FUNDAMENTALS OF SEMICONDUCTOR DEVICES

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PRE-REQUISITES : High school physics & math, 10+2 physics

INTENDED AUDIENCE : Students pursuing B.E./B.Tech in ECE/EE, or M. Sc Physics

INDUSTRIES APPLICABLE TO : Semiconductor

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. In parallel, the course will consistently seek to engage the audience by giving real-life examples pertaining to the content, and also seek to calibrate the content with respect to practical and commercial technologies which are all around us and which use semiconductor devices. There will be enough food for thought even for advanced learners such as PhD students and active researchers.

ABOUT INSTRUCTOR :

Prof. 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. His research interests lie in wide band gap semiconductor devices for high power & RF electronics/deep-UV opto-electronics. He has authored/co-authored 46 publications so far. He has been teaching a postgraduate level course Semiconductor Devices and IC Technology for PhD/Masters students at IISc for four years while he has also started a new advanced-level course titled Semiconductor Opto-electronics and Photovoltaics (jointly with another faculty member).

COURSE PLAN :

Week 1 : 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 2 : Equilibrium electron-hole concentration, temperature-dependence. Carrier scattering and mobility, velocity saturation, Drift-diffusion transport

Week 3 : Excess carrier decay & recombination, charge injection, continuity equation, quasi-Fermi level

Week 4 : 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 5 : Zener and avalanche breakdown, Capacitance-voltage profiling, metal/semiconductor junction – Ohmic and Schottky contacts, reference to device applications.

Week 6 : MOS capacitor, charge/field/energy bands, accumulation, inversion, C-V (high and low frequencies), deep depletion, Real MOS cap: Flat-band & threshold voltage, Si/SiO2 system.

Week 7 : 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 8 : 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 9 : 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-Quiesser 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.