B. Sc. Physical Sciences with Electronics as one of the Core Disciplines

DISCIPLINE SPECIFIC ELECTIVE COURSE – DSE 7-2: PHYSICS OF MATERIALS

Course Title & Code	Credits	Credit distribution of the course			Pre-requisite of the course
		Lecture	Tutorial	Practical	
Physics of Materials DSE 7-2	4	2	0	2	

COURSE OBJECTIVES

This course intends to provide knowledge of emerging topics in condensed matter physics. In addition, this course aims to provide a general introduction to advanced topics by covering polymers, liquid crystals, carbon-based materials, and Diluted Magnetic Semiconductors. More importantly, the students will be exposed to different characterization techniques used in experimental condensed matter physics.

LEARNING OUTCOMES

After completion of this course the students should be able to

- Identify different materials of technological importance in appliances and objects around us
- Explain the importance of concepts like density of states and its role in determining device characteristics
- Elucidate the ferroelectric, piezoelectric and pyroelectric materials and their applications.
- Explain the properties of liquid crystals and their application.
- Differentiate between different forms of carbon based materials and their applications
- Introduce the importance of dilute magnetic semiconductors as a new technologically advance material for electronic devices
- Explain various characterisation techniques used in understanding properties of different material

SYLLABUS OF DSE 7-2
THEORY COMPONENT
(Hours: 30)

Unit I **(4 Hours)**

Semiconductors
Basic concept of mobility and conductivity, density of states, determination of electron and hole concentration in doped semiconductor, Fermi level, Fermi energy, Fermi temperature, Fermi wavelength, Fermi surface.

Unit II **(9 Hours)**

Dielectric and magnetic materials
Dielectrics, Ferroelectric, Piezoelectric and Pyroelectric materials, applications of ferroelectrics in capacitors and memory device, Piezoelectrics in micro positioner and actuator, Pyroelectrics in radiation detectors and thermometry. Classification and applications of soft and hard magnetic materials, application in transformers, memory device, introduction of spintronics based systems (spin transport)

Unit III **(9 Hours)**

Polymers, Liquid crystals, Carbon based materials
Polymers: Chemical structure of polymers of few thermoplastic (polyethylene, PVC, PTFE, PMMA, Polyester, Nylons) and thermosetting (Epoxy resin) polymers, conducting polymers- application in organic electronics
Liquid crystals: Classification of liquid crystals, structural and orientational ordering (isotropic to Nematic), thermotropic liquid crystals, Phases and phase transitions; anisotropic; Birefringence and display devices
Carbon based materials: Structure and properties of Fullerenes, C_{60}, single walled and multi walled CNTs, Graphene and their energy band diagram.

Unit IV **(8 Hours)**

Synthesis of materials
Ceramic (Calcination, Sintering, Grain), thin films (general idea of vacuum, thermal evaporation, molecular beam epitaxy, pulsed laser deposition), Crystals (qualitative idea of zone refining and Czochralski method), Polymers (Polymerization mechanism).

PRACTICAL COMPONENT: PHYSICS OF MATERIALS

(Hours: 60)

At least six experiments to be performed from the following list

1. Study phase transition in a ferroelectric sample by measuring its dielectric constant as a function of frequency and temperature.
2. Study dielectric properties of given polymer sample as a function of frequency and temperature.
3. Study dielectric properties of given piezoelectric sample as a function of frequency and temperature.
4. Determine the coupling coefficient of a given piezoelectric crystal.
5. BH Hysteresis of different ferromagnetic materials (Loop Tracer).
6. Analyse the XRD spectra of a given ferroelectric ceramic sample and determine its lattice parameter.
7. Analyse the XRD spectra of a given ferromagnetic sample (basically ferrites, Fe_3O_4, $CoFe_2O_3$) and determine its lattice parameter.
8. Analyse the XRD spectra of a given compound semiconductor (ZnO, TiO_2, etc) thin film/ceramic sample and determine its lattice parameter.
9. Analyse the UV-Vis spectra of a given wide band gap semiconductor and determine its bandgap.
10. Study the IV characteristics of a polymer material by depositing/painting Aluminum electrodes.
11. To determine the g-factor of a sample by ESR Spectrometer.
12. Analyse the given SEM/TEM/AFM micrographs of the deposited thin film or nanostructure of any material and determine surface roughness, crystallinity, particle size etc.
13. Deposition of any kind of thin film by any technique available in the lab.
14. Liquid crystals (reading project)

REFERENCES

Essential readings for the Theory Component

1. Solid State Physics, M. A. Wahab, 2011, Narosa Publishing House
2. Elementary Solid State Physics, M. Ali Omar, 2006, Pearson
3. Semiconductor Devices: Physics and Technology, S. M. Sze, 2nd edition, 2002, Wiley India
4. Introduction to Polymer Physics, U. Eisele and S. D. Pask, 1990, Springer-Verlag
5. The physics of liquid crystals, Pierre-Gilles de Gennes, 2nd edition, 2003, Oxford University Press
6. Introduction to Liquid Crystals, P. J. Wojtowicz, E. Priestly and P. Sheng, 1975, Plenum Press
7. Dielectric Phenomenon in solids with Emphasis on Physical Concepts of Electronic Processes, K. C. Kao, Elsevier.
8. Physics of Ferroelectrics A Modern Perspective, K. M. Rabe Charles H. Ahn Jean-

Marc Triscone, Springer
9. Carbon Nanotubes: Properties and Applications, M. J. O'Connell, 2006, CRC Press
10. Dilute Magnetic Semiconductors, M. Jain, World Scientific.

Additional readings for the Theory Component

1. Encyclopaedia of materials characterization: surfaces, interfaces, thin films, R. C. Brundle et al., 1992, Butterworth-Heinemann
2. Physical Methods for Materials Characterization, P. E. J. Flewitt, R. K. Wild, (2nd Ed., CRC Press, 2015).
3. Dilute magnetic semiconducting materials, Br. R. Saravanan, MRF

References for the Laboratory Work

1. Advanced Practical Physics for students, B. L. Flint and H. T. Worsnop, 1971, Asia Publishing House.
2. A Text Book of Practical Physics, I. Prakash and Ramakrishna, 11th edition, 2011, Kitab Mahal
3. Elements of Solid State Physics, J. P. Srivastava, 2nd edition, 2006, Prentice-Hall of India
4. Elements of X-Ray Diffraction, B. D. Cullity and S. R. Stock
5. Physical Methods for Materials Characterization, P. E. J. Flewitt, R. K. Wild, 2nd edition, 2015, CRC Press
6. Encyclopedia of materials characterization: surfaces, interfaces, thin films, R. C. Brundle et al., 1992, Butterworth-Heinemann