Engineering Tripos Part IB, 2P3: Materials, 2021-22

Course Leader

Dr A J Kabla [1]

Lecturers

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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:

- show how the fundamental principles of thermodynamics and diffusion govern the properties and microstructure evolution of materials (Lectures 1-8);
- employ these principles to extend understanding of materials processing techniques (heat treatment, casting, forging), and how they can be used to manipulate microstructure and properties for particular engineering applications (Lectures 9-16).

Objectives

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

- By the end of Lectures 1-8:
- Apply thermodynamic and kinetic principles to predict a range of material behaviour, including rubber elasticity, oxidation and corrosion.
- Describe the concept of the thermodynamic driving force for microstructural change, explain the principles of phase transformations, and derive models for phase nucleation.
- Apply the thermodynamic principles of phase equilibrium in order to interpret phase diagrams.
- Understand how diffusion occurs, and derive and apply mathematical models of one-dimensional diffusion.
- By the end of the Lectures 9-16:
- Explain the importance of composition, thermal history and deformation history in controlling the evolution of microstructure and properties during materials processing.
- Select an appropriate heat treatment schedule for particular metal alloys, in order to deliver the properties required for specific engineering applications.
- Understand the analogy between mass diffusion and thermal diffusion, and use this to derive and apply mathematical models for heat flow in materials processing.
- Describe and compare the attributes of alternative shaping processes (e.g. casting, forging), and the consequences for alloy selection and properties.
- Derive and apply mathematical models describing the deformation response of materials, including metal forming processes and temperature-dependent creep.

Content

Materials thermodynamics and diffusion (8L, 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.
- Phase transformations: thermodynamic and kinetic principles; theory of nucleation and growth.
- Theory of diffusion in solids.
- Oxidation and corrosion.

Materials processing (8L, Dr Graham McShane - recorded sessions; Dr Hugh Shercliff - live sessions)

(1) Chap. 6, 13, 18, 19, GLU2; (2) Chap. 20,22,23; (3) Chap. 8-13,15,16,21,24-26,28; (4) Chap. 7,8,10,11,15.

- Heat treatment of aluminium alloys and steels: TTT and CCT diagrams; practical heat treatment; analysis of heat flow; surface engineering (case hardening).
- Shaping processes for metals: casting; deformation processing (rolling, forging); annealing, recovery and recystallisation; grain size control; modelling of deformation processing.
- Polymer processing: crystallisation; injection moulding; fibre drawing.
- Processing materials to operatre at high temperatures: high temperature deformation and creep in metals; deformation mechanism maps; achieving creep resistance.

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 - 3. Materials Thermodynamics

4 - 5. Materials Processing

Booklists

Please refer to the Booklist for Part IB 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 [3].

UK-SPEC

This syllabus contributes to the following areas of the UK-SPEC [4] 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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