M.Phil / Ph.D. Physics

SYLLABUS
(Effective from the Academic year 2020 – 2021 and onwards)

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KARPAGAM
ACADEMY OF HIGHER EDUCATION
(Deemed to be University)
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DEPARTMENT OF PHYSICS

KARPAGAM ACADEMY OF HIGHER EDUCATION
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DEPARTMENT OF PHYSICS
FACULTY OF ARTS, SCIENCE & HUMANITIES
RESEARCH PROGRAM – M.Phil / PhD in Physics
(2020–2021 Batch and onwards)

Course code	Name of the course	Instruction hours / week	credits	Maximum Marks (100)
20RPHY101	Paper-I: Research Methodology and Pedagogy	4	4	100
20RPHY201	Paper-II: Research Publication Ethics	4	4	100
20RPHY301	Paper III: Special Paper I-Solar Energy and Utilization	4	4	100
20RPHY302	Paper III: Special Paper II-Thin Film Physics			
20RPHY303	Paper III: Special Paper III- Crystal Growth			
20RPHY304	Paper III: Special Paper IV- Solid State Ionics			
20RPHY305	Paper III: Special Paper V-Concepts of Nanophysics and Nanotechnology			
20RPHY306	Paper III: Special Paper VI- Experimental Techniques In Materials Science			
Program Total		12	12	300

20RPHY101 PAPER – I: RESEARCH METHODOLOGY & PEDAGOGY

Unit – I

Ethics of Research – Objectives of Research – Historical Background of Physics Research – Research Works of Sir C.V. Raman, S.Chandrasekhar and Venkaraman Ramakrishnan (Nobel prize works only) (Nobel Lectures) – Experimental Research in Physics – Design of the experiment, Apparatus to be used, Results and Interpretation – Theoretical Research in Physics – Theory, Models, Methods to solve the problems, results and Interpretation – Literature Survey on Thesis Writing – Online literature survey – Science Citation Index – Impact factor of a journal – Thesis writing.

UNIT II -PROBABILITY DISTRIBUTIONS

Mean, Median peak value, and Standard Deviation – Binomial Distribution – Poisson Distribution – Gaussian or Normal Error Distribution – Modes of distributions.

Error Analysis

Instrumental and Statistical uncertainties – Propagation of errors – Estimation of means and errors – Method of least squares – Statistical fluctuations – Chi square test of a distribution

UNIT III - NUMERICAL INTEGRATION

Trapezoidal and Simpson's 1/3 rule for single integrals - Error estimates - Trapezoidal and Simpson's rule for double integrals

Interpolation: Two points Gaussian quadrature - Three points Gaussian quadrature - Cubic spline interpolation

Eigen values: Power method - Jacobi method (Only 2 x 2 and 3 x 3 matrices)

Simulation techniques: Monte Carlo simulation – Fuzzy logic.

UNIT IV- COMPUTER APPLICATIONS IN PHYSICS RESEARCH

Programming in C: Constants - Variables - Data types - Operators and Expressions -Input/Output Statements - Control statements - Functions - Arrays - One, two, multidimensional array declarations and initializations

Simple applications using C - Program: Program to integrate tabulated function using Trapezoidal rule - Program to integrate tabulated function using Simpson's 1/3 rule -Program to compute the solution of first order differential equation of the type y' = f(x,y) using RK4 method - Program to compute first order differential equation y' = f (x,y) using Milne's method - Program to compute the interpolation value at a specified value from a set of table points using natural cubic spline interpolation.

UNIT V-PEDAGOGICAL METHODS IN HIGHER LEARNING

Historical perspectives: Objectives and role of higher education – Learning and learning hierarchy – Information processing – Learning and outcomes – Motivation.

Education evaluation: A conceptual framework – Methods of evaluation – Self evaluation and student evaluation in higher education – Question banking – Diagnostic testing and remedial teaching.

SUGGESTED READINGS

1. E.Balagurusamy - Numerical methods , Tata McGraw Hill Publishing company Limited
2. Nye, J.F. (1985). Physical Properties of Crystals: Their Representation by Tensors and Matrices. Oxford University Press, New York.
3. P.Kandasamy - Numerical methods, K.Thilgavathy and K.Gunavathi, S.Chand and company limited
4. Numerical Mathematical Analysis by Scarborough J B, Oxford & Ibh, ISBN-10: 9788120417595
5. Bevington Philip, Robinson D. Keith – Data Reduction and Error Analysis for Physical Sciences, Mc Graw Hill Higher Education.

