The University Of Sheffield.

Electronic & Electrical Engineering.

EEE6213 **PRINCIPLES OF SEMICONDUCTOR DEVICE TECHNOLOGY**

Credits: **15**

Course Description including Aims

The unit describes the basic structure of materials and their relationship to the requirements of semiconductor devices for future applications, leading to methods of crystal growth, fabrication, modelling and characterization. The course will have an assignment component which will allow students to gain experience of modelling devices relevant to future CMOS on the nanohub (Purdue).

The aims are as follows:

This course aims to give students an understanding of semiconductor properties and processing, crystal and semiconductor growth and characterization and aspects related to device modelling. By the end of this course students should understand the principal device processing steps and the way in which they are implemented to model and produce simple device structures. The students will achieve hands-on experience with device modelling which will enable them to correlate what they have learnt with respect to basic material properties to industry requirements.

- Develop an understanding of crystal structure and its relationship to properties of materials ie semiconductors, conductors and insulators. The relationship to bandstructure and effective mass in relation to the requirements of future CMOS will be highlighted.
- Develop an understanding of crystal growth techniques and their requirements for both microelectronic and solar cell applications.
- Develop an understanding of deposition methods such as CVD, MBE, MOCVD. This will be accompanied by lab visits to the National Centre to reinforce lectures.
- Develop an understanding of device structures (MOSFET and TFET) and their relationship to circuit requirements.
- Develop an understanding of modelling methods which will facilitate a link between bandstructure and effective mass and device performance. This will be reinforced by a Modelling assignment on the nanohub.
- Develop an understanding of basic characterization methods (physical and electrical).
- Develop an understanding of the basic process flow for CMOS and BJT.
- Develop an understanding of gettering processes and yield.

Outline Syllabus

Historical perspective and overview. **Properties of Semiconductors, metals, insulators, semi-metals** : basic electrical, optical and structural characteristics including impurity effects, the Miller index notation and crystal defects. **Bulk Crystal Growth** : preparation of bulk Si and GaAs ingots and slices; Czochralski, floating zone, LEC and Bridgman growth. **Epitaxial Layer Growth** : CVD, MOCVD and MBE methods. **Semiconductor Characterisation Methods** : TEM, SEM, SIMS, AFM, SPM. **Oxidation and Etching** : dry, wet and deposited layers. **Lithography** : optical and e-beam methods, mask alignment. **Ion Implantation** : equipment, ion damage, annealing, dopant diffusion. **Gettering** : internal, external. **Metallization and Silicides** : metal deposition, ohmic contact and interconnect formation. **Device Processing Integration** : CMOS and bipolar device fabrication with resistors and capacitors, device packaging, failure and reliability issues. **Basic Mosfet and Tunnelfet:** Device Principles and characteristics **Modelling Methods**: Semiclassical versus NEGF.

Assignment 1 (25%): Simulate a Nanowire MOSFET using Si, Ge, GaAs, InAs and submit a report highlighting the impact of material properties on the device performance.

Time Allocation

36 hours lectures: of which 4-6 hours comprise visits to the NC to demonstrate equipment, characterization facilities and transistor fabrication; 1 hour involves practical aspects of registration on the Nanohub; 4 hours of group presentations in class.

25 hours assignment using "Nanowire" on the Purdue nanohub and writing a report.

4 hours preparation of presentation

Remaining hours independent study.

Recommended Background Knowledge

A first degree in Engineering, Physics or knowledge equivalent to our 3rd year EEE undergraduate degree programmes. Knowledge of basic semiconductor theory would be an advantage.

Assessment

Formal examination; 2 hours duration; answer 3 questions from 4	75 %
Modelling exercise on nanohub (short written report)	25 %

Recommended Books

James W Mayer and S S Lau	Electronic Materials Science for Integrated Circuits in Si and GaAs	Macmillan
R A Strading and P C Klipstein	Growth and Characterisation of Semiconductors	IOP Publishing

Other books

P E J Flewitt and R K Wild	Physical Methods for Materials Characterisation	IOP Publishing
Y Taur		McGraw-Hill
S A Campbell	Science and Engineering of Microelectronic Fabrication	Oxford

Objectives

By the end of the module, successful students will be able to

1. demonstrate good understanding of the properties and preparation of semiconducting materials.
2. display knowledge of modern device processing practices.
3. design a process flow to produce a simple device.
4. demonstrate ability to model MOSFET and TFET devices.

IET Learning Outcomes

Outcome Code	Supporting Statement
SM1m / SM1fl	This course brings together the physics of semiconductor materials, crystal growth, fabrication, modelling, characterisation and finally processing steps necessary for making technologies in CMOS and bipolar. An overview of state-of-the-art in the microelectronics industry and its future requirements in terms of material properties, lithography and device structures (from own specialisation and discipline) is presented. A video movie with the latest commercial manufacturing processes within a factory environment which brings together all of the above knowledge in current state-of-the-art is shown towards the beginning of the course. Laboratory visits are organised to show facilities for growth (MBE/MOVPE),

processing (ellipsometry, ICP etching, evaporation) and characterisation (SEM, AFM) within the university. (Thin Film) Transistor fabrication is demonstrated in the clean room during an additional visit. Revision of each of the topics is covered by 3 minute seminars delivered by students towards the end of each semester. Learning outcomes are tested via a written exam and one marked assignment associated with modelling: This is aimed to reinforce the learning of the relationship between material properties and device characteristics of future generation technology such as tunnel fet. It is currently undertaken on the Purdue Nanohub .

SM2fl The course tests the knowledgeability of the students in vector algebra (for crystallography) and basic algebra for calculations required to solve problems for semiconductor growth, diffusion, characterisation of basic properties. They are taught the basics of transport modelling using classical and NEGF methods, this is reinforced by an assignment on the nanohub on upcoming transistor technology requirements related to the tunnelfet (within a timeframe of 2025 for delivery of the International Technology Roadmap of Semiconductors).

SM3p / SM3m The course contents include solid state physics (to describe properties of semiconductors), material science (crystallography) and their exploitation in applications (technology) to electronics engineering.

SM4m The course tests the knowledge/ability of the students in vector algebra (for crystallography) and basic algebra for calculations required to solve problems for semiconductor growth, diffusion, characterisation of basic properties. They are taught the basics of transport modelling using classical and NEGF methods, this is reinforced by an assignment on the nanohub on upcoming transistor technology requirements related to the tunnelfet (within a timeframe of ~2025 for delivery of the International Technology Roadmap of Semiconductors).

EA1m / EA1fl Students are examined via problems handling growth and diffusion processes (including oxides), crystallographic orientations and calculations of basic properties such as resistivity, identification of appropriate characterisation techniques (electrical and physical). They are examined on CMOS and bipolar process flows for device fabrication.

EP2m Demonstrate in-depth knowledge and understanding of methods to determine material properties (bandgap, resistivity), specialised equipment for crystal growth, epitaxial growth, defect characterisation. Most of these are tested in the exam.