High Power Semiconductor Devices

By

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Objective: This short tutorial course on High Power Semiconductor Devices is designed to give an insight about the design, operation and applications of high power, high frequency semiconductor devices. The scope of the course is outlined below. There will be four sessions – each focused on a different aspect of this field of power devices – low and mid voltage MOSFETs, high voltage MOSFETs and IGBTs, Silicon Carbide devices for high voltage applications and Gallium Nitride devices for high voltage and high frequency applications. Each session will introduce to the participants the basic structure and operation of the devices being reviewed, the key figures of merit used to evaluate / compare these devices, details of the applications where they are used, the processing challenges faced by researchers today and the technology trends going forward. The instructors will cover both the theoretical aspects of device design and development, and the practical aspects of how and where these devices are likely to be used and how the applications drive the developments in devices and processes. This will provide comprehensive information about all the key aspects of high power devices to researchers interested in this field, and will give them a good base to start with. The field of power devices is still not sufficiently studied or captured in Indian universities and other research institutions. It'll be a unique and great opportunity for those interested in this area to hear it from some of the experts in this area. The pre-requisites for this tutorial short course is a basic understanding of the physics of semiconductor devices.

Tentative list of contents

Part A: Low and Mid Voltage Power Devices – Technology and Applications (One and a half hours) – Dr. Ritu Sodhi

1. Low Voltage MOSFETs (8V to 30V)
    a. Basic Power MOSFET – device structure and operation
    b. Key figures of merit – resistance and gate charge contributors
    c. Technology trends over the last few years
    d. Planar vs. Trench MOSFETs
    e. Basic process flow and cell topologies
    f. Main applications for these low voltage MOSFETs and how do we optimize the device structure for them

    g. New technology trends and process challenges
    h. Packaging technologies for these MOSFETs, for specific applications
2. Mid Voltage MOSFETs (40V to 250V)
    a. Key figures of merit for Mid Voltage MOSFETs
    b. How do they diverge from low voltage technology
    c. Technology trends over the last few years
    d. Planar vs. Trench MOSFETs
    e. Basic process flow and cell topologies
    f. Main applications for these low voltage MOSFETs and how do we optimize the device structure for them
    g. New technology trends and process challenges
    h. Has Si reached its limit? How does GaN fit in this space?

Tea break

Part B: High Voltage MOSFETs and IGBTs (One and a half hours) – Dr. Praveen Shenoy

1. High Voltage MOSFETs
    a. Major Rdson contributors
    b. Planar DMOS: Qg reduction
    c. Super junction FET
        i. Concept
        ii. Rdson advantage, Charge imbalance
        iii. Processes
        iv. Technology constraints
2. Insulated Gate Bipolar Transistor (IGBT)
    a. Basic Structure & Characteristics
        i. Operation & output characteristics
        ii. Static characteristics – V_{cesat}, V_{th}
        iii. Switching- t_{off}, E_{off} – lifetime control
        iv. V_{cesat}-E_{off} tradeoff
        v. Latch-up, prevention
    b. Structures- PT, NPT, FS
        i. Buffer layer
        ii. Trench IGBTs
        iii. Other structures like emitter shorted

Lunch Break

Part C: Silicon Carbide Devices for High Voltage Applications (One and a half hours) – Dr. Phil Mawby

1. Silicon Carbide material properties
2. Processing Issues
    a. Crystal growth
    b. Epitaxial growth
    c. Material defects
    d. Doping and implantation
    e. Oxide growth
3. Power devices in Silicon Carbide
    a. Diodes
    b. BJTs
    c. MOSFETs
    d. JFETs
4. Reliability issues

Tea break

Part D: Gallium Nitride Devices for High Voltage and High Power Applications (One and a half hours) – Dr. Shankar Madathil

1. Material Properties
    a. Material Properties, FOMs, growth technologies, doping technologies and polarization properties
2. GaN lateral device technologies
    a. Basic HEMT structure, main issues (current collapse, field engineering and E-mode technologies)
    b. Theoretical comparison between Si-UMOS, Si-IGBT and GaN-HEMT
3. Other technologies
    a. Integration trends / requirements
    b. Vertical device technologies in GaN