20RPHY201 PAPER – II: RESEARCH PUBLICATION ETHICS

(Effective from the academic year 2020-2021 and onwards)

UNIT I

Philosophy and Ethics:

Introduction to Philosophy: Definition, nature and scope, concept, branches - Ethics: Definition, moral philosophy, nature of moral judgments and reactions.

UNIT II

Scientific Conduct:

Ethics with respect to science and research – Intellectual honesty and research integrity – Scientific misconduct: Falsification – Fabrication and Plagiarism (FFP) - Redundant publications: duplicate and overlapping publications – salami slicing - Selective reporting and misrepresentation of date.

UNIT III

Publication Ethics:

Publication Ethics: Definition, introduction and importance - Best practices / standards setting initiatives and guidelines: COPE,WAME, etc. - Conflicts of interest - Publication Misconduct: definition, concept, problems that lead to unethical behavior and vice versa, type -Violation of publication ethics, authorship and contributor ship - Identification of publication misconduct, complaints and appeals - Predatory publishers and journals.

UNIT IV

Publication Misconduct:

Group Discussions: Subject specific ethical issues, FFP, authorship - Conflicts of interest - Complaints and appeals: examples and fraud from India and abroad. Software tools: Use of plagiarism software like Turnitin, Urkund and other open source software tools

UNIT V

Databases and Research Metrics:

Database : Indexing database - Citation database: Web of Science, Scopus, etc. Research Metrics: Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score - Metrics: h-index, g index, i10 index, altmetrics.

UNIT VI

Development of e-content & IP:

Integrated Library Management System (ILMS) : e-journals – e-books – e-shodhsindu – shodhganga – Database - e-content Development - Learning Management System (LMS) – e-PG- Pathshala – CEC (UG) SWAYAM – MOOCs – NPTEL - NMEICT. IPR: Patent – Copyrights - Trademark – Geographical Indication.

PRACTICE

Open Access Publishing:

Open access publications and initiatives - SHERPA / RoMEO online resource to check polisher copyright & self-archiving policies - Software tool to identify predatory publications developed by SPPU - Journal finder / journal suggestion tools viz. JANE, Elsevier Journal Finder, Springer Journal Suggester, etc.

References:

1. P. Oliver, (2003), The student's guide to research ethics, Open University Press Maidenhead, Philadelphia.

2. H. Zwart, (2010), Tales of Research Misconduct, Springer International Publishing AG.

3. Research Impact, https://guides.osu.edu/c.php?g=608754&p=4224917 .

4. Diane Elkins et al. (2015). E-Learning Fundamentals: A Practical Guide.

5. Nick Rushby et al. (n.d.) Wiley Handbook of Learning Technology. Wiley Education. Wiley

20RPHY301 PAPER – III : SPECIAL PAPER I : SOLAR ENERGY AND ITS UTILIZATION

UNIT 1- RADIATION GEOMETRY

Basis earth sun angles - Determination of Solar time - Derived Solar angles - Day length - Solar Radiation measurements - selective surfaces - Heat balance energy lost by radiation, convection and conduction - Physical characteristics of selective surfaces - Anti reflection coatings - Solar reflector materials - production methods of coatings.

UNIT II - FUNDAMENTALS OF HEAT TRANSFER

Transfer of Heat by Conduction: Study heat flow in a slab-steady heat flow in a cylindrical shell- Heat transfer through fins – Transient heat conduction. Thermal Radiation: Basic laws of radiation – Radiant heat transfer between two black bodies- Radiant heat transfer between grey bodies. Convention heat loss Evaluation of convective heat transfer co-efficient –Free convection from vertical planes and cylinders – Forced convection – Heat transfer for fully established flow in tubes.

UNITIII - SOLAR THERMAL SYSTEMS

General description of plate collector – thermal losses and efficiency of FPC –Energy balance equation – Evaluation of overall loss coefficient – Thermal analysis of flat plate collector and useful heat gained by the fluid performance of solar air heaters – Heating and drying of agricultural products Types of drier in use.

Solar concentrators and Receiver geometries – General characteristics of focusing collector systems Evaluation of optical losses – Thermal performance of focusing collectors.

