Engineering Tripos Part IB, 2P3: Materials, 2019-20

Course Leader

Dr G McShane [1]

Lecturer

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Timing and Structure

Weeks 1-8 Michaelmas term. 16 lectures, 2 lectures/week

Aims

The aims of the course are to:

- Build on the Part IA Materials course to extend understanding of:
- (i) the fundamental thermodynamic and kinetic principles that govern the microstructure and properties of materials;
- (ii) the practical materials processing techniques that employ these principles to manipulate microstructure and properties for engineering applications;
- (iii) strategies for modelling the deformation and failure of materials.

Objectives

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

- Understand the importance of temperature, composition and deformation in controlling the evolution of material microstructure and properties.
- Understand the general principles in interpreting phase diagrams and the theory of phase transformations.
- Understand and describe the concept of the thermodynamic driving force for microstructural change.
- Understand how diffusion occurs, and derive and apply mathematical models of one-dimensional diffusion.
- Understand the analogy between mass diffusion and thermal diffusion.
- Apply thermodynamic and kinetic principles to predict a range of material behaviour, including rubber elasticity, oxidation and corrosion.
- Apply these thermodynamic and kinetic principles to practical materials processing (e.g. solidification and casting; precipitation in metals; crystallisation in polymers; doping of semiconductors).
- Understand and model the deformation response of a range of engineering materials, including temperature-dependent creep and metal forming processes.
- Understand and model the stress-state dependence of failure for a range of engineering materials.

Content

Materials thermodynamics and diffusion (6L, Dr Alexandre Kabla)

(1) Chap. 17, GLU2; (2) Chap. 21,24-27; (3) Chap. 3-7; (4) Chap. 5,9,17 (5) Chap. 6, (6) Chap. 7, sections 7.4 and 7.5

- Role of entropy: entropic interpretation of the ideal gas law; polymer elasticity.
- Phases and phase diagrams (teach yourself).
- Free energy: thermodynamic basis of phase equilibrium; osmosis.
- Theory of diffusion in solids
- Oxidation and corrosion

Materials processing (6L, Dr G.J. McShane)

(1) Chap. 18, 19, GLU2; (3) Chap. 8-13,15,16,24-26; (4) Chap. 7,10,11,15.

- Phase transformations: thermodynamic and kinetic principles; theory of nucleation and growth; TTT and CCT diagrams.
- Casting of metals.
- Heat treatment of aluminium alloys and steels.
- Diffusion analysis in materials processing.
- Polymer processing.

Deformation and failure of materials (4L, Dr G.J. McShane)

(1) Chap. 6, 13; (2) Chap. 20,22,23; (3) Chap. 15,21,28; (4) Chap. 8.

- Modelling of deformation processing of metals.
- Annealing, recovery and grain size control in metals.
- High temperature deformation and creep in metals; deformation mechanism maps.
- Plasticity and failure: failure envelopes for metals, concrete and fibre composites.

REFERENCES

(1) ASHBY, M., SHERCLIFF, H. & CEBON, D. MATERIALS: ENGINEERING, SCIENCE, PROCESSING AND DESIGN
(2) ASHBY, M.F. & JONES, D.R.H. ENGINEERING MATERIALS 1
(3) ASHBY, M.F. & JONES, D.R.H. ENGINEERING MATERIALS 2
(4) CALLISTER, W.D. MATERIALS SCIENCE AND ENGINEERING: AN INTRODUCTION
(5) JONES, R.A.L. SOFT CONDENSED MATTER
(6) TABOR, D. GASES, LIQUIDS AND SOLIDS

Examples papers

1. Teach Yourself Phase Diagrams (issued before the start of term)
2. Materials Thermodynamics and Diffusion
3. Materials Processing
4. Deformation and Failure of Materials

Booklists

Please see the Booklist for Part IB Courses [3] for full references for this course.

Examination Guidelines

Please refer to Form & conduct of the examinations [4].

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [5] 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.

IA3

Comprehend the broad picture and thus work with an appropriate level of detail.

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.

S1

The ability to make general evaluations of commercial risks through some understanding of the basis of such risks.

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).

P4

Understanding use of technical literature and other information sources.

P7

Awareness of quality issues.

US1

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

US3

An understanding of concepts from a range of areas including some outside engineering, and the ability to apply them effectively in engineering projects.

US4

An awareness of developing technologies related to own specialisation.

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