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

Course Leader

Dr A J Kabla [1]

Lecturers

Dr A J Kabla, Dr H R Shercliff [2]

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)
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)

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 recrystallisation; grain size control; modelling of deformation processing.

Polymer processing: crystallisation; injection moulding; fibre drawing.

Processing materials to operate 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
The **UK Standard for Professional Engineering Competence (UK-SPEC)** [4] 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 [5] which sets out the standard for degree accreditation.

The **Output Standards Matrices** [6] indicate where each of the Output Criteria as specified in the AHEP 3rd edition document is addressed within the Engineering and Manufacturing Engineering Triposes.

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