**ANNA UNIVERSITY, CHENNAI**
**UNIVERSITY DEPARTMENTS**

**M.PHIL. CRYSTAL SCIENCE (FT)**

**REGULATIONS - 2019**
**CHOICE BASED CREDIT SYSTEM**

## 1. PROGRAMME EDUCATIONAL OBJECTIVES (PEOs):

I. To provide a specialization in pre-doctoral degree with advanced understanding in the concepts of crystal science, crystalline materials and crystallization.

II. To impart the necessity of literature survey for research and a broad understanding of crystal nucleation and growth and familiarize with crystal chemistry, crystal defects, and technological importance of the crystals.

III. To provide comprehensive knowledge on nucleation kinetics, crystalline materials,Crystal growth techniques and characterization techniques.

IV. To gain knowledge on growth methods, characterization of crystals, device processing and applications of crystalline materials.

## 2. PROGRAMME OUTCOMES (POs):

After going through one year of study, our M.Phil. (Crystal Science) Graduates will exhibit ability to:

| PO# | Graduate Attribute | Programme Outcome |
|---|---|---|
| 1 | Engineering knowledge | Apply knowledge of mathematics, basic science and engineering science. |
| 2 | Problem analysis | Identify,formulate and solve engineering problems. |
| 3 | Design/development of solutions | Design a system or process to improve its performance, satisfying its constraints. |
| 4 | Conduct investigations of complex problems | Conduct experiments & collect, analyze and interpret the data. |
| 5 | Modern tool usage | Apply various tools and techniques to improve the efficiency of the system. |
| 6 | The Engineer and society | Conduct themselves to uphold the professional and social obligations. |
| 7 | Environment and sustainability | Design the system with environment consciousness and sustainable development. |
| 8 | Ethics | Interaction industry, business and society in a professional and ethical manner. |
| 9 | Individual and team work | Function in a multi-disciplinary team. |
| 10 | Communication | Proficiency in oral and written Communication. |
| 11 | Project management and finance | Implement cost effective and improved system. |
| 12 | Life-long learning | Continue professional development and learning as a life-long activity. |

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## 3. PROGRAM SPECIFIC OUTCOMES (PSOs):

By the completion of M.Phil. (Crystal Science) program the student will have following Program specific outcomes.

1. Candidates completing the Master of Philosophy in Crystal Science will be acquired knowledge, general competence and analytical skills at an advanced level targeting future employment in research, industry, teaching or public administration.
2. In-depth knowledge and research experience within a specialized field of crystal science through a supervised master project.
3. Knowledge on various growth methods applied for growing crystals and characterization techniques within topical research fields.
4. Students get motivated to handle sophisticated instruments and they take up highlighted jobs in industry.

## 4. PEO / PO Mapping:

| PROGRAMME EDUCATIONAL OBJECTIVES | PROGRAMME OUTCOMES | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | PO1 | PO2 | PO3 | PO4 | PO5 | PO6 | PO7 | PO8 | PO9 | PO10 | PO11 | PO12 |
| I | ✓ | ✓ | | ✓ | | | | | ✓ | ✓ | | ✓ |
| II | ✓ | | ✓ | ✓ | ✓ | | ✓ | | | | ✓ | ✓ |
| III | | ✓ | | | ✓ | ✓ | | ✓ | | ✓ | | ✓ |
| IV | ✓ | | ✓ | | | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ |
| | | | | | | | | | | | | |

**Mapping of Course Outcome**
**and**
**Programme Outcome**

| | | Course Name | PO01 | PO02 | PO03 | PO04 | PO05 | PO06 | PO07 | PO08 | PO09 | PO10 | PO11 | PO12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| YEAR 1 | Semester 1 | Research Methodology | | ✓ | ✓ | | ✓ | | | ✓ | | | ✓ | ✓ |
| | | Theoretical and Experimental Aspects of Crystal Growth | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | ✓ | | | ✓ |
| | | Program Elective I (one from list of electives ) | ✓ | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | | ✓ | | ✓ |
| | | Program Elective II (one from list of electives ) | ✓ | ✓ | | ✓ | | ✓ | ✓ | ✓ | ✓ | | | ✓ |
| | Semester 2 | Seminar | ✓ | | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ |
| | | Dissertation | ✓ | | | | | | | ✓ | ✓ | ✓ | ✓ | ✓ |

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**REGULATIONS 2019**
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**CURRICULA AND SYLLABI**

**SEMESTER I**

| S. NO. | COURSE CODE | COURSE TITLE | CATEGORY | PERIODS PER WEEK | | | TOTAL CONTACT PERIODS | CREDITS |
|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | | |
| **THEORY** | | | | | | | | |
| 1. | CG5101 | Research Methodology | FC | 4 | 0 | 0 | 4 | 4 |
| 2. | CG5102 | Theoretical and Experimental Aspects of Crystal Growth | PCC | 4 | 0 | 0 | 4 | 4 |
| 3. | | Program Elective I | PEC | 4 | 0 | 0 | 4 | 4 |
| 4. | | Program Elective II | PEC | 4 | 0 | 0 | 4 | 4 |
| | | | **TOTAL** | **16** | **0** | **0** | **16** | **16** |

**SEMESTER II**

| S. NO. | COURSE CODE | COURSE TITLE | CATEGORY | PERIODS PER WEEK | | | TOTAL CONTACT PERIODS | CREDITS |
|---|---|---|---|---|---|---|---|---|
| | | | | L | T | P | | |
| 1. | CG5211 | Seminar | EEC | 0 | 0 | 2 | 2 | 1 |
| 2. | CG5212 | Dissertation | EEC | 0 | 0 | 32 | 32 | 16 |
| | | | **TOTAL** | **0** | **0** | **34** | **34** | **17** |

**TOTAL NUMBER OF CREDITS TO BE EARNED FOR THE AWARD OF DEGREE - 33**

**FOUNDATION COURSES (FC)**

| S. No | COURSE CODE | COURSE TITLE | PERIODS PER WEEK | | | CREDITS | SEMESTER |
|---|---|---|---|---|---|---|---|
| | | | Lecture | Tutorial | Practical | | |
| 1. | CG5101 | Research Methodology | 4 | 0 | 0 | 4 | 1 |
| | | | | | **Total Credits** | 4 | |

