

## School of Engineering *and* Materials Science

### J511: BEng Materials Science and Engineering for 2009/10

#### Programme Description

The Materials Science and Engineering, and Materials and Mechanical Engineering, programmes both provide a thorough grounding in the physical and chemical structure of materials, the properties of materials, manufacturing processes, design, and business studies/management.

Academically, the programmes are a bridge between the pure and applied sciences, while vocationally they constitute a training, which embraces a plurality of disciplines and is in demand throughout industry and business.

Both programmes cover all materials: metallic, ceramic, polymers, and composites. This is essential for students who wish to work in multiple-disciplinary engineering sectors such as automotive and aerospace manufacture, where optimisation of material selection is critical.

The MEng programme combined with an industrial training period is available for exceptional applicants seeking the challenge of a dual-discipline degree. The programme combines the core subjects of the materials Science and Engineering degree with those of mechanical engineering such as dynamics, stress analysis, design and management. An extended final-year project is usually linked to the industrial placement.

Recent placements have been undertaken in the automotive industry with Toyota, the aerospace industry with Rolls-Royce, and in other technology-based companies such as Corus. The MEng programme produces graduates well equipped to tackle engineering design problems in high technology industries where materials selection is critical.

#### Career Opportunities

Graduates perform research, production, development, design, management, and financial roles in all major industrial sectors and in public service. Many of our graduates now hold senior positions. Materials Science employs a higher proportion of female staff than many other branches of engineering and about 50 per cent of our undergraduates are female. There is a shortage of materials - engineers in all areas of industry and business, both materials-producers and materials-users. Materials-led manufacturing industries such as aerospace, automotive, and healthcare, are all currently limited by a shortage of graduates.

## Programme Structure

Year 1 Semester A:	MAT106 (4) Student Centred Learning 1	MAT100 (4) Materials Science 1: Properties of Matter	MAT102 (4) Materials Selection and Mechanical Modelling	MAT111 (4) Modelling in Materials
Year 1 Semester B:	MAT106 (4) Student Centred Learning 1	MAT206 (4) Materials Science 2: Processing and Applications	MAT115 (4) Mathematics for Materials Scientists	MAT203 (4) Introduction to Functional Materials

Year 2 Semester A:	MAT308 (5) Student Centred Learning 2	MAT309 (5) Materials Science 3: Materials Chemistry	MAT321 (5) Metals	MAT210 (5) Surfaces and Interfaces in Materials
Year 2 Semester B:	MAT308 (5) Student Centred Learning 2	MAT400 (5) Structural Characterisation	MAT303 (5/6) Polymers 2 (Composites)	MAT450 (5) Principles of Nanotechnology

Year 3 Semester A:	MAT502 (6) Engineering Ceramics	MAT501 (6) Failure of Solids	MAT500 (6) Final Year Undergraduate Research Project	MAT507 (6) Environmental Properties of Materials
Year 3 Semester B:	MAT601 (6) Manufacturing Processes	MAT602 (6) Materials Selection in Design	MAT500 (6) Final Year Undergraduate Research Project	MAT603 (6) Materials Science 3: Thermodynamics and Kinetics of Phase Transformations

### Notes on Programme Structure

The numbers in brackets indicate the "Academic Level" of each module, where a typical first year module is delivered at a level 4, whilst a master's module is delivered at level 7.

## Year 1 Modules

### MAT100: Materials Science 1: Properties of Matter

Introduction of Atomic structure and inter-atomic bonding; structure of crystalline solids; imperfections in solids; diffusion; mechanical properties of metals; dislocations and strengthening mechanisms; failure; phase diagrams; phase transformations in metals; development of microstructure and alteration of mechanical properties.

