INTRODUCTION TO SEMICONDUCTOR DEVICES

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INDUSTRIES APPLICABLE TO : Semiconductor Industry – Any company working in Semiconductor IC Design and Testing, Companies in Power Electronics and Power Systems domain

COURSE OUTLINE :
Semiconductor devices are at the heart of the present technological revolution, and they are increasingly prominent in our daily life. This course develops the basic concepts necessary to understand the fundamentals of semiconductor devices. We will apply these concepts to gain insight into the operation of various semiconductor devices such as pn junction diodes, MOSFETs, solar cells and LEDs. This course is primarily directed for undergraduate students pursuing ECE/EE or related programs.

ABOUT INSTRUCTOR :
Prof. Naresh Kumar Emani is an assistant professor in the electrical engineering department of Indian Institute of Technology Hyderabad. Prior to joining IIT Hyderabad he worked as a Scientist at Data Storage Institute(A*STAR), Singapore and Taiwan Semiconductor Manufacturing Company(TSMC), Hsinchu, Taiwan. He received his MTech degree in Microelectronics from IIT Bombay, and PhD degree from Purdue University. His research interests are in the areas of Dielectric Nanophotonics, Plasmonics, Silicon Photonics and Solar Photovoltaics. Further details can be found on his webpage https://iith.ac.in/~nke/

COURSE PLAN :

Week-1 : Semiconductors in daily life, semiconducting material properties, energy levels in atoms, energy band formation, bandgap and material classification, electrons and holes, effective mass

Week-2 : Carrier properties – intrinsic carrier density, Fermi level, donor and acceptor impurities, Fermi level in extrinsic semiconductors, temperature dependence of carrier density, generation and recombination of carriers

Week-3 : Thermal motion of carriers, carriers under electric field, mobility and drift current, diffusion of carriers, general expression for current in a semiconductor, energy bands under electric fields

Week-4 : pn junction electrostatics, fixed and free charge, depletion approximation, electric field at the junction, built-in potential, step junction vs linearly graded junction, energy band diagram of a PN Junction and quasi-Fermi levels

Week-5 : pn junction under applied bias, minority carrier injection and spatial variation in depletion and quasi-neutral regions, band-bending under applied bias, ideal diode equation

Week-6 : Diode non-idealities, breakdown, depletion and diffusion capacitance, p-i-n Diode, Metal Semiconductor Junctions

Week-7 : Ideal MOS capacitor structure, Qualitative analysis of field effect, block charge, electric field and potential diagrams, energy band diagrams, Accumulation and inversion regimes, Gate voltage drop across a MOS device

Week-8 : Threshold voltage of a MOS device, Capacitance-Voltage(CV) measurements, HFCV and LFCV of a MOS capacitor, Non-idealities in a MOS capacitor – work function difference and flatland voltage, tunneling over gate barrier and leakage current, high-k gate dielectrics

Week-9 : Long Channel MOSFETs, energy band diagram and qualitative understanding of MOSFET operation, ID-VD and ID-VG relationships, square law theory of MOSFET, sub-threshold slope, performance metrics of a MOSFET

Week-10: Technology scaling and Moore's law, qualitative understanding of Short channel effects – velocity saturation, channel length modulation, drain induced barrier lowering (DIBL), differences in IV characteristics of long and short channel MOSFETs, overview of modern FETs (FinFETs, tunnel FETs and nanowire transistors)

Week-11: Optoelectronic devices in daily life, III-V Semiconductors, direct and indirect bandgaps, optical absorption, pin photodetectors, solar cells, open circuit voltage and short circuit current

Week-12: Light emitting devices – Heterostructures, LEDs and their luminescent efficiency, double heterostructure and population inversion, diode lasers, LI characteristics and threshold current