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## PROGRAM CORE COURSES (PCC)

| S. No | COURSE CODE | COURSE TITLE | PERIODS PER WEEK | | | CREDITS | SEMESTER |
|---|---|---|---|---|---|---|---|
| | | | Lecture | Tutorial | Practical | | |
| 1. | CG5102 | Theoretical and Experimental Aspects of Crystal Growth | 4 | 0 | 0 | 4 | 1 |
| | | | | | **Total Credits** | 4 | |

## PROGRAM ELECTIVE COURSES (PEC)

| S. No | COURSE CODE | COURSE TITLE | PERIODS PER WEEK | | | CREDITS |
|---|---|---|---|---|---|---|
| | | | Lecture | Tutorial | Practical | |
| 1. | CG5001 | Bio-Crystallization | 4 | 0 | 0 | 4 |
| 2. | CG5002 | Characterization of Semiconductor Crystals | 4 | 0 | 0 | 4 |
| 3. | CG5003 | Characterization Techniques | 4 | 0 | 0 | 4 |
| 4. | CG5004 | Epitaxial Growth | 4 | 0 | 0 | 4 |
| 5. | CG5005 | Fabrication and Characterization of Solar Cells | 4 | 0 | 0 | 4 |
| 6. | CG5006 | Ferroelectrics | 4 | 0 | 0 | 4 |
| 7. | CG5007 | Nanomaterials and Nanotechnology | 4 | 0 | 0 | 4 |
| 8. | CG5008 | Semiconductor Devices | 4 | 0 | 0 | 4 |
| 9. | CG5009 | Semiconductor Physics | 4 | 0 | 0 | 4 |

## EMPLOYABILITY ENHANCEMENT COURSES (EEC)

| S. No | COURSE CODE | COURSE TITLE | PERIODS PER WEEK | | | CREDITS | SEMESTER |
|---|---|---|---|---|---|---|---|
| | | | Lecture | Tutorial | Practical | | |
| 1 | CG5211 | Seminar | 0 | 0 | 2 | 1 | 2 |
| 2 | CG5212 | Dissertation | 0 | 0 | 32 | 16 | 2 |
| | | | | | **Total Credits:** | **17** | |

## SUMMARY

| | M. PHIL. CRYSTAL SCIENCE (FT) | | | |
|---|---|---|---|---|
| | Subject Area | Credits per Semester | | Credits Total |
| | | I | II | |
| 1. | FC | 4 | 0 | **04** |
| 2. | PCC | 4 | 0 | **04** |
| 3. | PEC | 8 | 0 | **08** |
| 4. | EEC | 0 | 17 | **17** |
| | Total Credit | 16 | 17 | **33** |

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**CG5101 RESEARCH METHODLOGY**

| L | T | P | C |
|---|---|---|---|
| 4 | 0 | 0 | 4 |

**OBJECTIVE**

- To introduce the students on objectives and various techniques of research.
- To equip students with research methodology essential for pursuing higher studies.
- To make the students to apply scientific tools, concepts and theories to solve scientific problems.
- To enable students in writing scientific research reports, thesis and dissertation.
- To introduce the concept of intellectual property rights and its protection.

**UNIT I TECHNIQUES FOR RESEARCH 12**

Research: Definition, characteristics, objectives, research and scientific method - Types of Research: Descriptive vs. analytical, fundamental vs. applied, quantitative vs. qualitative, conceptual vs. empirical - Methodology: Introduction, research process overview, formulating the research problem - defining the research problem - research questions. Literature review: Concepts and theories. Formulation of hypothesis: Sources, characteristics, role of hypothesis - Research design.

**UNIT II EXPERIMENTAL DATA PROCESSING 12**

Data collection techniques - concept of measurement - validity and reliability of measurement. Sampling: Statistical population, sampling frame, sampling error, sample size, simple random sample, systematic sample, practical considerations of sampling - models - reconstruction of input signals - preliminary processing of experimental data: filtering - quasi-real experiments - reconstructed signal accuracy.

**UNIT III DATA ANALYSIS AND INTERPRETATION 12**

Basic concepts and definitions on data and error - various types of data and their error – propagation of errors – four steps to a meaningful experimental results. Basic statistical concepts – best estimate of true value of data – measures of central tendency - measures of dispersion - measures of asymmetry - measures relationship. Significance test – chi square test for goodness of fit – criteria for goodness of fit. Curve fitting - best fit - least square regression - nonlinear regression - optimization. Visualization and presentation of data - univariate analysis.

**UNIT IV TECHNIQUES OF RESEARCH WRITING AND PRESENTATION 12**

Effective scientific writing: Definition, article writing, essay writing, research paper writing, preparation of research project, thesis writing , dissertation writing, book writing, book-review writing. Criteria for good research - ethical issues related to publishing, plagiarism and self-plagiarism - citation methods: foot note, text note, end note, bibliography - citation rules - presentation of seminar talk and viva-voce talk.

**UNIT V INTELLECTUAL PROPERTY RIGHTS 12**

An overview of Intellectual property (IP) – Importance – Protection of IPR – Patents – Patentable and Non-Patentable inventions – Procedure for filing of patents – acquisition of patent rights – patents offices in India and jurisdiction – Modification of granted patents – protection against unfair competition – Enforcement of IPR - New developments of IPR.

**TOTAL : 60 PERIODS**

**OUTCOME**

At the end of this course, the students will be able to

- Understand research problem formulation and analyze research related informations.
- Apply research design methodology.
- Carryout systematic research experiments, data handling, interpretation and presentation.
- Follow research ethics.
- Appreciate the importance of IPR in research and development.

