SS865 SEMICONDUCTING MATERIALS AND DEVICES 3-1-0-4

Course Objective:

This course is intended to familiarize the research students about the theory behind the functioning of semiconductor devices. It also provide research students the insight useful for understanding new semiconductor devices and technologies.

Unit 1: Band structure and Electronic properties of Semiconductors

Semiconductor Statistics: Energy distribution functions, Density of states, Density of carriers in Intrinsic and Extrinsic semiconductors, Compensation in semiconductors, Heavy doping - Bandtail states, Effective mass, Hall Effect. Carrier Generation and Recombination, Characteristics of Excess Carriers: continuity equations, time-dependent diffusion equations. Excess - carrier lifetime: Effect of traps and defects,Surface effects.

Concept of band gap: Direct and indirect bands in semiconductor, Bandstructure of selected Semiconductors: Si,Ge, GaAs, GaN, ZnO, Chalcopyrites, Delafossites, Perovskites. Semiconductor alloys, Lattice-mismatched and pseudomorphic materials, variation of Energy bands with alloy composition, Amorphous Semiconductors.

Unit 2: *p-n* junctions

p-n junction formation, Electrostatics of the *p-n* junction: Contact potential and Space Charge. Current - Voltage relationship, Quasi- Fermi levels and High- level injection, Graded Junctions, Junction Breakdown, Tunnel Diode.

Unit 3: Metal-Semiconductor and Semiconductor Heterojunctions

Schottky Barriers: Ideal junction properties, Non-ideal Effects on the Barrier Height, Current-Voltage Relationship, Capacitance-Voltage. Ohmic Contacts: Ideal Non-rectifying Barriers, Tunneling Barrier, Specific contact resistance: Multiple -Contact Two-Terminal Methods. Heterojunctions: Heterojunction Materials, Energy-Band Diagrams, Two-Dimensional Electron Gas, Current-Voltage Characteristics, Band Offsets, Heterojunction Band Lineups - Types.

Unit 4: Metal Oxide Semiconductor Field Effect Transistor (MOSFET)

Review of Bipolar junction transistors (BJT) and Junction Field Effect Transistors (JFET). Introduction to Metal Oxide Semiconductor Capacitor (MOS), Capacitance - Voltage Characteristics of MOS structure, MOSFET Operation: Current -Voltage Characteristics, Substrate Bias Effects, Depletion and Enhancement MOSFETs. Challenges in Real MOSFETS: Subthreshold Conduction, Mobility Variation with Gate Bias, Important Effects in Short-Channel MOSFETs. Heterojunction FET: High electron mobility transistors (HEMT), Thin film transistors (TFT).

Unit 5: Optoelectronic Devices

Optical absorption: Photon absorption coefficient, electron-hole pair Generation rate. Solar cells: *p-n* junction solar cell, Conversion efficiency and solar concentration, Nonuniform absorption effects, Heterojunction solar cells. Photodetectors: Photodiode, *p-i-n* photodiode, Phototransistors.

Reference Books:

1. Donald Neamen and Dhrubes Biswas, Semiconductor *Physics and Devices*, 4th edition, McGraw Hill Education, 2017.

2. Umesh K Mishra and Jasprit Singh, *Semiconductor Device Physics and Design*, Springer,2008.

3. Marius Grundmann, *The Physics of Semiconductors - An Introduction IncludingDevices and Nanophysics,* Springer, 2006.

4. Simon Sze and Kwok Ng, *Physics of Semiconductor Devices*, 3rd edition, Wiley, 2008.

5. Pallab Bhattacharya, *Semiconductor Optoelectronic Devices*, 2nd edition, Pearson, 2017.

Course Outcomes:

On successful completion of the course, the student will able to

CO1: Understand and analyse the density of carriers and carrier transport in semiconductors

CO2: Gain deep knowledge on the physics of semiconductor junctions, metal-semiconductor junctions and heterojunctions.

CO3: Understand the working of the field effect transistors.

CO4: Describe the functioning of the optoelectronic devices.

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