SARDAR PATEL UNIVERSITY
VALLABH VIDYANAGAR
M.Sc. Semiconductor Science and Technology (Semester – I)
Effective from June-2025

Course Code	Course Title	Course Type	T/P	Credits	Number of Hours per Week
PS01CSST01	Fundamentals of Semiconductor Science and Technology	Disciplinary Major	T	4	4

Course Objective	- Provide a foundational understanding of semiconductor physics including charge carriers, energy bands, and carrier dynamics. - Study the principles and operation of semiconductor diodes including I-V characteristics and junction behaviour. - Introduce the fundamentals of photovoltaic devices and solar cell operation. - Explain the physics of metal-semiconductor contacts, including Schottky and ohmic behaviour. - Explore surface effects in semiconductors and their influence on device performance.

Course Content	
Description	**Weightage (%)**
UNIT I: The Semiconductor Ecosystem History of Indian Semiconductor Industry, Overview of the global semiconductor industry, Industry segments: Chip IP Cores, Electronic Design Automation (EDA) Tools, Specialized Materials and Chemicals, Wafer Fab Equipment (WFE), Fabless Companies, Integrated Device Manufacturers (IDMs) and Foundries, OSAT/ATMP, Clean room infrastructure and overview of semiconductor chip fabrication process flow, semiconductor supply chain and value chain dynamics with global and national perspectives, Government of India initiatives such as the India Semiconductor Mission (ISM) and Production Linked Incentive (PLI) scheme for semiconductor manufacturing. **Faculty selected topic related to recent development/discovery.**	25
UNIT II: Semiconductor Diode Bonds in Semiconductors, Commonly Used Semiconductors (Si and Ge), Effect of Temperature on Semiconductors: Superiority of Silicon over germanium, Intrinsic Semiconductor, Doping in Semiconductor, Extrinsic Semiconductor: n-type Semiconductor and p-type Semiconductor, Majority and Minority Carriers, Carrier concentration, p-n Junction, Depletion barrier physics, I/V characteristics of p-n Junction, Diode Equation, Applications of p-n junctions: Diode as clipper, Diode as a clamper circuit, Zener diode, Operating condition of diode: Maximum forward current, Peak inverse voltage (PIV) and power rating. **Faculty selected topic related to recent development/discovery.**	25
UNIT III: Photovoltaics Photovoltaic Effect, Introduction to the photovoltaic systems, I-V characteristics of a solar cell- Inter-connections of solar cells, Light Absorption and Material Selection, Types of Solar Cells (Monocrystalline, Polycrystalline), Solar Cell Structure and Layers (Front Contact, Absorber Layer, Back Contact, P-N Junction), Carrier Separation and Transport, Carrier Lifetime and Recombination Mechanisms, Theoretical Efficiency Limits (Shockley-Queisser	25

Limit), Efficiency of Solar Cells (EQE, IQE, IPCE, FF), Advanced Technologies for Enhancing Efficiency: Multi-Junction Cells, Concentrated photovoltaics (CPV), Optical Losses in Solar Cells, Cost Reduction Strategies: Thin-Film, Perovskite-Based Cells and Roll-to-Roll Manufacturing **Faculty selected topic related to recent development/discovery.**		
UNIT IV: Metal-Semiconductor Contacts and Metal Interconnects Contacts between materials, Concept of work function and Electron affinity, Schottky's work function difference model and energy band diagram of Ohmic and Non-Ohmic (Rectifying) contacts, Applications of Schottky barriers, Comparison between Schottky junction and PN-junction diodes. Metal Interconnects: Interconnect parameters, Electrical wire models and transmission lines. **Faculty selected topic related to recent development/discovery.**		25
Course Outcomes	- Demonstrate a clear understanding of intrinsic and extrinsic semiconductor properties and carrier transport mechanisms. - Analyze the behavior and characteristics of PN junction diodes under different biasing conditions. - Explain the working principles of photovoltaic devices and assess their efficiency parameters. - Evaluate metal-semiconductor interfaces and determine the nature of electrical contact. - Identify and interpret surface phenomena that impact the functionality of semiconductor devices.	