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**REFERENCES**

1. Wayne Goddard and Stuart Melville. Research methodology: An introduction. JUTA & Co., Lansdowne, 2007.
2. C.R.Kothari and G. Garg. Research methodology: Methods and techniques. New Age International Publishers, 2019.
3. Ranjit Kumar. Research Methodology: A Step by Step Guide for beginners. SAGE Publications Ltd., 2014.
4. Robert P. Merges, Peter S. Menell and Mark A. Lemley. Intellectual Property in New Technological Age. Aspen Publishers, 2009.
5. B.Ramakrishna and H.S. Anil Kumar. Fundamentals of Intellectual Property Rights: For Students, Industrialist and Patent Lawyers. Notion Press, 2017.


| CG5102 | THEORETICAL AND EXPERIMENTAL ASPECTS OF CRYSTAL GROWTH | L T P C |
|---|---|---|
| | | 4 0 0 4 |

**OBJECTIVE**

- To provide information on the important aspects of nucleation mechanisms involved in the growth of crystals and to evaluate the existing theories of crystal growth.
- To introduce the development and experimental aspects of crystal growth.
- To train the students in specific areas of growing techniques in making bulk single crystals related to Lasers, Electronics and Photovoltic activities.

**UNIT I NUCLEATION 12**

Supersaturation and supercooling – nucleation concept – Kinds of nucleation - Homogeneous nucleation - Equilibrium stability and metastable state -Classical theory of nucleation - Gibbs-Thomson equation –Kinetic theory of nucleation - Statistical theory of nucleation - Free energy of formation of nucleus considering translation, vibration and rotation energies. Homogeneous nucleation of Binary system - Induction period. Heterogeneous nucleation - Free energy of formation of a critical heterogeneous - cap shaped -disc shaped nucleus - Heterogeneous nucleation of Binary vapour – Secondarynucleation.

**UNIT II THEORIES OF CRYSTAL GROWTH 12**

Theories of crystal growth - Surface energy theory - Diffusion theory - Adsorption layer theory - Volmer theory -Bravais theory - Kossel theory - Stranski's treatment -Two dimensional nucleation theories of Crystal growth - Crystal growth by mass transfer processes -Bulk diffusion model - Surface diffusion growth theories - Mobility of absorbed molecules on a crystal surface - Physical modeling of BCF theory -BCF differential surface diffusion equation - single straight step - Multiple straight parallel steps - Growth rate of an F-face - Giant dislocation steps –Description, Derivation, and interpretation of Temkin's model of crystal growth - PCB theory of crystal growth - Computer simulation technique.

**UNIT III MELT GROWTH 12**

Growth of crystal from melt - Bridgman method - Kyropolous method - Czochralski method- Verneuil method - Zone melting method - LEC growth of III - V materials - Growth of oxide materials. Growth of crystal from flux - Slow cooling method - Temperature difference method - High pressure method - Solvent evaporation method - Top seeded solution growth -Growth of superconducting single crystal.

**UNIT IV VAPOUR GROWTH AND EPITAXY 12**

Growth of crystals from vapour phase - Physical vapour deposition - Chemical vapour transport - Open and closed system - Thermodynamics of chemical vapour deposition process - Physical, thermo-chemical factors affecting growth process. Epitaxy:Liquid Phase Epitaxy (LPE) - Vapour Phase Epitaxy (VPE)- Metalorganic Vapour Phase Epitaxy - (MOVPE)-Molecular Beam Epitaxy (MBE) - Atomic Layer Epitaxy (ALE) - Electroepitaxy - Chemical Beam Epitaxy (CBE).

**UNIT V SOLUTION GROWTH 12**

Growth of crystals from solutions - solvents and solutions - solubility - preparation of a solution - saturation and supersaturation - Measurement of supersaturation - Expression for supersaturation - Low temperature solution growth - Slow cooling method - Mason-jar method - Evaporation method - Temperature gradient method - Electrocrystallization. Crystal growth in gels - Experimental methods - Chemical reaction method - Reduction method - Complex decomposition method - Solubility reduction method - Growth of biologically important crystals - Crystal growth by hydrothermal method.

**TOTAL : 60 PERIODS**

**OUTCOME**

- Knowledge on fundamentals, theories and experimental aspects of crystal growth and epitaxy.

**REFERENCES**


1. J.C. Brice, Crystal growth processes, John Wiley and sons, New York, 1986.
2. A. Laudise, The Growth of single crystals. Prentice Hall, 1970.
3. B.Pamplin, Crystal Growth. Volume 16, Pergamon Press.1973.
4. F.F. Abraham, Homogenous nucleation theory, Advances in Theoretical Chemistry, Academic Press, New York, 1974.
5. R.F. Strickland, Kinetics and Mechanism of Crystallization, Academic Press, New York, 1968.
6. AM Alper, Phase Diagrams: Materials Science and Technology, Vol. I-VI, academic Press, New York, 1970.


| CG5001 | BIOLOGICAL CRYSTALLIZATION | L T P C |
|---|---|---|
| | | 4 0 0 4 |

**OBJECTIVE**

- Biological characterization is a specialized field and hence specific crystal growth techniques will be introduced to the students.
- To make students understand the important mechanisms involved in biological characterization.

**UNIT I BIOLOGICAL CRYSTALS 12**

Crystal Growth from solution - Driving force for crystallization - solubility in biological fluids - Growth kinetics - Nucleation - Diffusion effects - Dissolution - Morphology in vivo & Invitro studies -Crystals responsible for the crystal deposition diseases – Mono sodium urate monohydrate - Calcium pyrophosphate dihydrate - Cholesterol - Steroids - Dicalcium phosphate dihydrate - Hydroxy apatite - Calcium oxalate - Calcium hydrogen phosphate dihydrate - Lithium heparin crystals.

**UNIT II CRYSTAL AND JOINT DISEASES 12**

Crystals and joint diseases: Crystal deposition diseases - Deposition of crystals in joints - Crystals induced damage to joints - Crystals and its environment - Mechanism of crystals formation - Induced joint diseases - Acute inflammatory response - Protein binding - Causes for the initiation and termination for the acute inflammation - Chronic inflammation and fibrosis - Destruction of articular cartilage and bone – Gout - Introduction - History - Metabolism of uric acid - hyperuricaemia - Crystallization of urate - Gout crystal - monosdium urate monohydrate - Pathology of gout - Unanswered question regarding gout - Other urine disorders associated with crystals.