UNITIV-PHOTOVOLTAICS

Description of the photovoltaic effect – Electrical characteristics calibration and efficiency

measurement – silicon solar energy converters – Thermal generation of recombination centers silicon. Role of thin films in solar cells Properties of thin films for solar ells

CdSe, CdTe, In P, Ga As, Cd Cu_2, Cu In SnO_2, Cd_2SnO_4 ZnO)- Transport properties of metal films – poly crystalline film silicon solar cells (Photovoltaic characteristics, junction analysis loss mechanisms) Amorphous silicon solar cells (Structural compositional optical and electrical properties)

UNIT V- ENERGY STORAGE AND SOLAR APPLICATIONS

Types of energy storage Thermal storage Latent heat storage – Electrical storage principle of operation of solar ponds-Non convective solar ponds – Theoretical analysis of solar pond – solar distillation – solar cooking –solar pumping.

SUGGESTED READINGS

1. Charles E. Backus (1976). Solar cells. IEEE Press
2. Garg, H.P. (1982). Treatise on solar energy volume I fundamentals of Solar Energy.
3. Kasturi Lal Chopra and Suhit Ranjan Das (1983). Thin film solar cells.
4. Rai, G.D. (1996). Solar energy utilization.
5. Rai, G.D.Thermal performances testing of FPC and CPC

20RPHY302 PAPER – III: SPECIAL PAPER II. THIN FILM PHYSICS

(Effective from the academic year 2020-2021 and onwards)

UNIT I- PREPARATION OF THIN FILMS

Spray pyrolytic process – characteristic feature of the spray pyrolytic process – ion plating – Vacuum evaporation – Evaporation theory – The construction and use of vapour sources – sputtering Methods of sputtering – Reactive sputtering – RF sputtering - DC planar magnetron sputtering.

UNIT II- THICKNESS MEASUREMENT AND NUCLEATION AND GROWTH IN THIN FILM

Thickness measurement: electrical methods – optical interference methods – multiple beam interferometry – Fizeau – FECO methods – Quartz crystal thickness monitor.

Theories of thin film nucleation – Four stages of film growth incorporation of defects during growth.

UNIT III- ELECTRICAL PROPERTIES OF METALLIC THIN FILMS

Sources of resistivity in metallic conductors – sheet resistance - Temperature coefficient of resistance (TCR) – influence of thickness on resistivity – Hall effect and magneto resistance – Annealing – Agglomeration and oxidation.

UNIT IV- TRANSPORT PROPERTIES OF SEMICONDUCTING AND INSULATING FILMS

Semiconducting films; Theoretical considerations - Experimental results – Photoconduction – Field effect thin films – transistors, Insulation films Dielectric properties – dielectric losses – Ohmic contracts – Metal – Insulator and Metal – metal contacts – DC and AC conduction mechanism .

UNIT V - OPTICAL PROPERTIES OF THIN FILMS AND THIN FILMS SOLAR CELLS

Thin films optics –Theory – Optical constants of thin films – Experimental techniques – Multilayer optical system – interference filers – Antireflection coating, thin films solar cells: Role, Progress, and production of thin solar cells – Photovoltaic parameter, thin film silicon (Poly crystalline) solar cells : current status of bulk silicon solar cells – Fabrication technology – Photo voltaic performance: Emerging solar cells: GaAs and $CulnSe_2$.

SUGGESTED READINGS:

1. Anderson, J.C. The use of thin films in physical investigation, 1968,
2. Berry, Koil and Harris. Thin films technology, 1968 Princeton ; London : Van Nostrand
3. Chopra, K.L. Thin film Phenomena, 1969, McGraw-Hill Inc.
4. Chopra, K.L. and Das, S.R. Thin films solar cells, Springer
5. Holland, L. Vacuum deposition of thin films, 1966, Springer US
6. Maissel, L.I. and Clang, R. Hand book of Thin films Technology, 1970, New York : McGraw-Hill.
7. Vilsan, J.L. Thin films processes, 1978, Academic Press.

20RPHY303 PAPER – III: SPECIAL PAPER III: CRYSTAL GROWTH

(Effective from the academic year 2020-2021 and onwards)

UNIT I- FUNDAMENTALS OF CRYSTAL GROWTH

Importance of crystal growth – Classification of crystal growth methods – Basic steps: Generation, transport and adsorption of growth reactants – Nucleation: Kinds of nucleation –Classical theory of nucleation: Gibbs Thomson equations for vapour and solution – Kinetic theory of nucleation – Becker and Doring concept on nucleation rate – Energy of formation of a spherical nucleus – Statistical theory on nucleation: Equilibrium concentration of critical nuclei, Free energy of formation.