**Reading List:**

M Nelkon, P Parker. *Advanced Level Physics*. 1995  
W D Callister. *Materials Science and Engineering*. 1977

### MAT102: Materials Selection and Mechanical Modelling

This course introduces principal modelling techniques in solid mechanics and serves as a macro-mechanical complement to the courses Materials Science 1: Properties of Matter (MAT 100) and Functional Materials (MAT203) focusing on micromechanical aspects of materials science. Fundamental concepts (e.g. Newton's laws, force/movement, stress/strain, energy/work, statics/dynamics, friction/creep/fatigue etc.) will be studied to derive mechanical models for the description of the behaviour of materials. Corresponding applications for real-life design tasks are finally discussed to get insight into basic mechanics-based material selection criteria.

**Reading List:**

Hibbeler, R.C. *Statics and Mechanics of Materials*. Pearson Education. 2004  
RC Hibbeler - Engineering Mechanics: Statics TA351 HIB  
RC Hibbeler - Mechanics of Materials TA405 HIB  
RC Hibbeler - Mechanics for Engineers: Statics and Dynamics TA350 HIB  
PP Benham, RJ Crawford, CJ Armstrong - Mechanics of Engineering Materials TA405 BEN  
JM Gere and SP Timoshenko - Mechanics of Materials TA405 GER

### MAT106: Student Centred Learning 1

SCL aims to develop in the students an awareness of all aspects of the subject and professional life throughout the first two years of the degree programmes offered in materials science. Cognitive and transferable skills are developed in an integrated series of seminars, practical exercises, industrial visits and problem based learning case studies. All of the exercises draw on subject matter being taught within core course units in the relevant semester.

**Reading List:**

Michael F Ashby. *Engineering materials. 1, An introduction to their properties and applications*. Butterworth-Heinemann. 1996  
William D Callister. *Materials science and engineering : an introduction*. Wiley. 2002

### MAT111: Modelling in Materials

This module provides an introduction to modelling of materials approached through Molecular modelling. The module will include a basic introduction to molecular modelling, modelling of simple molecules such as water and ammonia and more complex molecules such as polymers. Property prediction will also be covered.

**Reading List:**

Alan Hinchcliffe. *Molecular modelling for beginners*. Wiley. 2006

### MAT115: Mathematics for Materials Scientists

The course takes the student to post 'A' Level standard in some topics and provides the mathematical skills appropriate to the courses for which it is a pre-requisite. It also aims at giving the students an introduction to basic (symbolic) computing using MATLAB. Topics covered are numbers, algebra and geometry, functions, differentiation, integration, and basic vector algebra.

**Reading List:**

Glyn James. *Modern Engineering Mathematics*. Pearson Prentice Hall. 2008  
A Croft and R Davidson - Mathematics for Engineers 3rd Edition (2008) Pearson, Harlow.

### MAT203: Introduction to Functional Materials

Introducing functional materials, including insulators, piezoelectrics, pyroelectrics, microwave dielectrics and

electro-optical ceramics; ionic conductors for fuel cells; semiconductors and the basics of LED, solar cell and laser devices; organic electronics; superconductors; shape memory alloys and magnetic materials.

**Reading List:**

Callister, William D. *Materials Science and Engineering*. 1997  
<http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html>

## MAT206: Materials Science 2: Processing and Applications

This course extends what was taught in MAT100 and now covers the properties, processing and applications of materials. In particular the processing and application of metals, polymers and ceramics. This includes their electrical, thermal, magnetic and optical properties.

**Reading List:**

W D Callister. *Materials Science and Engineering An Introduction*. Wiley. 2007  
W D Callister (1997) *Materials Science and Engineering: An Introduction*. 4th Edition. John Wiley Inc. New York.

## Year 2 Modules

### MAT210: Surfaces and Interfaces in Materials

This course gives fundamentals in surface and interface science. It covers definition of surface and interfaces, surface free energy, different types of interfaces, adsorption, capillarity, molecular basics of surface activity and its application to adhesion, wetting, emulsion and colloids. Main surface characterisation techniques are to be taught in the course. The module includes lab work where the students get some experience in preparation and characterisation of materials surfaces.

**Reading List:**

Arthur W. Adamson, Alice P. Gast. *Physical Chemistry of Surfaces*. Wiley- Interscience.

