FUNCTIONAL MATERIALS AND APPLICATIONS

Course code	23ME4701C	Year	IV	Semester	I
Course category	Professional Elective - IV	Branch	ME	Course Type	Theory
Credits	3	L-T-P	3-0-0	Prerequisites	Metallurgy and Material science, Manufacturing Processes, Machine tools
Continuous Internal Evaluation:	30	Semester End Evaluation:	70	Total Marks :	100

Course Outcomes: At the end of the course students will be able to

CO's	Statement	Blooms Level	Units
CO1	Explain crystal structures, crystallographic planes and directions, crystal imperfections, dislocations, slip systems, plastic deformation, polymorphism, and phase changes in materials.	**L2**	**1**
CO2	Describe the electrical and magnetic properties of materials using classical and quantum free electron theories, energy band concepts, and magnetic behavior of solids.	**L3**	**2**
CO3	Analyze semiconductor materials and transport phenomena including intrinsic and extrinsic semiconductors, carrier concentration, drift, diffusion, Hall effect, ohmic contacts, and Schottky diode characteristics.	**L3**	**3**
CO4	Explain the optical properties of materials, optical processes in semiconductors and quantum wells, and the working principles of optoelectronic devices such as detectors, solar cells, LEDs, lasers, modulators, and plasmonic devices.	**L3**	4
CO5	Describe nanostructured electronic materials including quantum confinement, quantum wells, wires, dots, tunneling, mesoscopic structures, single electron devices, photonic crystals, spintronics, and carbon nanotubes with their applications.	**L3**	**5**

Contribution of Course outcomes towards the achievement of program outcomes & Strength of correlations (High :3, Medium:2, Low:1)													
	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PSO1**	**PSO2**
CO1	3	2	1	1	-	1	-	-	1	-	1	2	1
CO2	3	2	2	1	1	1	-	-	1	-	1	2	1
CO3	3	3	2	2	2	1	-	-	1	-	1	3	2

CO4	3	2	3	1	2	2	-	-	1	-	1	3	2
CO5	3	2	2	1	2	1	-	1	2	-	2	2	2

Unit	Contents	CO
I	**CRYSTALLOGRAPHY:** Crystal structures: BCC, FCC and HCP – directions and planes - linear and planar densities – crystal imperfections- edge and screw dislocations – grain and twin boundaries - Burgers vector and elastic strain energy- Slip systems, plastic deformation of materials - Polymorphism – phase changes.	**CO1**
II	**ELECTRICAL AND MAGNETIC PROPERTIES OF MATERIALS:** Classical free electron theory - Expression for electrical conductivity – Thermal conductivity, expression - Quantum free electron theory: Tunneling – degenerate states – Fermi- Dirac statistics – Density of energy states – Electron in periodic potential – Energy bands in solids – tight binding approximation - Electron effective mass – concept of hole. Magnetic materials: Dia, para and ferromagnetic effects – paramagnetism in the conduction electrons in metals – exchange interaction and ferromagnetism – quantum interference devices – GMR devices.	**CO2**
III	**SEMICONDUCTORS AND TRANSPORT PHYSICS:** Intrinsic Semiconductors – Energy band diagram – direct and indirect band gap semiconductors – Carrier concentration in intrinsic semiconductors – extrinsic semiconductors - Carrier concentration in N-type & P-type semiconductors – Variation of carrier concentration with temperature – Carrier transport in Semiconductors: Drift, mobility and diffusion – Hall effect and devices – Ohmic contacts – Schottky diode	**CO3**
IV	**OPTICAL PROPERTIES OF MATERIALS:** Classification of optical materials – Optical processes in semiconductors: optical absorption and emission, charge injection and recombination, optical absorption, loss and gain. Optical processes in quantum wells – Optoelectronic devices: light detectors and solar cells – light emitting diode – laser diode - optical processes in organic semiconductor devices –excitonic state – Electro-optics and nonlinear optics: Modulators and switching devices – plasmonics	**CO4**
V	**NANOELECTRONIC MATERIALS:** Quantum confinement – Quantum structures – quantum wells, wires and dots – Zener-Bloch oscillations – Resonant tunneling – quantum interference effects - mesoscopic structures - Single electron phenomena – Single electron Transistor. Semiconductor photonic structures – 1D, 2D and 3D photonic crystal. Active and passive optoelectronic devices – photo processes – spintronics – carbon nanotubes: Properties and applications.	**CO5**

Learning Resource
Text books:
TEXT BOOKS: 1. V.Raghavan. Materials Science and Engineering: A First Course, Prentice Hall India Learning Private Limited, 2015. 2. S.O. Kasap, Principles of Electronic Materials and Devices, Mc-Graw Hill, 2018. 3. Jasprit Singh, Semiconductor Devices: Basic Principles, Wiley (India), 2007. 4. Jasprit Singh, Semiconductor Optoelectronics: Physics and Technology, Mc-Graw Hill India (2019) 5. G.W.Hanson. Fundamentals of Nanoelectronics. Pearson Education (Indian Edition), 2009.
Reference books
1. R.Bala subramaniam, Callister's Materials Science and Engineering. Wiley (Indian Edition), 2014. 2. Wendelin Wright and Donald Askeland, Essentials of Materials Science and Engineering, CL Engineering, 2013. 3. Robert F.Pierret, Semiconductor Device Fundamentals, Pearson, 2006 4. Pallab Bhattacharya, Semiconductor Optoelectronic Devices, Pearson, 2017 5. Ben Rogers, Jesse Adams and Sumita Pennathur, Nanotechnology: Understanding Small Systems, CRC Press, 2017.

E-Resources & other digital Material:
1. https://ocw.mit.edu/courses/3-091-introduction-to-solid-state-chemistry-fall 2018/resources/lecture-18/ 2. https://onlinecourses.nptel.ac.in/noc23_mm26/preview 3. https://ocw.mit.edu/courses/res-3-004-visualizing-materials-science-fall 2017/pages/student-projects-by-year/epfl2017/crystallography-a-visualisation-tool/?utm_source=chatgpt.com