Recommended Textbooks and References:

1. Principles of Electronics – V.K. Mehta & Rohit Mehta, S. Chand Publishing

2. Semiconductor Devices: Physics and Technology – S.M. Sze & Kwok K. Ng, Wiley

3. Semiconductor Physics and Devices – Donald A. Neamen, McGraw-Hill Education

4. Solid State Electronic Devices – Ben G. Streetman & Sanjay Banerjee, Pearson

5. Modern Semiconductor Devices for Integrated Circuits – Chenming C. Hu, Prentice Hall

6. Solid State and Semiconductor Physics- John P. McKelvey

7. Digital Integrated Circuits: A Design Perspective, Jan M. Rabaey, Prentice Hall Electronics and VLSI Series.

8. Metal-Semiconductor Contacts – William Rhoderick & Robert H. Williams, Oxford University Press

Recommended Weblinks:

1. **https://sites.google.com/view/advancedsemiconductors**
2. **Fundamentals of Semiconductor Devices** - *Prof. Digbijoy N. Nath, IISc Bangalore*
   • **Course Link:** https://archive.nptel.ac.in/courses/108/108/108108122/

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M.Sc. Semiconductor Science and Technology (Semester – I)

Effective from June-2025

Course Code	Course Title	Course Type	T/P	Credits	Number of Hours per Week
PS01CSST02	Evolution of Semiconductor Electronics	Disciplinary Major	T	4	4

Course Objective	- To introduce students to the fundamentals of transistor (BJT) operation, biasing, and amplifier circuits. - To develop a deeper understanding of non-linear integrated circuits, including operational amplifiers and their applications. - To provide knowledge of digital electronics, covering logic gates, Boolean algebra, and simplification techniques for combinational and sequential circuits. - To study memory devices and microprocessors, focusing on semiconductor memory technologies and the evolution of microprocessors. - To enable students to understand the practical applications of integrated circuits, logic design, and microprocessor systems in real-world scenarios.

Course Content	
Description	**Weightage (%)**
UNIT I: The Bipolar Junction Transistor-BJT Introduction, The Bipolar Transistor action, The basic principle of operation, Simplified transistor current relations, The Modes of operation, Amplification with bipolar transistor, Minority carrier distribution, Forward-active mode: Low frequency common-base current gain, Mathematical derivation of current gain factors, Nonideal effects: Base width modulation, High injection, Emitter Bandgap Narrowing, Current crowding, Breakdown voltage, Frequency limitations: Time-delay factors, Transistor cut-off frequency. **Faculty selected recent topic from current science and latest discovery**	25
UNIT II: Non-linear Integrated Circuits Operational amplifier: Introduction, Common Mode Rejection Ratio (CMRR), Internal circuit of Operational Amplifier, Schematic symbol of operational amplifier, Inverting and Non-inverting input and polarity relation, Bandwidth, Slew Rate, OP-Amp with negative feedback, Pin diagram, Applications: Inverting amplifier, Noninverting amplifier, Voltage follower, Multistage OP-Amp circuits, Summing amplifier, Integrator, Differentiator and Comparator circuits, Schmitt Trigger: UTP and LTP adjustments, Digital to Analog and Analog to Digital Convertors using Op-Amp. **Faculty selected recent topic from current science and latest discovery**	25
UNIT III: Digital Electronics Overview of number systems and evolution of logic circuits, Basic terms related to digital IC-gates, RTL and DTL gates, TTL gates, Transfer characteristics of TTL gates, Current source and sinking, Calculation of Fanout of standard TTL gates, Brief introduction to TTL families, (74S, 74L, 74LS, 74ALS), Open collector gates and buffer drivers, Tri-state logic gate.	25