**UNIT III HYDROXYAPATITE 12**

Introduction - Crystallization of hydroxy apatite - Hydroxy apatite deposition and joints - Relationship between the apatite deposition and osteoarthritis - Other calcium phosphate Miscellaneous crystals and particles - Crystals deposited in synovial joints - Extrinsic crystals and particles found in synovial joints.

**UNIT IV STEROIDS 12**

Steroids - The chemistry of sterols - Analysis of steroids and related steroids - steroids in biological membranes cholesterol and atherosclerosis - sterol storage diseases - cholesterol gallstones: Plasma cholesterol in liver disease - solubilization of cholesterol - conditions required for the formation of stones - Bile supersaturated with cholesterol - Origin of biliary lipids - The pathogenesis of supersaturated bile - Secretion rates of biliary lipids - Effect of removing the gall bladder - Medical treatment of gallstones - Dissolution of cholesterol stones by chenodeoxycholic acid - Experimental gallstones in animals - Plasma lipids - lipoproteins - the cause of hypercholesterolaemia - Lipid composition of blood cells - Xanthomas in biliary obstruction - parenchymatous liver disease.

**UNIT V CRYSTALLISATION OF PROTEINS 12**

Various crystallization technique - Hanging Drops-Sitting Drops-Sandwich Drops-Reverse Vapor Diffusion- pH Gradient Vapor Diffusion-Practical Tips for Vapor Diffusion –Dialysis-Batch Techniques –Micro batch –Protein Samples-Dynamic Light Scattering – Precipitants- Buffers and pH – Temperature-Crystallization Strategies-A Flexible Sparse Matrix Screen-An Alternative to Sparse Matrix Screens-Reverse Screen- Imperial College Grid Screen-Interpretation of the crystallization Drop Results – Seeding-Macro seeding –Oils for Crystals –Crystallization Cryo-Data Collection – Crystallization of Membrane Proteins.

**TOTAL : 60 PERIODS**

**OUTCOME**

- Knowledge on bio-crystallization, protein crystallization and characterization of biological crystals.

**REFERENCES**

1. N.B.Myant The biology of cholesterol and related steroids, William Heinemann Medical Books Ltd, London, 1981.
2. Paul Dieppe & Paul Calvert, Crystals & Joint disease, Chapman and Hall Ltd, London, 1983.
3. Sujata V. Bhat, Biomaterials, Narosa Publising House, New Delhi,2002
4. Albert L.Lehninger, Principles of Biochemistry, CBS, Publishers, India, 1984.
5. Brain R. Pamlin, Inorganic Biological Crystal Growth, Pergamon Press Ltd., UK, 1988
6. A.Ducruix and R.Giege, Crystallization of Nucleic Acids and Proteins A Practical Approach, Oxford University Press, England, 1992
7. Terese M. Bergfor’s, Protein Crystallization Techniques, Strategies and Tips, International University Line, 1999.

**CG5002 CHARACTERIZATION OF SEMICONDUCTOR CRYSTALS**

| L | T | P | C |
|---|---|---|---|
| 4 | 0 | 0 | 4 |

**OBJECTIVE**

- To train the students on the fundamentals of structural characterization to enable the students to understand the usefulness of optical characterization.
- To provide information on the evaluation of the quality of the semiconductor crystals in terms of its structure, electrical and optical perfection.

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**UNIT I X-RAY DIFFRACTION 12**

X-ray diffraction - Powder method - rotating crystal method - specimen preparation - measurement of d-values - indexing procedure for cubic and tetragonal crystals -Single crystal diffractometer - double crystal diffractometer - triple crystal diffractometer- four crystal diffractometer.

**UNIT II STRUCTURAL AND ELECTRICAL CHARACTERIZATION 12**

X-ray topography(XRT) - Berg-Barret-Lang geometry - Crystal perfection analysis - Hall effect - Evaluation of Carrier Concentration - Hall Mobility - resistivity -. DeepLevel Transient Spectroscopy (DLTS) - analytical technique for impurity/defect analysis.

**UNIT III MECHANICAL PROPERTIES 12**

Evaluation of doped impurity segregation coefficient - Hardness - anisotropy - types of Hardness - Evaluation of the Cracks patterns - Mechanical properties-fracture toughness.

**UNIT IV OPTICAL AND MORPHOLOGICAL STUDIES 12**

Optical microscope, Scanning Electron Microscope (SEM) - morphological studies – Transmission Electron Microscope (TEM) - structural analysis - Luminescence –Photoluminescence(PL) – Thermoluminescence (TL) - Electroluminescence (EL) – Bulk Analysis.

**UNIT V QUALITY EVALUATION TECHNIQUES 12**

Rutherford Back Scattering analysis(RBS) - principle of channeling semiconductor epilayers interface analysis - Impurity analysis.Dissolution - Etching - Mechanism of dissolution- Various types of Etching – Thermaletching - Chemical etching - Electrolytic etching - Photo-etching - Selective etching - Mechanism of selective etching - Etch pit - Model of etch-pit formation at dislocationsites - Hillock - calculation of Etch Pit Density and Hillock Density - types ofMorphologies of etch figures - Semiconductor etchants - AB etchant - DSL etchant -DCL etchant - Applications of etching techniques.

**TOTAL: 60 PERIODS**

**OUTCOME**

- Knowledge on structural, mechanical, optical and electrical characterization of semiconductor crystals.

**REFERENCES**

1. S.M. Sze, Semiconductor Devices, Physics and technology, Wiley Publisers, New York,1985
2. B.R. Pamplin, Progress in Crystal Growth Characterization, Pergamon Press Ltd.,U.K, 1982
3. Dieter.K. Schroder, Semiconductor Material and Device characterization, John Wiley & Sons Inc., New York, 1990.
4. B.D. Cullity, Element of X-ray Diffraction, Addison Wesley Publication, 1978.
5. C.R. Grover, Microelectronic Materials, Taylor and Francis Group, 1998.