### MAT303: Polymers 2 (Composites)

A comparative study of polymers as engineering materials. Mechanical properties of polymers and polymers reinforced with fibres and particles. Micro-mechanics and property prediction.

**Reading List:**

D Hull. *Introduction to Composite Materials*. Cambridge University Press. 1996

R J Young and P A Lovell. *Introduction to Polymers*. Chapman and Hall, London. 1991

N G McCrum, C P Buckley and C.B. Bucknall. *Principles of Polymer Engineering*. Oxford Sci Publications. 1997

### MAT308: Student Centred Learning 2

SCL aims to develop in the students an awareness of all aspects of the subject and professional life throughout the first two years of the degree programmes offered in materials science. Cognitive and transferable skills are developed in an integrated series of seminars, practical exercises, industrial visits and problem based learning case studies. All of the exercises draw on subject matter being taught within core course units in the relevant semester.

**Reading List:**

Boddy, D. *Management: An introduction*. Prentice Hall. 2005

Slak, N., Chambers, S. and Johnston, R. *Operations Management*. Prentice Hall. 2004

### MAT309: Materials Science 3: Materials Chemistry

This module develops an understanding of the synthesis of polymers and used as precursors to other materials applications. The following topics will be covered; Addition, condensation and free radical polymerisation, Synthesis of materials from precursors by solution chemistry, Step Growth (Condensation) Polymerisation, The Conformations of Polymer Chains, Emulsion processing and chemical vapour deposition, Chemical reaction kinetics, Applications and Environmental Impact of Polymers, Chemical Structural and Physical Properties of Polymers. The course also will discuss polymer degradation and the monitoring of the degradation. Spectroscopic techniques such as IR and Raman spectroscopy to characterise chemical structural properties of polymers will be covered comprehensively.

**Reading List:**

R J Young and P A Lovell. *Introduction to Polymers*.

D R Gazkell. *Introduction to the Thermodynamics of Materials*.

D V Ragone. *Thermodynamics of Materials*.

### MAT321: Metals

The plastic deformation of metals and other classes of materials. The characterisation and properties of dislocations and their relationships to plastic deformation. The influence of micro-structural defects on the behaviour of dislocations and on the mechanical properties. A study of strengthening mechanisms in specific metal alloys.

**Reading List:**

Verhoeven, John D. *Fundamentals of physical metallurgy*. Wiley. 1975

Hull, Derek. *Introduction to dislocations*. Butterworth-Heinemann. 2001

Callister, William D. *Materials science and engineering : an introduction*. John Wiley & Sons. c2007

### MAT400: Structural Characterisation

The theory of X-ray diffraction and analytical electron microscopy. Applications of X-ray techniques, scanning and

transmission electron microscopy in materials science and engineering. Other techniques that can be used to identify materials are introduced.

**Reading List:**

P.J.Goodhew, F.J.Humphreys and R.Beanland. *Electron Microscopy and Analysis*.

B D Cullity. *Elements of X-ray Diffraction*. Prentice Hall. 2001

## MAT450: Principles of Nanotechnology

This module introduces the principles that underpin the nanotechnology revolution and is aimed at physical scientists and engineers. The governing physics that changes as a function of scale is studied together with the physical phenomena that are exploited in nanoscale materials. These include quantum mechanical effects, nanoscale conduction and heat transfer, optical properties and size effects in mechanical behaviour. The various types of nano-materials and the development of nanostructures are discussed.

**Reading List:**

Ben Rogers. *Nanotechnology: Understanding Small Systems*. CRC press. 2007

G Ali Mansoori. *Principles of Nanotechnology: Molecular-Based Study of Condensed Matter in Small Systems*. World Scientific. 2005

## Year 3 Modules

### MAT500: Final Year Undergraduate Research Project

A 30 credit project specific to BSc and BEng programmes. The purpose of the project will be to provide in depth knowledge of a particular research area in Materials. There will be no set rules concerning format, which will depend on the nature of the subject and personal choice. The project will typically involve experimentation which will be carried out in an associated subject area chosen by a member of academic staff (supervisor). Time for experimentation is limited and considerable emphasis will be placed on the analysis, interpretation and discussion of the experimental results obtained.