<table>
<tr><td colspan="2">Basic n-MOS inverter, CMOS inverter, MOS gate circuits, Handling of open and unused inputs of logic gates.
Faculty selected recent topic from current science and latest discovery</td><td></td></tr>
<tr><td colspan="2">UNIT IV: Combinational, Sequential logic circuits and Memory

Binary Adder: Half and full adder, subtractor, Simplification of Boolean expressions, Flipflop, Encoder, Decoders, Multiplexers, De-multiplexers, Registers and Counters.
Semiconductor Memories: Read Only Memory and Random-Access memory, expanding memory size.
Introduction to Microprocessor, Microcontroller and Embedded System.
Faculty selected recent topic from current science and latest discovery</td><td>25</td></tr>
<tr><td>Course Outcomes</td><td colspan="2">- Understand the basic operation and configuration of Bipolar Junction Transistors (BJT) and their role as amplifiers.
- Analyse and compare various transistor configurations such as CB, CE, and CC.
- Design and troubleshoot OP-AMP based circuits like amplifiers, comparators, and waveform generators.
- Interpret digital logic systems using Boolean algebra, Karnaugh maps, and implement combinational and sequential logic circuits.
- Explore microprocessor architecture, memory systems, and instruction-level programming, focusing on Intel 8085 and its evolution.</td></tr>
</table>

Recommended Textbooks and References:

1. Semiconductor Physics and Devices: Basic Principles, Donald A Neaman, 3rd Edition, Tata McGraw-Hill.
2. Integrated Circuits - K. R. Botakar, Khanna Publishers.
3. Electronic Principles - Albert Malvino and David Bates, McGraw-Hill Education.
3. Electronic Devices and Circuit Theory - Thomas L. Floyd, Pearson Education.
4. Op-Amps and Linear Integrated Circuits - Ramakant A. Gayakwad, Pearson Education.
5. Digital Electronics – A. Anand Kumar, PHI Learning Pvt. Ltd.
6. Digital Fundamentals - Thomas L. Floyd, Pearson Education.
7. Principles of Electronics – V. K. Mehta and Rohit Mehta (S. Chand Publication).
8. Electronic Devices and Circuit Theory" by Robert L. Boylestad and Louis Nashelsky.

Recommended Weblinks:

1. https://sites.google.com/view/advancedsemiconductors
2. https://www.101computing.net/creating-logic-gates-using-transistors/
3. https://www.youtube.com/watch?v=OWlD7gL9gS0
4. **Semiconductor Devices and Circuits -** Prof. M. Gopal, IISc Bangalore
   https://onlinecourses.nptel.ac.in/noc21_ee80/preview
5. **Microelectronics: Devices to Circuits -** Prof. Sudeb Dasgupta, IIT Roorkee
   https://onlinecourses.nptel.ac.in/noc21_ee86/preview
6. **Digital Electronics -** Prof. Gautam Saha, IIT Kanpur
   https://onlinecourses.nptel.ac.in/noc25_ee20/preview

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SARDAR PATEL UNIVERSITY
VALLABH VIDYANAGAR

M.Sc. Semiconductor Science and Technology (Semester – I)

Effective from June-2025

Course Code	Course Title	Course Type	T/P	Credits	Number of Hours per Week
PS01CSST03	Physics of Condensed Matter	Disciplinary Major	T	4	4

Course Objective	- To introduce fundamental concepts of crystal structures and their classification in solid-state physics pertaining to the materials used for semiconductor device fabrication and packaging. - To explain the principles and techniques of X-ray diffraction and its application in material characterization. - To develop an understanding of lattice vibrations, phonon theory, and their role in thermal properties of materials. - To examine various types of crystal defects and their influence on the mechanical and electrical properties of materials. - To study the elastic behaviour of solids and extend the discussion to low-temperature physics and associated quantum phenomena.