UNIT II- THEORIES OF CRYSTAL GROWTH

An introductory note to Surface energy theory, Diffusion theory and Adsorption layer theory –Concepts of Volmer theory, Bravais theory, Kossel theory and Stranski's treatment – Two-dimensional nucleation theory: Free energy of formation, Possible shapes and Rate of nucleation – Mononuclear, Polynuclear and Birth and Spread models – Modified Birth and Spread model – Crystal growth by mass transfer processes: Burton, Cabrera and Frank (BCF) bulk diffusion model, Surface diffusion growth theory.

UNIT III - EXPERIMENTAL CRYSTAL GROWTH-PART-I: MELT GROWTH TECHNIQUES.

Basics of melt growth – Heat and mass transfer – Conservative growth processes: Bridgman-Stockbarger method – Czochralski pulling method – Kyropolous method – Nonconservative processes: Zone-refining – Vertical and horizontal float zone methods – Skull melting method – Vernueil flame fusion method.

UNIT IV- EXPERIMENTAL CRYSTAL GROWTH-PART-II: SOLUTION GROWTH TECHNIQUES.

Growth from low temperature solutions: Selection of solvents and solubility – Meir's solubility diagram – Saturation and supersaturation – Metastable zone width – Growth by

restricted evaporation of solvent, slow cooling of solution and temperature gradient methods– Crystal growth in Gel media: Chemical reaction and solubility reduction methods – Growth from high temperature solutions: Flux growth Principles of flux method – Choice of flux – Growth by slow evaporation and slow cooling methods – Hydrothermal growth method.

UNIT V -EXPERIMENTAL CRYSTAL GROWTH-PART-III: VAPOUR GROWTH TECHNIQUES

Basic principles – Physical Vapour Deposition (PVD): Vapour phase crystallization in a closed system – Gas flow crystallization – Chemical Vapour Deposition (CVD): Advantageous and disadvantageous – Growth by chemical vapour transport reaction: Transporting agents, Sealed capsule method, Open flow systems – Temperature variation method: Stationary temperature profile, Linearly time varying temperature profile and Oscillatory temperature profile.

SUGGESTED READINGS

1. Brice, J.C. (1986). Crystal Growth Processes. John Wiley and Sons, New York.
2. Mullin, J.W. (2004), Crystallization. Elsevier Butterworth-Heinemann, London.
3. Pamplin, B.R. (1975). Crystal Growth. Pergamon Press, Oxford.
4. Sunagawa Ichiro. (2005). Crystals: Growth, Morphology and Perfection. Cambridge University Press, Cambridge.
5. Vere, A.W. (1987). Crystal Growth: Principles and Progress. Plenum Press, New York.

20RPHY304 PAPER – III: SPECIAL PAPER IV: SOLID STATE IONICS

(Effective from the academic year 2020-2021 and onwards)

UNIT I

Crystalline solids – space lattice – the basis and crystal structure; crystal translational vectors, symmetry operation primitive lattice cell and unit cell symmetry elements, Fundamental type of lattice, atomic packing, atomic radius, lattice constants and density, crystal structure other cubic structure – type of bonding – Ionic bonding – Energy of formation of NaCl molecules, Madelung constants – potential energy of diagram of ionic molecules – calculation of repulsive exponent – Born Haber cycle characteristics of ionic bond.

UNIT II Transport Properties of Ionic Conductors

Ionic conductivity – Normal and super ionic conductors – Mass transport in crystals – Diffusion – Atomic diffusion theory – Experimental determination of the diffusion constant – Ionic conduction – Experimental results – for ionic conduction – The Einstein relation – Dielectric loss in ionic crystals – Electronic conduction in ionic crystals – Excess conductors – Deficit conductors – Amphoteric semiconductor.

UNIT III

Phenomenological Models – Huberman's Theory – Ries Strassler Toom's Theory – Weleh and Diene Theory – Lattice Gas theory – Free ion model – Domain Model – Rica and Roth Theory – The Path Probability Method – The static variables – the Path variables – The path Probability – Stationary state condition – Classification of Superionic solids – Crystalline and Amorphous – Glasses – Dispersed solid Electrolytes – polymers – Ion exchange resins – biological basis resins – Classification over conducting ion species – mode and mechanism of conduction in each case and their corresponding criteria to be superionic conductors.

