Pearson BTEC Level _ Higher Nationals in Engineering (RQF)

Unit 9: Material, Properties & Testing

Unit Workbook 1

in a series of 4 for this unit

Learning Outcome 1

Atomic Structure & Physical Properties of Materials

Contents

INTRODUCTION 3
GUIDANCE 4
1.1 Physical Properties of Materials 5
1.1.1 Classification and Terminology 5
1.2 Atomic Structure & Characteristics 6
1.1.2 Metals and Alloys 6
1.1.3 Ceramics and Glass 8
1.1.4 Polymers 10

INTRODUCTION

Explain the relationship between the atomic structure and the physical properties of materials.

- *Physical Properties of Materials:*
  - Classification and terminology of engineering materials.
  - Material categories: metallics, ceramic, polymer and composites.
  - Atomic structure, electrostatic covalent and ionic bonding.
  - Crystalline structures: body-centred and face-centred cubic lattice and hexagonal close packed.
  - Characteristics and function of ferrous, non-ferrous phase diagrams, amorphous and crystalline polymer structures.

GUIDANCE

This document is prepared to break the unit material down into bite size chunks. You will see the learning outcomes above treated in their own sections. Therein you will encounter the following structures;

Purpose

Explains *why* you need to study the current section of material. Quite often learners are put off by material which does not initially seem to be relevant to a topic or profession. Once you understand the importance of new learning or theory you will embrace the concepts more readily.

Theory

Conveys new material to you in a straightforward fashion. To support the treatments in this section you are strongly advised to follow the given hyperlinks, which may be useful documents or applications on the web.

Example

The examples/worked examples are presented in a knowledge-building order. Make sure you follow them all through. If you are feeling confident then you might like to treat an example as a question, in which case cover it up and have a go yourself. Many of the examples given resemble assignment questions which will come your way, so follow them through diligently.

Question

Questions should not be avoided if you are determined to learn. Please do take the time to tackle each of the given questions, in the order in which they are presented. The order is important, as further knowledge and confidence is built upon previous knowledge and confidence. As an Online Learner it is important that the answers to questions are immediately available to you. Contact your Unit Tutor if you need help.

Challenge

You can really cement your new knowledge by undertaking the challenges. A challenge could be to download software and perform an exercise. An alternative challenge might involve a practical activity or other form of research.

Video

Videos on the web can be very useful supplements to your distance learning efforts. Wherever an online video(s) will help you then it will be hyperlinked at the appropriate point.

1.2 Atomic Structure & Characteristics

Each of the engineering material classification groups, generally, have distinctly different structures at an atomic level, whilst there are also some variations in structure within those specific groups too.

1.1.2 Metals and Alloys

Metals are almost exclusively crystalline solids at room temperature. Within all metal atoms, the electrons exit the outer shell which goes on to create something of a sea of electrons and leaving a positively charged metal ion. The general structure of a metal is these metal ions, closely packed together and forming a lattice in a very regular arrangement.

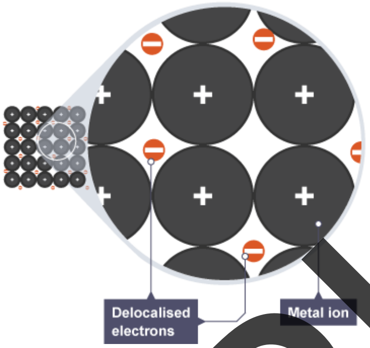

Figure 1.2: *Metallic Structure Model*

This sea of electrons surrounds all atoms and therefore cannot be considered to be associated with only one, with the strong force of attraction between the metal ions and the electrons being electrostatic. The electrons are able to move around freely which means that the metal has very good electrical and heat conductivity properties. When a metal melts, the atomic structure changes to allow the atoms more freedom to move. The majority of both alloys and metals form into one of three types of structure: body-centred cubic (BCC), hexagonal close packed (HCP) or face-centred cubic (FCC). The differences between these structures is the number of neighbouring atoms along with the orientation of the atoms.

Within a BCC type of structure, the closest neighbouring atoms are positioned at each corner of a cube shape, plus one atom centred in the middle of this cube. Every corner atom of the cube is also a corner atom of another cube; therefore, one corner atom is effectively shared with eight other unit cells, this is known as having a coordination number of 8. In total then, a BCC unit cell is composed of two atoms with the one whole atom in the cube centre and eight eighths of atoms making up each corner. A representation of the BCC atomic structure can be seen below.