**CG5003 CHARACTERISATION TECHNIQUES**

| L | T | P | C |
|---|---|---|---|
| 4 | 0 | 0 | 4 |

**OBJECTIVE**

- To provide information on the optical and X-ray techniques to characterize crystals.
- To make the students understand the salient features of characterization techniques including thermal analysis.

**UNIT I FUNDAMENTALS OF SPECTROSCOPY 12**

Absorption and Emission spectroscopy - Nature of electromagnetic radiation - Atomic energy levels - Molecular electronic energy levels - vibrational energy levels - Raman effect - X-ray energy levels.

**UNIT II STRUCTURAL ANALYSIS 12**

Infrared spectroscopy - Near IR - Mid IR - Far IR Region - Correlation of infrared spectra with molecular structure - structural Analysis - Radiation sources - Detectors - Thermal Detectors - Photon Detectors - Spectrophotometers - Fourier Transform Interferometer - Sample handling.

**UNIT III SPECTROSCOPY STUDIES 12**

Raman spectroscopy - Theory - Resonance Raman Spectroscopy - Comparison of Raman with Infrared Spectroscopy - Diagnostic - Structural Analysis - Polarization measurements - Instrumentation - Quantitative analysis.

**UNIT IV X-RAY ANALYSIS 12**

X-ray methods - Production of X-rays and X-ray Spectroscopy - Instrumental units - Detectors for the measurements of radiation - Semiconductor detectors - Direct X-ray methods - Nuclear magnetic Resonance Spectroscopy - Basic principles - Quantitative analyses - Scanning Electron Microscopy - Electron Spectroscopy for Chemical Analysis - Electron Probe Micro Analysis.

**UNIT V THERMAL ANALYSIS 12**

Thermal analysis - Differential Thermal Analysis - Instrumentation – Differential Scanning calorimetry - Thermogravimetry - Instrumentation - Methodology of Differential Scanning Calorimetry & Thermo Gravimetric Analysis - Conductance method - Electrical conductivity - Measurement of electrical conductance - Measurement of dielectric constant. Microhardness - Etching studies.

**TOTAL : 60 PERIODS**

**OUTCOME**

- Knowledge on spectroscopic analysis, thermal and structural characterization of materials.

**REFERENCES**


1. X.F. Zong, Y.Y.Wang, J. Chen, Material and Process characterization for VLSI, World Scientific, New Jersey, 1988.
2. H.H.Willard, D.L.Merrti, Dean and Settle, Instrumental methods of analysis, CBS publishers.1992.
3. Dieter.K. Schroder, Semiconductor Material and Device characterization, John Wiley & Sons Inc., New York, 1990


| **CG5004** | **EPITAXIAL GROWTH** | **L T P C** |
|---|---|---|
| | | **4 0 0 4** |

**OBJECTIVE**

- To provide information on the principles of epitaxial techniques to enable the students to operate the epitaxial growth systems such as LPE, VPE and MOVPE.
- To make the students understand the usefulness of the epitaxial techniques in current day technology.

Attested

**UNIT I LIQUID PHASE EPITAXY 12**

Phase diagrams of III-V compounds - LPE apparatus & procedure - tipping - dipping - sliding - homoepitaxy Heteroepitaxy - principle of LPE for growth from binary, ternary and quaternary system - limitations of LPE.

**UNIT II VAPOUR PHASE EPITAXY 12**

Principle of method & Apparatus – growth of III-V compounds by Hydride VPE and Chloride VPE - Reactor design - substrate preparation and orientation - degreasing and etching - Dopant & impurities - epitaxial defects - application - Mechanism of vapour phase epitaxy - Nucleation kinetics of III-V compounds. Buried and regrowth of structures -selected area growth - growth of III-V compound Semiconductors - InP - GaAs - GaInAs - GaInAsP and other III-V compounds.

**UNIT III METAL ORGANIC VAPOUR PHASE EPITAXY 12**

Mechanism of MOVPE growth - Thermodynamic concepts - growth rate calculations - Low pressure MOCVD (LPMOCVD) applications of III-V materials grown from MOVPE – growth of As, P, N based binary, ternary, quaternary , III-V-compounds applications towards fabrication of solar cells, LED's – laser and high power and frequency of deliver (qualitative)

**UNIT IV MOLECULAR BEAM EPITAXY 12**

Molecular beam deposition - Apparatus - growth of GaAs - Experimental preparation - Thermodynamics considerations - Reaction Kinetics - Kinetics of alloy growth - Dopant incorporation in MBE grown films - principle of RHEED oscillations - applications. Chemical beam epitaxy (CBE) - Atomic layer epitaxy (ALE).

**UNIT V OTHER EPITAXIAL TECHNIQUES 12**

Nanostructures growth chemical beam epitaxy – atomic layer epitaxy –Design of ALE apparatus - Monolayer growth – growth late – ALE based MOVPE and MBE – Dip PEN lithography – atom manipulation by STM

**TOTAL : 60 PERIODS**

**OUTCOME**

- Knowledge on various epitaxial growth of crystalline layers and their analysis.

**REFERENCES**


1. Pallab Bhattacharya, Semiconductor Optoelectronic Devices, Prentice Hall of India, New Delhi, 1994.
2. D.W.Hees and K.F.Jensen, Microelectronics processing, American Chemical Society Washington DC, 1989.
3. David L.Pulfery & N.Garry Tarr, Introduction of Microelectronic Devices, Prentice Hall, New York, 1989.
4. T.Suntola and M.Simpson, Atomic Layer Epitaxy, Prentice Hall, New York, 1990.
5. MOCVD – G.B. String fellow J. Crystal Growth 178, 1 (1997).


**CG5005 FABRICATION AND CHARACTERIZATION OF SOLAR CELLS L T P C**
**4 0 0 4**

**OBJECTIVE**

- To provide information on the salient features of fabricating the solar cells to make the students understand the present technology available related to the processing of solar cell.

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**UNIT I ENERGY SOURCE 12**

Sources of energy - Solar cell energy conversion - Materials and material problems -Spectral distribution of solar radiation - The Sun and Sun Earth relative motion -Measurements of solar insulations - Solar simulation.

