deposition (PVD) and Chemical Vapor deposition (CVD) Evaporation Methods: Thermal Evaporation (vacuum evaporation), Flash evaporation, Laser evaporation, Molecular beam epitaxy Chemical Vapor Deposition: Basic aspects of CVD, reactions in CVD, Types of CVD: atmospheric pressure, low pressure, plasma enhanced CVD. Sputtering: Basic principle of sputtering process, brief regarding triode sputtering, ion beam sputtering

Reference books:

1. Thin Film Phenomenon, K. L. Chopra, Mc Graw Hill, 1969.

2. Hand Book of Thin Film Technology, L. I. Maissel and R. Glang Mc Graw Hill, 1969

3. Thin Film Processes. J. L. Vossen and W. Kem, (Academic Press, 1978)

4. The Material Science of Thin Films, M. Ohring (Academic Press, 1972)

5. Chemical Solution Deposition of semiconductor Films, Gary Hodes, Marcel Dekker Inc

6. Thin Film Deposition Using Spray Pyrolysis, J. Electroceramics, 14 (2005) 103-111

7. Preparation of Thin Films, Joy George, Marcel Dekker, Inc.

8. Handbook of semiconductor electrodeposition, R.K.Pandey, S.N.Sahu, S.Chandra

9. Spin Coating for rectangular substrates, A Thesis written by G. A. Luurtesema, University of California, Berkeley, 1997

MS-403: CHARACTERIZATION OF MATERIALS

UNIT-1: UV-VIS-IR SPECTROSCOPY (PERIOD-10 HOURS)

Range of IR absorption, requirement for IR radiation absorption, theory of IR absorption spectroscopy, linear molecules, symmetric molecules, asymmetric molecules, Instrumentation, FTIR-application, limitations Color and light absorption, the chromospheres concept, theory of electronic spectroscopy-orbital's involved in electronic transitions, laws of light absorption,- Beer's and Lamberts law, Instrumentation, UV-spectrophotometer, sample and reference cells, application of UV-Vis spectroscopy, Band gap determination (Direct , Indirect) for thin films.

UNIT-2: RAMAN SPECTROSCOPY (PERIOD-08 HOURS)

Characteristic properties of Raman lines, differences between Raman spectra ad infrared spectra, mechanism of Raman effect, instrumentation, intensity of Raman lines, Application of Raman spectroscopy.

UNIT-3: X-RAY DIFFRACTION (PERIOD-08 HOURS)

Crystalline state, X-ray diffraction process, preliminary discussion and single crystal pattern, and their information content, structure and structure factor determination, particle size determination, crystallography by diffraction of radiations other than X ray, application of X-ray diffraction measurement and analysis

UNIT-5: ELECTRON MICROSCOPY

Why uses electrons, electron lenses, factors limiting the performance of electromagnetic lenses (PERIOD-02 HOURS)

Transmission electron microscopy (TEM): Constituent parts and their functions with attachments, selected area, high resolution, reflection and scanned diffraction, dark field electron microscopy, reflected electron microscopy, X-ray microanalysis quantitative interpretation of crystalline image contrast. (PERIOD-06 HOURS)

Scanning electron microscopy (SEM): History, signal detection, equipment, nature of SEM image, secondary electron emission: the distribution of emitted secondaries, selection of secondaries in SEM, secondary electron yield, effect of angle, voltage and field contrast, specimen charging effect, factors affecting resolving power of SEM, relation between working distance, final aperture size and beam divergence in SEM.

Energy dispersive X-ray spectroscopy (EDS): principle, instrumentation, sample analysis, limitations (PERIOD-10 HOURS)

UNIT-5: ATOMIC FORCE MICROSCOPY (PERIOD-04 HOURS)

Operating principle, Different operating modes: Contact, tapping, non-contact, forces between the tips and surfaces, limitations of AFM.

Reference books:

1. Elements of X-ray diffraction

D. Cullity, Addision-Wesely Publishing Comp, USA.

2. Encyclopedia of Materials Characterization, (Series)

C Richard Brundle, Charles A Evans, Jr Shaun Wilson, Surface, Interfaces, Thin Films

3. SEM Characterization of semiconductors D. B. Holt, and D.C. Joy, Academic Press, New Delhi

4. Fundamental of molecular spectroscopy. N. Banwell, Tata McGraw-Hill Publ. Company Ltd New Delhi

5. Electron Microscopes, J. A. Swift

6. Introduction to Diffraction in Materials Science and Engineering, Aaron D Krawitz, John Willey and Sons Inc

7. Atomic Force Microscopy, Cheryl R Blanchard, The Chemical Education, 1/vol.