Course Content	
Description	**Weightage (%)**
UNIT I: Crystal Structure and its Characterization Concept of Solid, Introduction to crystal structures, classification of materials based on structure: amorphous, polycrystalline, and single-crystalline materials, relationship between grain size and grain boundaries with structure, effects of grain boundaries on material properties, Classification of crystal systems, Lattice parameters, Unit cell and Bravais lattices, Planes, Miller Indices, Symmetry elements, zones and forms, X-ray diffraction principles, Bragg's law, and its derivation, Reciprocal lattice and its properties, Ewald construction for diffraction analysis, X-ray diffraction techniques, Wafer orientation and alignment marks: Wafer Flats and surface plane identification for Si and GaAs. Typical Si and GaAs wafer specifications. **Faculty selected recent topic from current science and latest discovery**	25
UNIT II: Lattice Vibrations and Thermal Properties Lattice vibration: Basic concepts of lattice vibrations and their importance in understanding material properties, the vibration of mono-atomic lattices, Brillouin zone, group velocity and continuum limit, lattices with two atoms per primitive cell, phonon modes in two-atom lattices, excitation of the optical branch and its role in infrared absorption in ionic crystals, quantization of lattice vibrations, concept of phonons and its momentum, Inelastic neutron scattering by phonons, phonon-phonon interactions, Thermal Properties: Thermal conductivity, Thermal diffusivity, Heat capacity, Temperature dependence of heat capacity, Specific heats of solids, Thermal expansion, Thermal stresses, Thermoelectric power. **Faculty selected recent topic from current science and latest discovery**	25

UNIT III: Defects in Solids	25
UNIT III: Defects in Solids Introduction to defects in solids, importance of defects in materials, types of defects in crystals: point defects, line defects, surface defects, and volume defects, Point imperfections (Frenkel and Schottky) and its concentration, Line imperfections, edge dislocation, screw dislocation, dislocation density, Burgers vector and Burgers circuit, dislocation motion, energy of a dislocation, slip planes and slip directions, Surface imperfections, tilt and twist boundary, stacking faults: stacking faults in FCC crystals, stacking faults in HCP crystals. **Faculty selected recent topic from current science and latest discovery**	25
UNIT IV: Elastic Properties and Low temperature Physics Introduction to flexible Electronics, Introduction to elasticity, fundamental concepts of stress and strain, stress and strain components, types of deformations, stress-strain relations, elastic moduli, Hook's law, stiffness and compliance matrices, work done by elastic forces, reduction of independent elastic constants due to symmetry considerations, Overview of temperature scales and thermometry. Properties of materials at low temperatures: Thermal, electrical, and mechanical properties. Cryogenic fluids: Helium, nitrogen, and hydrogen. Low-temperature generation techniques: Joule-Thomson expansion, Adiabatic demagnetization cooling. Dilution refrigerators. Quantum phenomena at low temperatures: Superconductivity and Bose Einstein condensation (BEC). **Faculty selected recent topic from current science and latest discovery**	25
Course Outcomes	- Identify and describe the different types of crystal structures and interpret their classification based on symmetry and lattice parameters. - Apply X-ray diffraction methods such as Bragg's law and Laue technique to analyze crystal structures. - Explain lattice vibrations and phonon interactions and connect them to thermal properties like heat capacity and conductivity. - Classify crystal defects and assess their impact on material strength, conductivity, and overall performance. - Analyze elastic properties and relate them to mechanical behavior of materials; understand the behavior of materials under cryogenic conditions and describe quantum phenomena such as superconductivity and BEC.

Recommended Textbooks and References:

1. Introduction to Solid State Physics Charles Kittle, Eight edition, Wiley, 2015.
2. Elements of Solid State Physics J. P. Srivastava, Prentice Hall of India, 2009
3. Solid State Physics: Structure and Properties of Materials, M. A. Wahab, Second edition, Narosa Publishers, 2005
4. Elementary Solid State Physics: Principles and Applications M. A. Omar, Addison-Wesley, 1975
5. Elements of X-ray diffraction B. D. Cullity and S. R. Stock, Third edition, Pearson, 2014.
6. Introduction to dislocations, D. Hull and D. J. Bacon, Fifth edition, Butterworth-Heinemann (Elsevier), 2011
7. Low Temperature Physics Christian Enns and Siegfried Hunklinger, Springer-Verlag (2005).