**UNIT II OPTICAL SOURCE 12**

Photon absorption in semiconductors – Carrier transport across p-n junction solar cells - Heterojunction solar cells - Schottky barrier and MIS solar cells - Contacts andsurface properties: Contact structures - Antireflection coatings - Surface texturing -Gird design - Etching - Solar cell arrays - Radiation damage on solar cells.

**UNIT III EFFICIENCY ANALYSIS OF SOLAR CELLS 12**

The calculation of solar efficiency -The ideal cell under illumination -The effects of seriesand parallel resistance - Other treatments of the calculation of the solar efficiency -The effect of temperature and illumination on solar cell efficiency - Loss analysis – Somecommon and emerging solar cells - Fabrication process and photovoltaic performance ofsome standard solar cells like Silicon, Gallium arsenide (GaAs), Indium phosphide(InP), Copper indium selenide(CuInSe2), Cadmium Telluride (CdTe), $Cu_2S$ based solar cells andpolycrystalline thin film silicon solar cells and amorphous silicon solar cells – photo-electrochemical cell.

**UNIT IV DIFFERENT TYPES OF SOLAR CELLS 12**

Novel concepts in design of high efficiency solar cells - High intensity effects -Unconventional non-concentrator cells: Metal insulator semiconductor cells (MIS) -Induced junction cell and front surface field cell - Multiple pass cell - Liquid junctioncells - Unconventional concentrator cells: parallel multiple vertical junction cells -Series multiple perpendicular junction cell - V grooved multijunction solar cell - Integrated back contact (IBC) cell - High low junction emitter cell - Graded band gapsolar cell - Multiple cell systems: Spectrum splitting and cascade cells -Thermophotovoltaic (TPV)system - photoelectrolytic cell.

**UNIT V EVALUATION TECHNIQUES 12**

Characterization techniques - Photovoltaic measurements I-V characteristics – Spectralresponse - Optical scanning - light beam induced current(LBIC) pictures and electronbeam induced current(EBIC) micrograph for the direct determination of minoritycarrier diffusion length- junction analysis: I-V analysis - Capacitance measurements- DLTS Technique. Material characterization-X-ray diffraction – Reflection highenergy electron diffraction (RHEED) - Scanning electron microscopy (SEM) – Scanningtransmission electron microscopy (STEM) - Transmission electron microscopy (TEM) -Auger electron spectroscopy (AES) - Electron spectroscopy for chemical analysis(ESCA) - Secondary ion mass spectroscopy (SIMS).

**TOTAL: 60 PERIODS**

**OUTCOME**

- Knowledge on fabrication, analysis and different types of solar cells.

**REFERENCES:**


1. Fahrenbruch and Bube, Fundamentals of solar cells Academic press, UK, 1983
2. K.L.Chopra and Suhit Ranjan das, Thin film solar cells, Plenum press, UK,1983
3. Cheuning Hu & Richard M.White, Solar cells - Basic to advanced system, McGrawHill Company, New York, 1983.
4. H.H. Willard, D.L. Merrit, Dean and Settle, Instrumental methods of analysis, CBS Publishers, 1992.
5. R.K. Willardson, Albert C. Beer, Semiconductors and semimetals, Vol.8, Academic Press, New York, 1992.
6. Diter K. Schroder, Semiconducting materials and devices Characterization, John Wiley & Sons Inc. New York. 1990
7. M.K. Achuthan and K.N. Bhat, Fundamentals of Semiconductor Devices – Tata McGraw Hill Publishing Company Ltd., New Delhi, 2007.

**CG5006 FERROELECTRICS** **L T P C**
**4 0 0 4**

**OBJECTIVE**

- To provide information on the various aspects of ferroelectric crystals and their properties.
- To introduce the students the usefulness of ferroelectric crystals and its applications.

**UNIT I FERROELECTRIC PROPERTIES 12**

Dielectrics - Dipole moment - Polarization - piezoelectric materials - polar materials -pyroelectric materials - Ferroelectric materials and their characteristic properties and polarizability - Ferroelectric domains - Hysteresis - First and second order transitions.

**UNIT II OPTICAL PROPERTIES 12**

Optical and related properties - Refractive index and Birefringence - Optical dispersion- Thermooptic behaviour - Elastooptic behaviour - Electrooptic characteristics - Non-Linear optical effects - photo refractive effect - Light scattering effect - Absorption -Photoluminescence - Electroluminescence and Luminescence.

**UNIT III OPTICAL MODULATORS 12**

The modulation of optical radiation - Electro optic effect – Electro optic Retardation -Electro optic Amplitude modulation - Phase modulation of light - Transverse Electro optic-modulators – Electro optic beam deflection - The photoelastic effect - Bragg diffraction oflight by Acoustic Waves - Deflection of light by sound - Bragg scattering in NaturallyBirefringent crystals.

**UNIT IV NONLINEAR OPTICS 12**

Nonlinear optics - wave propagation in Nonlinear dielectrics - Electrooptic and Nonlinear Optic co-efficient -The nonlinear susceptibility - Optical second Harmonic generation- phase matching condition – higher order nonlinearity.

**UNIT V APPLICATION OF FERROELECTRICS 12**

Order-Disorder Ferroelectrics - Triglycine Sulphate - Sodium nitrate – Displacive Ferroelectrics - oxygen Octahedran - Applications of Ferroelectrics – Pyroelectricdetection - Memories and display.

**TOTAL: 60 PERIODS**

**OUTCOME**

- Knowledge on materials for ferroelectric, nonlinear optics and other optical applications.

**REFERENCES:**


1. C. Kittal, Introduction to Solid state Physics,John Wiley Publications, 7th Ed, NewYork,1996
2. A.J.Dekkar, Electrical Engineering Materials, Prentice Hall, New Delhi, 1996
3. E. Lines and A.M.Glass, Principles and applications of ferroelectrics materials,Clarendon press, Oxford ,1979.
4. Amnon Yariv , Quantum Electronics , John Wiley and sons Inc, New York, 1975
5. C. Burfoot, D. Van, Ferroelectrics, Nostrand Co Ltd, London, 1967.


