Title: CHIPS Revolution: Semiconductor-based Diodes, Transistors, and Memory Devices

Goals: To introduce students to the exciting field of semiconducting materials and semiconductor device physics. To provide students with an understanding of elementary band theory and the operation of technologically important electronic devices such as PN junction diodes, metal-semiconductor contacts, MOSFETs BJTs, and memory devices. To introduce emerging semiconductor device technologies. To introduce the students to state-of-the-art simulation tools for device modeling.

What will the student be able to do at the end of the course?

1. *Understand* concepts of bandstructure and chemical doping in semiconductors.
2. *Basics* of Gallium Nitride, which is used in power semiconductor devices and LEDs.
3. *Apply* major concepts of semiconducting devices using the concept of electrons and holes in semiconducting materials.
4. *Apply* the drift-diffusion methods to semiconductor devices.
5. *Apply* the phenomena of photon-induced and thermal generation and recombination of carriers.
6. *Analyze* transistor technologies including current generation and emerging transistors.
7. *Design* a contemporary semiconducting device.
8. *Introduce* state-of-art semiconductor device modeling (Computer Aided Design tools) – pending TA approval.

Prerequisites

- Physics 122: Electricity and Magnetism (or equivalent)
- MATH 207: Differential equations (or equivalent; we will provide notes to review in class)

Textbooks

Instructor's Notes

Other reading material provided by instructor

Optional: Ben G. Streetman and Sanjay K. Banerjee, *Solid State Electronic Devices*, 7th Ed., John Wiley & Sons, 2014. (Excellent Comprehensive Book) I like this book.

Reference Text: Simon M. Sze, Yiming Li, Kwok K. Ng, Physics of Semiconductor Devices 4th Edition, Wiley, 2021. I like this book.

Topics:

1. **Periodic Solids**, Brillouin zone, Bloch's Theorem, Band structure from QM, Band structure of Si and GaAs (high symmetry points/lines), Direct and Indirect Semiconductors
2. **Semiconductor Basics**, Density of States, Concept/Properties of Holes, Electron and Hole Density, Doping, Mobility
3. **Drift-Diffusion equations**
4. **Diodes**, Band diagram, Qualitative treatment of Avalanche and Zener diodes
5. **Metal-Semiconductor Junctions**, band diagram, and Schottky Diodes
6. **Metal-Oxide-Semiconductor Junction**, MOS Capacitor (low and high frequency), Threshold voltage
7. **MOSFET**, Dennard's Scaling Analysis, Short channel effects, Tunnel transistor basics
8. **LED and Solar Cell,** discussed in terms of PN junction diodes.
9. **Memory Devices,** Operation principle of Flash Memory, DRAM, SRAM, Phase change memory, Resistive memory, MRAM / Magnetic memory, and so on.
10. **Device Modeling,** Industry standard tool Sentaurus

Prepared By: M. P. Anantram

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