8. Matter and Methods at low Temperature (3rd edition) Frank Pobell, Springer-Verlag Berlin Heidelberg (2007).
9. Experimental Techniques in Low Temperature Physics (3rd Edition) Guy K. White, Clarendon Press, Oxford (1979)
10. Solid State and Semiconductor Physics- John P. McKelvey
11. Semiconductor Material and Device Characterization, Dieter K. Schroder, Willey-Interscience Publication, John Wiley & Sons Inc.

Recommended Weblinks:

1. https://sites.google.com/view/advancedsemiconductors
2. **Condensed Matter Physics:** https://www.youtube.com/watch?v=_Ckh-60B6LY
3. **Crystal Structure and characterization:** https://youtu.be/d_dasJl8GrA?si=_qTK4H5co4n5Ea7X
4. **Lattice vibrations and thermal properties:** https://youtu.be/r8FgeW5hHhc?si=b8Gj1oTPE9dXotTN, https://youtu.be/RPusJNXEVMQ?si=mTbJg1_5eZHi6ZvE ,
5. **Defects of solids:** Defects in Crystalline Solids(Part-1):-Prof. Shashank Shekhar
6. **Elastic Properties:** Prof. S. Sankaran, Department of Metallurgical and Materials Engineering, IIT Madras. https://youtu.be/p0cPzZWvDfc?si=5cyG1L2qAyAFOdAi
7. **Low Temperature Physics:** Cryogenic Engineering by Prof. M.D. Atrey, Department of Mechanical Engineering, IIT Bombay. **https://nptel.ac.in/courses/112101004**

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M.Sc. Semiconductor Science and Technology (Semester – I)
Effective from June-2025

Course Code	Course Title	Course Type	T/P	Credits	Number of Hours per Week
PS01CSST04	Quantum Theory of Solids and Statistical Physics	Disciplinary Major	T	4	4

Course Objective	- To understand and predict the behaviour of physical systems at atomic and macroscopic scales using the principles of quantum theory and statistical analysis. - To explain the electronic properties of crystalline solids by analysing how electrons behave in periodic lattice potentials using quantum mechanics. - To describe the distribution of electron energies in a metal and understand its electrical, thermal, and magnetic properties through the geometry of the Fermi surface in momentum space. - To determine the concentration and behaviour of charge carriers (electrons and holes) in semiconductors using statistical mechanics, crucial for predicting electronic device performance. - To quantify uncertainty and extract meaningful insights from data using probabilistic and statistical tools.

Course Content	
Description	**Weightage (%)**
UNIT I: Introduction to the Quantum Theory of Solids Introduction, Formation of Energy Bands, The Bloch theorem, The Kronig-Penney Model, The k-Space Diagram, Electrical Conduction in Solids: The Energy Band and the Bond Model, Drift Current, Electron Effective Mass, Concept of the Hole, Metals, Insulators, and Semiconductors, Direct and Indirect bandgap in semiconductor, Extension to Three Dimensions: The k-Space Diagrams of Si and GaAs, Distribution function and the Fermi energy, Fermi-Dirac statistics, Density of States Function: Mathematical Derivation, Extension to Semiconductors. **Faculty selected recent topic from current science and latest discovery**	25
UNIT II: Carrier Statistics in Semiconductors The Semiconductor in Equilibrium: Charge carriers in Semiconductor-Equilibrium distribution of electrons and holes, The n_0 and p_0 equations, The Intrinsic Carrier Concentration, The intrinsic Fermi level position, Dopant Atom and Energy Levels: Qualitative Description, Ionization Energy, The Extrinsic Semiconductor: Statistics of Donors and Acceptors, Charge Neutrality: Compensated Semiconductor, Equilibrium Electron and Hole Concentration, Position of Fermi Energy Level: Mathematical derivation, Variation of Fermi energy level with doping concentration and Temperature. **Faculty selected recent topic from current science and latest discovery**	25
Unit III: Carrier Transport Phenomena Introduction, Carrier Drift, Drift Current Density, Mobility Effects, Conductivity, Velocity Saturation, Carrier Diffusion, Diffusion Current Density, Total Current Density, Graded Impurity Distribution, Induced Electric Field, The Einstein Relation, Carrier Generation and Recombination, Excess Carrier Generation and Recombination, Characteristics of Excess Carriers, Continuity Equations, Time-Dependent Diffusion Equations, Ambipolar Transport, Quasi-Fermi Energy Levels and Excess-Carrier Lifetime, The Hall Effect. **Faculty selected recent topic from current science and latest discovery**	25