**Reading List:**

J. Anderson. *Assignment and Thesis Writing*. Liley, Brisbane. 1998

### MAT501: Failure of Solids

The physics of fracture and fracture mechanics. Application of fracture mechanics to engineering applications. Influence of temperature on the mechanical properties of materials. High temperature deformation by dislocation movement and by diffusion. Practical aspects of creep deformation. Failure of materials under cyclic loading. Theories of fatigue. Practical aspects of fatigue in engineering materials.

**Reading List:**

M F Ashby. *Engineering Materials [1]*.

S Suresh. *Fatigue of Materials*.

H L Ewalds and R J H Wanhill. *Fracture Mechanics*.

*The Markham Colliery Disaster*. Open University Publication.

J F Knott and P Withey. *Worked Examples in Fracture Mechanics*.

### MAT502: Engineering Ceramics

Review to physical and structural origin of the mechanical, electrical and optical properties of ceramics. Relate this knowledge to their applications and commercial importance. Review the processing and characterisation of ceramics. (Particular reference will be made to the following structural ceramics: alumina; silicon nitride; zirconia; and silicon carbide.) Review of functional ceramics: varistors; ferroelectrics; piezoelectrics; pyroelectrics; optoelectronics; and ferrites. Throughout the course the students will develop their knowledge so that they can relate structure, properties and applications.

**Reading List:**

W D Kingery, H K Bowen and D R Uhlmann. *Introduction to Ceramics*. J Wiley, NY. 1976

D W Richerson. *Modern Ceramic Engineering*. Marcel Dekker, NY. 1992

Y-M Chiang, D P Birnie and W D Kingery. *Physical Ceramics*. J Wiley NY. 1996

### MAT507: Environmental Properties of Materials

Recycling – possibilities of recycling schemes for different types of materials like glasses, plastics and metals will be discussed.

Environmental politics – such as the EU end of life vehicle directive will be discussed as well as other political drivers for creating a sustainable society.

Ecodesign – the benefits of designing for recycling using a cradle to grave design methodology. Examining in detail designs for single material or reduced number of materials systems that can be easily disassembled.

Life Cycle Analysis (LCA) – Detail of how the life cycle analysis is undertaken, including instruction in the use of appropriate life cycle analysis software.

**Reading List:**

Environmental Life Cycle Analysis by David F. Ciambrone

### MAT601: Manufacturing Processes

Review of the processes of casting and shaping metal components, introducing and relating the necessary casting and plasticity theory. Fundamentals of welding processes and defects in welds. Discussion of the defects introduced into the materials by the various processes and the non-destructive tests used to evaluate and monitor such defects.

**Reading List:**

L Edwards and M Endean. *Manufacturing with Materials*.

## MAT602: Materials Selection in Design

Introducing material selection concepts including processing constraints in design. An appreciation of the interaction of processing and material related cost considerations and the need to adopt a simultaneous engineering approach. The use of design guides such as Ashby diagrams is a key skill developed in the course.

### **Reading List:**

M F Ashby. *Materials Selection in Mechanical Design*. Butterworth-Heinemann, Oxford. 1997

F A A Crane, J A Charles & Justin Furness. *Selection and Use of Engineering Materials*. Butterworths-Heinemann. 1997

## MAT603: Materials Science 3: Thermodynamics and Kinetics of Phase Transformations

Surface energy, diffusion, solidification of pure metals and alloys, precipitation, liquid crystals, recrystallisation and grain growth, sintering processes.

### **Reading List:**

Collings, Peter J. *Liquid crystals : nature's delicate phase of matter*. Adam Hilger. 1990

D A Porter, K E Easterling. *Phase transformations in metals and alloys*. Chapman and Hall, London. 1992

Y.M. Chiang, D. Birnie, W.D. Kingory. *Physical Ceramics*. Wiley, NY. 1997