**CG5007 NANOMATERIALS AND NANOTECHNOLOGY** **L T P C**
**4 0 0 4**

**OBJECTIVE**

- To provide information on the various aspects of Nano materials preparations andrelated growth conditions
- To train the students on the evaluation of nano materials and their specific applications.

**UNIT I INTRODUCTION TO NANOMATERIALS 12**

Introduction to nanoscale materials-preparation of nano-structured materials, thin films, multiplier's, patterned nanostructures-production of nano-particles- gas and liquid phases- Vapour deposition-decomposition of supersaturated solid solutions-Controlled crystallization of glasses- Sol-gel processing - Mechanical alloying and mechanical milling –Bulk Nano composite materials-Nanoporous materials. Thin films by Laser ablation-Carbon Nanotubes- Synthesis andapplications of Nanocomposites.

**UNIT II SEMICONDUCTOR NANOSTRUCTURES 12**

Semiconductor nanostructures- fabrication techniques-Electronic structure and physical processes in semiconductor nanostructures- semiconductor nanostructure based electronic and electro-optical devices – Semiconductor Quantum dots –Quantum cascade Lasers – Quantum dot optical memory-MEMS-MOEMS-NEMS-processing technology – Photolithography- Electron Beam lithography-Lithography instrumentation – Nano-phosphors- Sensors –industrial applications.

**UNIT III NANOMAGNETIC MATERIALS 12**

Nanoscale magnetic materials and devices-nanostructure-fabrication and properties of nanostructure magnets-properties of nanomagnetics-applications and devices-Nanocomposite magnets-Nano ferroelectrics-Nano-domain engineering-Nanoarrays-Nanoparticles and Micro-organisms-Nano-materials in Bone Substitutes & Dentistry-Nanoparticles in food and Cosmetic applications-drug delivery and its applications-Biochips and analytical devices-Biosensors.

**UNIT IV PROPERITIES OF NANOMATERIALS 12**

Influence of Nanostructuring on mechanical, optical, electronic, magnetic, and chemical properties-grain size effects on strength of metals-optical properties of quantum dots and quantum wires-electronic transport in quantum wires and carbon nanotubes –magnetic behavior of single domain particles and nanostructures-surface chemistry of tailored monolayers-self assembling.

**UNIT V CHARACTERISATION OF NANOMATERIALS 12**

Optical microscope Surface Analytical Instrumentation Techniques for Nano-technology – Low Energy Electron Diffraction (LEED), RHEED, Scanning probe Microscopy, SEM, EDAX, TEM, XRD (Powder), STM,XRF, -UV Photo electron spectroscopy ESCA-Auger, UV*PS.

**TOTAL: 60 PERIODS**

**OUTCOME**

- Knowledge on different nanomaterials, structures and applications of nanomaterials.

**REFERENCES**:


1. M C Petty, M R Bryce, D Bloor (eds.), 'Introduction to molecular electronics', Edward Arnold, London, 1995.
2. G.Hadziioannou, P F van Hutten, 'Semiconducting polymers: Chemistry, Physics,and Engineering', Wiley-VCH, 2000.
3. Nanomaterials: Synthesis, Properties and Applications, Ed. A. S.Edelstein and R.C. Cammarata, IOP (UK), 1996.
4. Nanotechnology, ed. By Gregory Timp, Springer-Verlag, NewYork 1999.
5. "Fundamental properties of Nanostructured materials", Ed. D. Fiorani, G.Sberveglieri,World Scientific, 1994.
6. Handbook of Nanoscience, Engineering , and Technology ("HNET"), Ed. W.A. Goddard, D.W.Brenner, S.E. Lyshevski, G.J. Lafrate, CRC Press, New York, 2003.
7. Instrument Methods of Analysis H. W. Willard, L.L.Merritt., J.A Dean and F.A Settle (VI Edition), East West Publishers (1992).
8. Microelectronic materials, C.R.M. Grovernor, IOP Publishing Ltd, 1989.

**CG5008** **SEMICONDUCTOR DEVICES** **L T P C**
**4 0 0 4**

**OBJECTIVE**

- The selected concepts on device structures and fabrications will be introduced to the students to enable the students to understand the effective process and steps involved in device fabrications.
- To motivate the students in the technologically designed fabrications and devices such electrical and optical devices.

**UNIT I SEMICONDUCTOR PROPERTIES 12**

Basic Process in Semiconductor Devices: Equilibrium properties - electrons and holes -impurities in semiconductors - carrier concentration as a function of temperature – High doping effects - Non-equilibrium phenomena - carrier transport - Transport properties in high fields - recombination and generation processes - breakdown mechanism -Basic equations for Semiconductor devices - equations for the interior of devices -boundary conditions - Systems, Material preparation - Material Characterization -important processes for optoelectronic devices - Hetero junctions and Hetero-structures and device configuration.

**UNIT II BIPOLAR DEVICES 12**

Ion implantation : Ion implantor - general description - ion sources - range distribution -Theoretical approaches - sample holder - profiles - MeV implants ion damage -Annealing - Rapid thermal annealing - Laser annealing. Bipolar devices: p-n junctiondiode - basic device technology - depletion region and depletion capacitance - I-Vand C-V Characteristics - junction breakdown - terminal functions - Heterojunction -Bipolar transistor - Static characteristics - microwave transistor - power transistor -switching transistor - related device structures - Thyristors - basic characteristics -Schottky diode - Three terminal thyristor - related power thyristor – Unijunctiontransistor and trigger thyristor - Field-controlled thyristor.

**UNIT III METAL – SEMICONDUCTOR CONTACTS 12**

Unipolar devices: Metal-Semiconductor contacts - Energy - Band Relation – Schottky Effect - Characterization of Barrier Height - Device Structure - Ohmic Contact - JFET and MESFET - basic device characteristic - general characteristic - Microwave performance - MIS diode - Si-SiO2 MOS diode - Charge-Coupled Device -MOSFET - basic device characteristic - Nonuniform doping and buried-channel devices- short-channel effect - MOSFET Structures - Nonvolatile memory devices.

