Engineering Tripos Part IIB, 4C3: Advanced Functional Materials and Devices, 2021-22

Module Leader
Prof. J H Durrell [1]

Lecturers
Prof. J Durrell, Prof. S Hofmann [2]

Timing and Structure
Michaelmas term. 14 lectures + 2 Exercise Classes/Practical Demonstrations. Assessment: 100% exam. Will be taught in person with lectures recorded.

Aims
The aims of the course are to:

- introduce a range of modern functional materials and devices emphasising their processing, properties and limitations.
- introduce principles to describe the origins of the electronic, optical, and magnetic properties of materials, and to explore structure-property relationships for bulk, thin film and nano-materials.
- discuss how these properties can be characterised and engineered for applications ranging from bulk superconductors to piezoelectric sensors, integrated CMOS, solid state lighting, displays and non-volatile memory.
- provide analysis of the key issues shaping the field and the key technologies reshaping society.

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

- appreciate the range and diversity of modern functional materials.
- understand band diagrams and basic implications of quantum mechanics.
- understand qualitatively the origin of ferromagnetic and superconducting order in materials and how this results in useful materials properties.
- understand how extrinsic and intrinsic factors affect the performance of magnetic, superconducting and electrical materials.
- be able to apply their understanding of functional materials to making materials selection decisions.
- understand ferroic, non-linear response materials and the underlying phase transitions.
- understand interface behaviour and basic junctions as the basis for semiconductor device engineering.
- understand size-effects and how materials structure and properties can be controlled from the bulk to thin films and down to the nanoscale.
- understand manufacturing and characterisation requirements of these materials.
- identify current and future materials for a range of state-of-the-art sensor, integrated circuit, lighting, display and memory technologies.

Content
Magnetic, Superconducting and Electrical Materials (7L+ 1, Prof. J Durrell)

- Basics: Recap of magnetic and electrical fields in materials
  (1L – flipped classroom: worksheet to study before lecture)
- Magnetic Materials and Applications (2L);
- Superconducting Materials and Applications (2L);
- Electrical and Multi-ferroic Materials and Applications (2L);
- Guided Classwork Exercise and Superconductivity Demonstration (1L)

Optoelectronic materials and devices (7L + 1, Prof S Hofmann)

Setting the scene – Materials for digital technology and modern information society (1L)

Introduction to Modern Theory of Solids and Opto-Electronic Device Materials

- Bonds and Bands in Solids (1L)
- Mind the Gap: Semiconductors & Insulators (1L)
- From thin films to emerging nanomaterials (2L)

Material Challenges in Opto-Electronic Device Applications

- Interface is the Device: Very large scale integration (VLSI): CMOS technology (1L)
- Let there be light: light emitting diodes, lasers and display technology (1L)
- Guided Classwork Exercise and EE lab/clean room tour (1L)

Booklists


Available online to CUED students
[https://www.cambridge.org/core/books/magnetism-and-magnetic-materials/AD...  [3]

‘Superconductivity’. Poole (Elsevier)

Available online to CUED students: [https://cam.userservices.exlibrisgroup.com/view/action/uresolver.do?oper...  [4]

Braithwaite N. and Weaver G., ‘Electronic Materials’, Butterworths  (JA179)

Ohring M., The Materials Science of Thin Films  (JA204)


Useful as a simple guide on quantum mechanics :

Campbell S.A., ‘Science and Engineering of Microelectronic Fabrication’  (OUP)

Plummer J. D., Silicon VLSI technology  (NQ79)

Dresselhaus et al., Topics in Applied Physics, Carbon Nanotubes, DOI: 10.1007/3-540-39947-X

Avouris et al., 2D Materials: Properties and Devices, [https://doi.org/10.1017/9781316681619  [5] (available online via UCam library)
Reference:

Kittel C., ‘Introduction to Solid State Physics’ (Wiley)

Elliott S.R., ‘Physics and Chemistry of Solids’ (Wiley)

Madou M. J., Fundamentals of Microfabrication (DM.7&8 Folio)

Examination Guidelines

Please refer to Form & conduct of the examinations [6].

UK-SPEC

The UK Standard for Professional Engineering Competence (UK-SPEC) [7] describes the requirements that have to be met in order to become a Chartered Engineer, and gives examples of ways of doing this.

UK-SPEC is published by the Engineering Council on behalf of the UK engineering profession. The standard has been developed, and is regularly updated, by panels representing professional engineering institutions, employers and engineering educators. Of particular relevance here is the Accreditation of Higher Education Programmes (AHEP) document [8] which sets out the standard for degree accreditation.

The Output Standards Matrices [9] indicate where each of the Output Criteria as specified in the AHEP 3rd edition document is addressed within the Engineering and Manufacturing Engineering Triposes.