Unit title: Materials Science and Technology

Unit code: **H/601/0419**

Level: **4**

Credit value: **15**

Aim

This unit examines aspects of materials science. Learners are provided with an understanding of structure-property relationships, analytical testing and evaluation and the selection of a material for a given application.

Unit abstract

Materials science is perhaps one of the oldest scientific fields, with some of the earliest examples of ceramic and metal experimentation pre-dating recorded history. These areas were joined by polymers in the early 20th century, and the discipline now displays considerable growth in areas such as smart materials. This unit develops knowledge and understanding gained in the core units on the structure of solids enabling learners to gain an understanding of the principles of materials science.

The unit begins with an examination of the causes behind a material's behaviour and properties by considering the microscopic nature of matter. This leads into an exploration of the processes involved in altering these properties on a permanent or transitory basis, the latter being most significant with smart materials.

To enable learners to understand how a material is characterised by its properties, the unit covers the techniques commonly used to analyse matter, such as electron microscopy and neutron diffraction, as well as the industry standard physical tests. The unit concludes with an overview of the processes used in selecting materials for given applications, involving a look at the compromises that need to be taken.

Learning outcomes

On successful completion of this unit a learner will:

1 Understand the structure-property relationships for materials

2 Understand the factors that control the properties of materials

3 Be able to characterise a material from the outcomes of analytical tests

4 Understand the selection process for choosing a material in a given application.

Unit content

1 **Understand the structure-property relationships for materials**

Microscopic structure: bonding between atoms; packing of atoms in solids; polymer chains; cross linking; fundamentals of elasticity; plastic flow; role of defects e.g. dislocations; micro-mechanisms of fracture; creep mechanisms; corrosion of materials; wear; polymer degradation

Physical properties: density; thermal expansion; specific heat capacity; heat transfer coefficient; electrical insulating properties; magnetic properties; nuclear properties e.g. cross section, isotopic composition; phase change temperatures

Mechanical properties: elastic properties; strength; hardness; ductility; toughness; fatigue resistance; creep resistance; high temperature properties; corrosion resistance; wear resistance; fracture toughness

2 **Understand the factors that control the properties of materials**

Composition: alloying; co-polymerisation; additives; cross-linking; crystallinity; composite materials

Material processing: phase equilibrium diagrams; solid solution hardening; work hardening; phase transformations e.g. diffusion, non-diffusion transformations; kinetics of transformations e.g. nucleation, growth; radiation hardening

Smart materials: external stimuli; non-Newtonian fluids; ferrofluids; complex fluids; shape memory materials; magnetoresponsivity; thermoresponsivity; electrochromic materials; photochromic materials; piezoelectricity; applications of smart materials e.g. LCD screens, 4WD systems; replacement of traditional materials with smart materials; economic and environmental costs of smart materials

3 **Be able to characterise a material from the outcomes of analytical tests**

Microscopic techniques: sample preparation e.g. metallographic, petrographic; optical macroscopy; optical microscopy; electron optical techniques e.g. Scanning Electron Microscope (SEM), Transmission Electron Microscope (TEM), Scanning Transmission Electron Microscope (STEM); electron diffraction techniques; x-ray diffraction analysis eg Energy Dispense X-ray Analysis (EDXA), Wavelength Dispersive X-ray Analysis (WDXA); neutron diffraction; atomic force microscopy; nuclear magnetic resonance imaging (MRI)

Physical testing: tensile testing; hardness testing; creep testing; fatigue testing; fracture toughness testing; corrosion testing; international testing standards; quality assurance issues

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4 **Understand the selection process for choosing a material in a given application**

Design requirements: service requirements; key design properties; normal external conditions; transient conditions; design life; quality; chemical compatibility; reliability e.g. chances of failure, consequences of failure; cost limitations; aesthetics; maintenance requirements

Fabrication: raw material form; availability; joinability; adhesives; castability; forgeability; weldability; coatings; ease of repair

Learning outcomes and assessment criteria

Learning outcomes On successful completion of this unit a learner will:	**Assessment criteria for pass** The learner can:
LO1 Understand the structure-property relationships for materials	1.1 explain the microscopic structure and behaviour of common materials 1.2 review the physical properties of materials 1.3 justify the use of a material in a given application on the basis of its mechanical properties
LO2 Understand the factors that control the properties of materials	2.1 explain the role of composition on the properties of a material 2.2 assess the use of material processing in modifying the properties of a material 2.3 evaluate the growth in use of smart materials in traditional material roles
LO3 Be able to characterise a material from the outcomes of analytical tests	3.1 use analytical microscopic techniques in material science 3.2 perform physical testing of a given material to characterise its properties, using safe practices
LO4 Understand the selection process for choosing a material in a given application	4.1 evaluate the choice of material in a given application on the basis of the design requirements of the application 4.2 justify the choice of a given material in an application on the basis of the material's fabrication

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Guidance

Links

This unit has particular links with the following units within this qualification:

- *Unit reference number R/601/0352: Organic Chemistry*
- *Unit reference number R/601/0349: Inorganic Chemistry*
- *Unit reference number F/601/0220: Analysis of Scientific Data and Information*
- *Unit reference number M/601/0360: Inorganic Chemistry of Crystal Structures and Transition Metal Complexes*
- *Unit reference number F/601/0413: Industrial Chemistry*
- *Unit reference number L/601/0415: Polymer Chemistry.*

Essential requirements

Delivery

Where possible, the unit must be delivered using a combination of theory and practical experiments. Access to electron microscopes, NMR machines etc could be achieved through arranged visits to analytical, research or medical facilities. The content is sufficiently flexible that this can be biased towards the specialist knowledge of the member of staff concerned as long as the basic understanding of the links are made between the chemistry and the materials science.

Assessment

Learning outcome 1 involves understanding the links between the properties of a material and its microscopic structure.

Learning outcome 2 considers the mechanisms used to alter the properties of a material. Evidence should include case studies or experimental studies, where appropriate.

Learning outcome 3 examines the role of analytical and physical testing in categorising a material's properties. Evidence must include experimental studies of physical testing.

Learning outcome 4 involves the process for selecting an appropriate material in a given application. Evidence should include case studies where appropriate.

Resources

Learners will need access to basic metallurgical/materials laboratory preparation and engineering workshop facilities for observations, demonstrations and practical work. This should ideally include apparatus to determine the toughness and hardness of a material. Atomic and nuclear physics equipment, such as gamma ray sources or Tel-X-Ometers, could be used to supplement the analytical testing. Samples of materials, particularly smart materials, should be readily accessible.

Employer engagement and vocational contexts

Learners will benefit from visits to industrial and research facilities to observe practical applications of materials science and technology.

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