**UNIT IV OPTICAL DEVICES 12**

Special Microwave devices: Tunnel devices - tunnel diode - backward diode – MIS tunnel diode - MIS switch diode - MIM tunnel diode - tunnel transistor - IMMPATT and related transit-time diodes - static characteristics - dynamic characteristics – device design and performance - BARITT and DOVETT diodes - TRAPATT diodes -Transferred-electron devices - transferred- electron effect - modes of operation – device performances. Photonic Devices: Light Emitting diodes - LED for fiber optics – LED performance - reliability - Semiconductor Laser - Lasers for optical communication system - Photodetectors - Photoconductor- Photodiode - Avalanche Photodiode - Phototransistor - Solar cells - Thin film Solarcells.

**UNIT V APPLICATION OF SEMICONDUCTOR DEVICES 12**

Applications of III-V Compounds: Semiconductor device processing for Integrated Circuits - Silicon Integrated Circuit Processing - Gallium Arsenide Digital Integrated Circuit Processing - Semiconducting Thin Films for electronic components - Solid State Sensors, Optical Sensors - Opto-electronic components - Semiconducting oxide thin films for solar cell fabrications - Semiconducting thin films for solar cell applications.

**TOTAL : 60 PERIODS**

Attested

**OUTCOME**

- Knowledge on fundamentals, different aspects and applications of semiconductor devices.

**REFERENCE:**
1. S.M.Sze, Physics of Semiconductor devices (2nd edition) Wiley Eastern Ltd., New Delhi, 1981.
2. D.A. Fraser, The Physics of Semiconductor devices Clarendon Press, Oxford, UK, 1986.
3. M.S. Thyagi, Introduction to Semiconductor Materials and Devices, John Wiley & Sons, New York, 1991.
4. Dieter. K. Schroder, Semiconductor Material and Device characterization, John Wiley& Sons Inc., New York, 1990.
5. David L. Pulfrey and N. Garry Tarr, Introduction to Microelectronic Devices, Prentice-Hall international editions, New Delhi, 1989.
6. Peter Gise & Richard Blanchard, Modern Semiconductor fabrication technology, PrenticeHall, New Jersey, 1986
7. Cheening Hu and Richard M. White, Solar Cells Basic to advanced Systems, McGraw Hill Book Company, New York, 1983.

**CG5009 SEMICONDUCTOR PHYSICS** **L T P C**
**4 0 0 4**

**OBJECTIVE**
- To provide updated information of the evaluation of semiconductor physics.
- To enable the students to evaluate the usefulness of the physical properties for specific device applications.

**UNIT I INTRODUCTION TO SEMICONDUCTORS 12**

Bonds and Bands in Semiconductor: Chemical band in semiconductor-The Semiconducting bond - Energy bands - Bond approach vs Band Model - Elementary properties of semiconductors - Types of semiconductors - intrinsic and extrinsic semiconductors - p,n type semiconductors - Doping of semiconductors (High level and Low level) - Elementary theory of semiconductors - control of carrier concentration - Energy levels in crystalline solids - energy level diagrams - carrier concentration in thermal equilibrium - Free electron Theory - Transport properties. Junction Properties of semiconductors - Homogeneous, Inhomogeneous semiconductors - direct and indirect bandgap semiconductor Recombination mechanism - Electron, Hole recombination through traps - Junction properties of p-n, n+-n, p+-p junctions - Surface recombination - Recombination with donors and acceptors at low temperatures - Quantum theory of junction devices - Generation of recombination processes in junction devices

**UNIT II OPTICAL PROPERTIES OF SEMICONDUCTORS 12**

Optical constants - Light absorption spectrum - Light absorption edge - Effect of free charge carriers on the absorption edge - Fundamentals of - Light absorption by free charge carriers - Intrinsic light absorber - Light absorption dependence on temperature, pressure, alloy composition and degeneracy - Transition between the valence and conduction, within the valence and conduction bands - ambient absorption spectrum - Photo resistive effect - Demper effect - Photovoltaic effect - Faraday effect.

**UNIT III ELECTRON TRANSPORT PHENOMENA 12**

Theory of electron transport in crystalline semiconductors - Boltzmann's transport equation for Bloch states - relaxation time - relaxation time approximation to the low field transport coefficients – Different scattering mechanisms - electron scattering by static defects - phonons - high fields effects - hot electron transport theory - dynamics of localized phonon modes - shallow impurity states in semiconductors - electronic states and structural properties of Deep Centers in semiconductors - impurity bands - the electronic structure of surfaces and interfaces - space charge layers at Semiconducting interfaces - the theory of surface waves.

Attested

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**UNIT IV THERMAL EFFECT IN SEMICONDUCTOR 12**

Thermal conductivity - Thermo-electric power - Thermo magnetic effects - condition of degeneracy - strong magnetic fields - relative magnitudes of the magnetic effects. Optical and High frequency effects in Semiconductor: Optical constants of semiconductors - the fundamental absorption - exciton absorption photoconductivity - the photo-magnetic effect - high frequency effects in magnetic field - impurity absorption - lattice absorption - Infra-red emission from semiconductors - diffusion of electron and positive holes.

**UNIT V APPLICATION OF SEMICONDUCTOR 12**

Use of Semiconductors in electrical technology - Rectifiers - Transistors - Photodiode - Photo-electric power generator - Photo cells - Infra-red detectors - Infra-Red and Microwave modulators - Thermopiles - Thermo-electric refrigerators - Thermistors, Varistors and Other non-linear resistor.

**TOTAL: 60 PERIODS**

**OUTCOME**

- Knowledge on optical, electronic, thermal and other transport properties of semiconductors.

**REFERENCES:**


1. S.M. Sze, Semiconductor Devices, Physics and technology, Wiley Publishers, New York, 1985.
2. Jasprit Singh-Electronic properties of Semiconductor structures, Cambridge University Press, 2003.
3. Pallab Bhattacharya, Semiconductor Optoelectronic Devices, Prentice- Hall of India, 1999.
4. Donald A. Neaman, Semiconductor Physics and devices, Tata McGrew-Hill Edition 2007.