Approval: 14th senate meeting

Course number :EE526
Course Name : Power Semiconductor Devices
Credit : 3-0-0-3
Prerequisite : IC160-Applied Electronics or equivalent, EE311-Device electronics for integrated circuit or equivalent
Intended for :BTech Third and Final year/M.Tech./MS/PhD
Distribution : Elective for third and final year Electrical Engineering, M.Tech. Power Electronics and Drives (PED), M.Tech VLSI, MS, PhD
Semester : Even/Odd

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1. **Preamble:**

This course designed to build up an in-depth understanding among the UG/PG students about the semiconductor devices for power applications. The major goal of this course is to make the students familiarized with different power device structure and fabrications to demonstrate the basic concepts of different device operations and their characteristics for real world applications. Engineering of devices structure for extended current and voltage limit along with the operating frequency for emerging power applications are integral part of the course.Additionally, it will introduce concepts of different wide-bandgap semiconductors and their structural engineering such as quantum well for high power density requirements. Moreover, the modern fabrication challenges and associated device performances will also be presented such as hetero-epitaxy and defects in devices. In brief, the objective of this course is to provide a detail understanding of the state of the art power semiconductor device operation and technologies.

2. **Course Modules with quantitative lecture hours:**

Module: 1 Introduction and Emergence of power semiconductor devices [2 hours]

Overview of energy intensive civilization and its growth, impact on sustainable world, circuit requirements from power devices, power devices requirements from materials.

Module: 2 Materials Properties and Transport Physics [6 hours]

Basics of semiconductor physics, polarization, quantum structures, bandgap narrowing, impact ionization, resistivity, recombination, scattering.

Module: 3 Semiconductor Junctions [4 hours]

Review of p-n junction and metal-semiconductor junction, heterojunction, insulator-semiconductor junction, Zener and avalanche breakdown, design of breakdown voltage and edge terminations, parasitic circuit elements in rectifiers.

Module: 4 Power Diodes and rectifiers [4 hours]

Power Schottky rectifiers, forward conduction and reverse blocking, device capacitance and thermal analysis, P-i-N rectifiers, switching performance.

Module: 5 BJT for Power Application [4 hours]

Structure, operating principle, current gain, emitter current crowding, output and on-state and switching characteristics, Darlington configuration.

Module: 6 Power MOSFETs and HEMTs [6 hours]

Ideal specific on-resistance, device structure and operation, characteristics, blocking voltage, VD-MOSFET, U-MOSFET, high frequency operation, switching characteristics, heterostructure, triangular potential well, 2DEG, charge control model, small-signal characteristics, power-frequency limit.

Module: 7 Thyristors [4 hours]

Structure and operation, blocking and on-state and switching characteristics, Gate Turn-Off thyristor and triac structure and operations.

Module: 8 Insulated Gate Bipolar Transistor [4 hours]

Structures, operation and output characteristics, equivalent circuit, blocking and on-state characteristics, current saturation model, power loss optimization, superjunction.

Module: 9 Widebandgap semiconductors and Advanced Technologies[8 hours]

Properties and advantages of SiC and GaN, shielded technology, lateral and vertical device, enhancement mode device, reliability aspects,fabrication, homo-epitaxy, hetero-epitaxy, molecular beam epitaxy, metal organic chemical vapor deposition, packaging and thermal management, power IC, integration of devices with CMOS, oxide electronics.

- Students will perform one project/practical work based on modeling, simulation with Technology Computer Aided Design (Synopsys Sentaurus/ Silvaco ATLAS) or fabrication for further improvement of devices performances as instructed.

3. **Text books:**

1. B. J. Baliga, Fundamentals of Power Semiconductor Devices ,Springer, 2008, ISBN 978-0-387-47314-7
2. Yung C Liang and Ganesg S Samudra, Power Microelectronics: Device and Process Technologies, World Scientific, ISBN-13: 978-9812791009.

4. References:

1. B. Streetman and S. Banerjee, Solid State Electronic Devices, 7th Edition, 2006, ISBN 013149726.
2. S.M. Sze, Physics of Semiconductor Devices, 2nd ed., Wiley, 2008
3. M. Meneghini, G. Meneghesso, E. Zanoni, Power GaN Devices: Materials, Applications and Reliability, Springer, 2017, ISBN 978-3-319-43199-4.
4. Ned Mohan, Tore M. Undeland, Riobbins, Power electronics: converters, applications, and design, Wiley, 2007, ISBN-10: 8126510900
5. R.S. Ramshaw, Power Electronics Semiconductor Switches, Champman& Hall, 2013, ISBN 9781475762198.