Engineering Tripos Part IIA, 3B5: Semiconductor Engineering, 2021-22

Module Leader

Dr H Joyce [1]

Lecturers

Dr H Joyce and Prof S Hofmann

Lab Leader

Prof S Hofmann

Timing and Structure

Michaelmas term. Weeks 1-4 (Dr H Joyce), Weeks 5-8 (Prof S Hofmann). 16 lectures in total with 2 lectures per week.

Aims

The aims of the course are to:

- Provide a framework of basic semiconductor physics
- Demonstrate how semiconductor physics dictates the operation and performance of electronic devices in circuits and systems.

Objectives

As specific objectives, by the end of the course students should be able to:

- Explain the concept of wave-particle duality especially with regard to electrons.
- Calculate allowed electron energy levels in single atoms from solutions of Schrodinger Equation, and be familiar with the concept of energy bands.
- Explain electron behaviour in energy bands and bonds.
- Be familiar with the idea of the Fermi level, and the formation of n and p type semiconductors by the deliberate addition of dopant atoms.
- Apply the continuity equation to different semiconductor problems.
- Explain the formation of p-n junctions, and be familiar with how current flow across the junction is limited by minority carrier flow.
- Know how p-n junction formation can be used in the design of JFETs and bipolar transistors.
- Compare and contrast the performance of JFET and bipolar Transistors.
- Know how metal semiconductor junctions can be used in the design of MESFETs and HEMTs, and be able to compare operation with that of the JFET.
- Explain the operating modes of a MOS Capacitor and MOSFET, and be familiar with how device design affects I-V characteristics.
- Understand how MOSFETs may be utilised as simple memory devices.

Content

Quantum Mechanics and Semiconductor Physics

- Introduction to quantum mechanics: wave-particle duality, Schrodinger's equation
- Physics of semiconductors: E-k diagrams, energy bands, direct and indirect band gaps, density of states, Fermi level, intrinsic and extrinsic semiconductors, drift and diffusion, recombination and generation, continuity equation

Semiconductor Devices

- Basic junctions and heterostructures: p-n junctions band diagrams, junction in equilibrium, current flow in p-n junction, metal-semiconductor junctions, heterojunctions
- Device engineering: the bipolar junction transistor (BJT), the heterojunction bipolar transistor (HBT), the junction field effect transitor (JFET), the metal semiconductor field effect transistor (MESFET), the high electron mobility transistor (HEMT) and the metal oxide semiconductor field effect transistor (MOSFET) - how they operate and I-V characteristics

Examples papers

Four examples papers are provided during the course, covering lectures 1-4, lectures 5-8, lectures 9-12 and lectures 13-16.

Coursework

Schottky Barrier Diode

Learning objectives:

- Experimentally probe semiconductor engineering concepts related to theory given in lectures.
- Use oscillator circuit to investigate voltage dependence of the capacitance of a Schottky barrier diode and understand how this is a powerful technique for characterisation of semiconductor doping.
- Compare the current-voltage characteristics of Schottky and p-n diodes and explore deviations from ideal diode behaviour.

Practical information:

- Sessions will take place in the EIETL, during weeks 1-8 of Michaelmas term.
- This activity involves preliminary work (read and understand the lab handout).

Full Technical Report:

Students will have the option to submit a Full Technical Report.

Booklists

Please refer to the Booklist for Part IIA Courses for references to this module, this can be found on the associated Moodle course.

Examination Guidelines

Please refer to Form & conduct of the examinations [2].

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [3] standard:

Toggle display of UK-SPEC areas.

GT1

Develop transferable skills that will be of value in a wide range of situations. These are exemplified by the Qualifications and Curriculum Authority Higher Level Key Skills and include problem solving, communication, and working with others, as well as the effective use of general IT facilities and information retrieval skills. They also include planning self-learning and improving performance, as the foundation for lifelong learning/CPD.

IA1

Apply appropriate quantitative science and engineering tools to the analysis of problems.

KU1

Demonstrate knowledge and understanding of essential facts, concepts, theories and principles of their engineering discipline, and its underpinning science and mathematics.

KU2

Have an appreciation of the wider multidisciplinary engineering context and its underlying principles.

E1

Ability to use fundamental knowledge to investigate new and emerging technologies.

E2

Ability to extract data pertinent to an unfamiliar problem, and apply its solution using computer based engineering tools when appropriate.

E3

Ability to apply mathematical and computer based models for solving problems in engineering, and the ability to assess the limitations of particular cases.

P1

A thorough understanding of current practice and its limitations and some appreciation of likely new developments.

P3

Understanding of contexts in which engineering knowledge can be applied (e.g. operations and management, technology, development, etc).

US1

A comprehensive understanding of the scientific principles of own specialisation and related disciplines.

US2

A comprehensive knowledge and understanding of mathematical and computer models relevant to the engineering discipline, and an appreciation of their limitations.

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