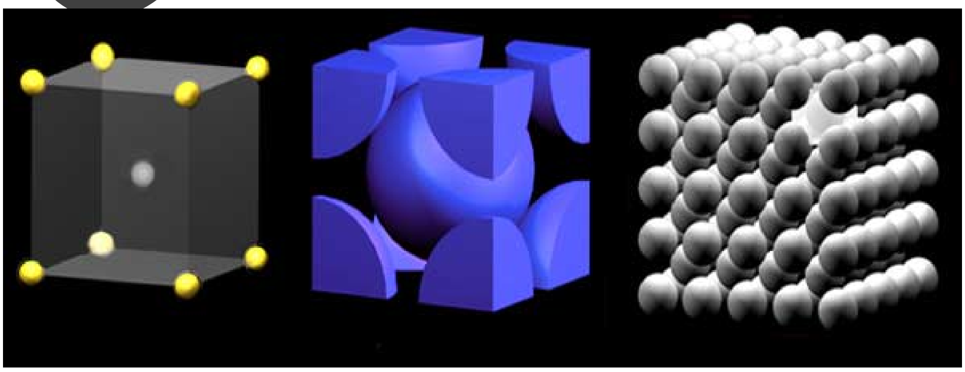

Figure 1.3: *BCC Structure*

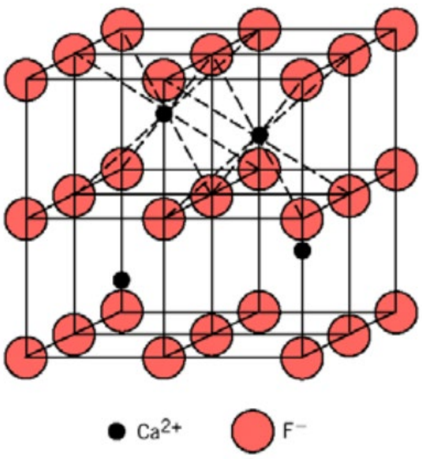

Figure 1.9: *FCC-Style Structure of Fluorite*

The crystalline structures of ceramics are wide ranging, which causes a wide range of properties in the material group. Generally speaking, ceramics are hard, with a high compressive strength, whilst also benefiting from being chemically unreactive, however they also exhibit some potentially less desired properties such low tensile strength and ductility along with poor electrical and heat conductivity.

Glass is a different matter to ceramics, in terms of structure as it is disordered and amorphous in nature, as seen below:

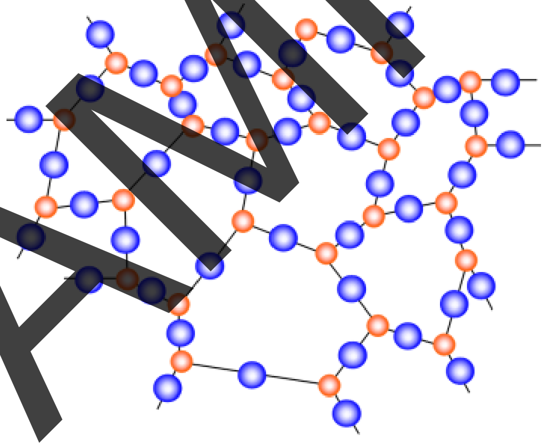

Figure 2.1: *Amorphous Glass Structure*

Various different types of glass are commonly in use today, including Soda-Lime Silica, Borosilicate and Phosphate glass. Glass is commonly transparent and is an incredibly useful material due to this and its other unique properties. Glass will transmit, reflect as well as refract light and can therefore be used to produce optical lenses for glasses, telescopes etc. as well as optical fibre for high-speed internet usage. Glass-fibre is an extruded form of the material and is used as a highly effective thermal insulator or as part of a fibreglass composite, heralded for its structural properties. Glass is generally brittle, corrosion resistant, unreactive with foods, relatively inert and has a high tensile strength.

structural adhesives, metal coatings and in composite materials like GRP. In the majority of cases, epoxies are used as bonding or coating materials and are often utilised in extreme environments due to their potential to cure underwater and to withstand UV radiation. A very common example of an epoxy used within industry is the adhesive 'Loctite' which comes in two parts that, and when mixed together, cures to form a very tough and high strength bond. It also does not shrink and is resistant to many commonly used solvents, as well as being waterproof.

One other of the widely used thermoset plastics is Polyester which is utilised in industry to produce fabric and so therefore clothing quite often too. Polyester is a polymer class that contains the 'ester' functional group. Polyesters can be either naturally occurring or synthetically produced materials and, depending on the chemical structure, can be either a thermoplastic or a thermoset.

With a polyester as a thermoset, its structure is non-linear and in fact a three-dimensional network. These types of polyester are commonly used as resins within the composite industry and they are successful partly due to their relatively low cost compared to epoxies. Polyester has the capability to be sanded and given a fine optically clear surface and it is not affected by UV radiation. These polyester resins are able to be used in a wide variety of applications because they will accept a large variety of fillers. The mechanical properties are not as good as epoxies and also requires slightly more precaution during processing, additionally there is a high shrinkage factor when curing (which, incidentally, is very quick). It is used on bulk moulding compounds, in fibre-glass structures and in toner in laser printers.

<u>Elastomer & Rubber Polymers:</u>

Natural Rubber is a highly elastic substance garnered from latex sap, usually of the Hevea and Ficus trees, this sap is then refined so that it can be used as a practical material. Natural rubber is 'vulcanised' in order to imbue it with favourable properties, when stressed, the material will deform and then revert to its original shape when the stress is relieved. Natural rubber acts as a highly effective water barrier, has high tensile strength and resistance to fatigue, maintains low heat generation and is very able to stick to both itself as well as other materials (this factor makes it very easy to fabricate into different products). It is used across a variety of applications from medical gloves and condoms to vehicle tyres, balloons, and even in some adhesives.

There are several synthetic rubbers that are used as alternatives to natural rubber, over the years there have been advancements in synthetic rubber (SR) production and different materials have been produced which have varying properties. SR products are processed and 'vulcanised' in the same way as natural rubber, but the raw material is obtained via polycondensation or polymerisation of unsaturated monomers. This group of rubbers has better abrasion resistance than natural rubber as well as better heat and aging resistance. The mechanical properties are otherwise fairly similar to natural rubber, along with added properties such as being resistant to grease and oil and flame retardant. SR is used in similar applications to natural rubber such as in tyres but is more often used in products such as hoses, seals and conveyor belts. Some common types include acrylonitrile butadiene (known as Nitrile) which is often used to make O Rings, styrene butadiene which is used extensively in vehicle tyres, butyl rubber (often called butyl) used to make chemical resistant gloves and ethylene propylene rubber (EPR) closely related to EPDM which are both used to produce self-amalgamating tape, garden hoses and high voltage cable insulation.