UNIT IV: Experimental Techniques and Methods

Structural characterization – XRD surface Analysis, EXAFS, IPS and Quasi neutron scattering – Thermo dynamical characterization – Differential scanning calorimetry,

Differential Thermal Analysis, Thermo Gravimetric Analysis and Thermo electric power – Ion transport properties – Electrical conductivity – Two probe method – four probe method – Immitance spectroscopy – Dynamical conductivity – state conductivity – polarisation characteristic – determination of small electronic transport numbers.

UNIT V Electrochemical Techniques and Applications

Fundamentals of electrochemistry, Linear Sweep Voltammetry, Cyclic Voltammetry, Chronoamperometry, Linear polarization, Electrochemical Impedance spectroscopy. Batteries: Primary and secondary batteries, Li-ion batteries, Supercapacitors: Electric double layer capacitor, Pseudocapacitor, Fuel Cells: Solid oxide Fuel cells, Direct Methanol Fuel Cells, Proton Exchange Membrane Fuel cells, Sensors: Oxygen sensors and electrochemical sensors, Electrochromic displays.

SUGGESTED READINGS

1. Superionic solid – Principles and applications (Ed. S.Chandra) North Holland 1981.
2. Solid state ionics (Eds. T Kudo and Fueki) VCH Publishers, Kodansha 1990.
3. Lectures on solid state physics (Eds. G Bush and H Schade), international series on Natural Philosophy Vol. 79 Pergamon, press 1976.
4. “Solid Electrolytes” (Eds. S Geller) Springer Verlag New York 1977.
5. Impedance Spectroscopy Theory, Experiment, and Applications, (Eds) Evgenij Barsoukov and J. Ross Macdonald, Wiley interscience (2005).
6. Physics of Electrolytes – Transport Processes solid Electrolytes and in Electrodes (Eds. J Hladik) Academic press, New york 1972.
7. Fundamentals of Electrochemistry, 2nd Edition, V.S.Bagotsky, Wiley Interscience. (2006).
8. Electrochemical Methods: Fundamental and Application, Allen J.Bard Wiley and Sons Publications (2001).

20RPHY305 PAPER – III: SPECIAL PAPER V :

CONCEPTS OF NANOPHYSICS AND NANOTECHNOLOGY

(Effective from the academic year 2020-2021 and onwards)

UNIT I- INTRODUCTION TO NANOTECHNOLOGY

Defining nanotechnology, Historical development – Beyond Moore's law, Comparison of bulk and nano materials – change in band gap and large surface to volume ratio, Classification of nanostructured materials – one, two and three-dimensional confinement, quantum dots, quantum wires and quantum wells, scope of applications.

UNIT II- SYNTHESIS AND CHARACTERIZATION

Classification of fabrication methods – Top to bottom approach – Ball milling, etching etc bottom to top approach – Physical and chemical methods – Molecular Beam Epitaxy, optical and electron beam lithography, Ion implantation, sputtering, thermal evaporation, pulsed laser deposition, chemical vapor deposition, controlled precipitation, sol gel methods. Grain size determination – XRD (Debye Scherer equation), TEM, AFM, STM and Light scattering techniques. Composition analysis – ICP – AES, EDAX, SIMS.

UNIT III- OPTICAL AND VIBRATIONAL PROPERTIES OF NANOPARTICLES

Basic concepts – Band structure of solids, excitons, effective mass, reciprocal lattice, Brillouin zone, phonons etc. Size and dimensionality effects – Bulk to nano transition – Density of states, potential well - quantum confinement effect – weak and strong confinement regime. Blue shift of band gap - Effective mass approximation (Rigorous mathematical treatment not necessary). Phonon confinement effect and presence of surface modes. Characterization tools - UV – Visible absorption and Photoluminescence techniques, Raman and IR spectroscopy

UNIT IV -CARBON NANOSTRUCTURES

Carbon nanostructures – carbon molecules – carbon clusters. Fullerene - structure of C_{60} and its crystal – larger and smaller fullerenes – other bucky balls. Carbon nanotubes – fabrication – structure – electrical properties – vibrational properties – mechanical

properties. Applications of carbon nanotubes – Field emission and Shielding – computers – Fuel cells – Chemical sensors – Catalysis – Mechanical reinforcement.