UNIT IV: Statistical concepts Types of measured quantities, Discrete quantities, continuously distributed quantities, Histogram, Normalized histogram, best estimate of true value of data, Standard deviation of the means, best estimate of uncertainty. Normal Distribution: Properties of Gaussian distribution, Area under the normal distribution curve, Determination of mean value for a Gaussian distribution, Determination of standard deviation for Gaussian distribution, Central limit theorem, Chi-square test for goodness of fit, Criteria for goodness of fit. Graphical representation and curve fitting of data: Graphical representation of functional relationships, Determination of parameters in linear relationships, Graphical method, Method of least squares, Linear least square curve fitting, Lorentz fitting. **Faculty selected recent topic from current science and latest discovery**		25
Course Outcomes	- To predict and explain the behaviour of matter from atomic to macroscopic scales using quantum principles and statistical reasoning. - To analyse electronic behaviour in crystals using quantum mechanics, forming the basis for band theory and modern solid-state devices. - To understand the distribution of electron energies in metals, explaining their electrical and thermal properties through the geometry of the Fermi surface in momentum space. - To predict the concentration, movement, and behaviour of charge carriers in semiconductors, crucial for designing and optimizing electronic and optoelectronic devices. - To provide foundational tools for analysing data, modelling uncertainty, and making predictions using probability, distributions, and statistical inference	

Recommended Textbooks and References

1. Semiconductor Physics and Devices Basic Principles- Donald A. Neamen
2. Puri, R. K., & Babbar, V. K. (2010). *Solid State Physics*. S. Chand & Company Ltd.
3. Kittel, C. (2004). *Introduction to Solid State Physics* (8th ed.). John Wiley & Sons.
4. Srivastava, J. P. (2014). *Elements of Solid State Physics* (4th ed.). Prentice Hall of India.
5. Marder, M. P. (2000). *Condensed Matter Physics* (2nd ed.). Wiley.
6. Landau, L. D., & Lifshitz, E. M. (1976). *Mechanics* (3rd ed.).
7. Pathria, R. K. (1996). *Statistical mechanics* (2nd ed.). Butterworth-Heinemann.
8. Huang, K. (1987). *Statistical mechanics*. John Wiley & Sons.
9. Srivastava, R. K., & Ashok, J. (2005). *Statistical mechanics*. Prentice Hall of India.
10. Nakra, B. C., & Chaudhry, K. K. (2004). *Instrumentation, measurement, and analysis* (2nd ed.). Tata McGraw-Hill.
11. Bevington, P. R., & Robinson, D. K. (2003). Data reduction and error analysis for the physical sciences (3rd ed.). McGraw-Hill.
12. Solid State and Semiconductor Physics- John P. McKelvey
13. Solid State Physics: Structure and Properties of Materials M. A. Wahab (Narosa Publishers) (2009).

Recommended Weblinks:

1. https://youtu.be/ZemvjQdLffo?si=MlNa12L7Z1EW6Tj8
2. https://youtu.be/WG1swonq1JU?si=n1DhaGM01UCxJArr
3. https://youtu.be/6k2a3pkWfxo?si=d4XLT5A6x5uwvBk0
4. https://youtu.be/3aRIwDDMc88?si=URnfLnBDPhmV_Ozx
5. https://sites.google.com/view/advancedsemiconductors

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