

# FUNDAMENTALS OF SEMICONDUCTOR DEVICES



**ELECTRICAL  
ENGINEERING**



**PROF. DIGBIJOY N. NATH**

Centre for Nano Science and Engineering  
IISc Bangalore

<b>TYPE OF COURSE</b>	: New   Core   UG/PG	<b>COURSE DURATION</b>	: 12 weeks (28 Jan'19-19 Apr'19)
<b>INTENDED AUDIENCE</b>	: B.E./B.Tech in ECE/EE, or M. Sc Physics	<b>EXAM DATE</b>	: 28 April 2019
<b>PRE-REQUISITES</b>	: High school physics & math, 10+2 physics		

## COURSE OUTLINE :

This course seeks to cover the basics of semiconductor devices including the physics of energy bands, doping and carrier statistics and transport leading up to the understanding of common semiconductor devices including p-n junctions and their applications, BJTs and MOSFETs. The course will also give a flavour of the basics of compound semiconductors and their devices, and also touch base with opto-electronic devices such as solar cells, photodetectors and LEDs. The course will ensure that undergraduates, college teachers and other interested audience with no background in semiconductors are able to grasp the content.

## ABOUT INSTRUCTOR :

Digbijoy N. Nath completed his B.E. (Hons) in Electrical and Electronics Engineering from BITS, Pilani (Rajasthan) and PhD in Electrical Engineering from Ohio State University, Columbus specializing in gallium nitride based semiconductor devices. He has been as Assistant Professor at Centre for Nano Science and Engineering (CeNSE) at Indian Institute of Science (IISc), Bangalore since Aug 2014.

## COURSE PLAN :

- Week 01** : Importance of semiconductor devices and their diverse applications. Introduction to semiconductors, concept of energy bands and how bands form. Effective mass of electrons, E-k diagram. Concept of holes. Concept of Fermi level, Fermi-Dirac distribution. Doping (extrinsic & intrinsic semiconductor), density of states.
- Week 02** : Equilibrium electron-hole concentration, temperature-dependence. Carrier scattering and mobility, velocity saturation, Drift-diffusion transport
- Week 03** : Excess carrier decay & recombination, charge injection, continuity equation, quasi-Fermi level
- Week 04** : p-n junction: static behaviour (depletion width, field profile), p-n junction under forward & reverse bias, current equations, generation-recombination current and reference to typical devices.
- Week 05** : Zener and avalanche breakdown, Capacitance-voltage profiling, metal/semiconductor junction – Ohmic and Schottky contacts, reference to device applications.
- Week 06** : MOS capacitor, charge/field/energy bands, accumulation, inversion, C-V (high and low frequencies), deep depletion, Real MOS cap: Flat-band & threshold voltage, Si/SiO<sub>2</sub> system.
- Week 07** : MOSFET: structure and operating principle, derivation of I-V, gradual channel approximation, substrate bias effects, sub-threshold current and gate oxide breakdown. Control of threshold voltage, short channel effects. Moore's Law and CMOS scaling
- Week 08** : Introduction to compound semiconductors & alloys, commonly used compound semiconductors, heterostructure band diagrams and basics of MODFET & HEMT, introduction to quantum well, applications of heterostructure device technologies
- Week 09** : BJT: working principle, DC parameters and current components, base transport factor, Early Effect, charge control equation & current gain, need for HBT. Applications of BJTs/HBTs in real-life.
- Week 10** : (Basics of) - transistors for high-speed logic, transistors for high frequency (RF), transistors for high power switching, transistors for memories, transistors for low noise, transistors for the future.
- Week 11** : Solar cells: principle, efficiency, Fill factor, Shockley-Queisser limit, silicon solar cells, multi-junction solar cell, Photodetectors: operation, figures of merit (responsivity, QE, bandwidth, noise, Detectivity), examples from IR to UV detectors.
- Week 12** : LEDs: working principle, radiative/non-radiative recombination, various types of efficiencies (EQE, WPE, IQE), light extraction and escape cone. Blue LED and the Nobel Prize, visible LEDs and chromaticity.