UNIT V -NANOMACHINES AND NANODEVICES

Extension of conventional devices by nanotechniques – Bipolar and MOS transisitors – structure and technology, electrical characteristics, limitations, low temperature behavior. Microelectromechanical systems (MEMSs), Nanoelectromechanical systems (NEMSs), Resonant Tunneling Diode, Quantum Cascade lasers, Single Electron Transistors – Operating principles and applications.

SUGGESTED READINGS

1. Mick Wilson, Kamali Kannangara, Geoff Smith, Michelle Simmons and Burkhard Raguse “Nanotechnology”, Overseas Press New Delhi 2005
2. W. R. Fahrner (Ed.) “Nanotechnology and Nanoelectronics”, Springer 2006.
3. Charles P Poole Jr and Frank J Owens “Introduction to Nanotechnology”, Wiley student edition 2003.

20RPHY306 PAPER – III: SPECIAL PAPER VI :

EXPERIMENTAL TECHNIQUES IN MATERIALS SCIENCE

(Effective from the academic year 2020-2021 and onwards)

UNIT -1 METHODS OF MATERIALS BULK SYNTHESIS

Solid state reaction - ceramic technique - microwave synthesis - sol-gel method - wet-chemical methods - Hydrothermal method.

Growth of Single Crystals - Introduction to Methods of Growth of Crystals –BCF theory- Czochralski Method - Bridgman, Zone Melting and Zone Refining Methods.

UNIT-2 PREPARATION OF THIN FILMS

Types of thin Film Growth process - Spin coating - vacuum evaporation - sputtering - Pulsed laser deposition - Vapor Methods – CVD – PVD - Fundamental aspects of Epitaxial Growth methods.

UNIT – 3 STRUCTURAL CHARACTERIZATIONS AND IMAGING TECHNIQUES

X-ray diffraction ((XRD) - Electron and neutron diffraction - elementary ideas of photoelectron spectroscopy (PES) - Basic principle of atomic resolution electron microscopy - Scanning and Transmission electron microscopy (SEM, TEM) - Scanning tunneling and atomic force microscopy (STM, AFM) techniques.

UNIT – 4 OPTICAL CHARACTERIZATIONS AND SPECTROSCOPIC TECHNIQUES

Ultraviolet / visible (UV/Vis) absorption spectroscopy - Raman and Infrared Spectroscopy - Fluorescence spectroscopy - Elementary idea of laser based non-linear techniques. Room temperature as well as low temperature Photoluminescence - Cathode Luminescence - Mössbauer spectroscopy - Impedance spectroscopy

UNIT-5 PHYSICAL PROPERTY MEASUREMENTS

Intensive and extensive properties - Physical property measurements (DSC, DTA, TGA,) - Transport properties (R-T) – Photoconductivity study (C-V, I-V) - Low conductivity measurement (Dielectric Spectroscopy) - P-E loops for ferroelectrics - magnetic properties of bulk and nano phases of material (VSM & SQUID).

Suggested Readings:

1. H.H. Willard, L.L. Merritt, J.A. Dean and F.A. Settle, Instrumental Methods of Analysis, 6th Ed., C.B.S. Publishers, New Delhi, 1991.
2. Metals Handbook, Characterization of Materials, 10th Ed., Vol. 9, American Soc. of Metals, Metals Park, Ohio, 1986.
3. G.A. Higgerson, Experiments in Materials Technology, Affiliated East-West Press, 1973.
4. L.C. Azzarof, Elements of X-ray Crystallography, McGraw-Hill, New York, 1968.
5. M.V. Heimendahl, Electron Microscopy of Materials-An Introduction, Academic Press, 1980.
6. Elton N. Kaufmann, Characterization of Materials volumes 1 and 2, John Wiley & Sons, Inc., Hoboken, New Jersey, 2003.
7. L. E.Murr. Electron and Ion microscopy and Microanalysis principles and Applications. Marcel Dekker Inc., New York, 1991.
8. V.Raghavan, Materials Science for Engineering, Prentice Hall of India Pvt Ltd, 2006.
9. Meissel. L.T and R. Glang., 2000 Handbook of thin film technology, Tata McGraw Hill, New Delhi.