MECH0007 Topic Notes

UCL

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Chapter 1

Course Outline

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1.1 Coursework and exam

- Metallography and Microstructure - Lab week (week 26), held in Materials Lab Sub Basement Roberts.
- Manufacturing Case Study - Friday afternoon consultancy slots (14:30 onwards), Materials Lab Sub Basement Roberts.
- One three hour exam, consistent of two sections: MCQ (sort of?) and conventional. Timetabled revision slots in summer term.

Add notes about the following topics:

- Cracking - welding vs riveting, arrestment of cracks in a material.
- Casting and forging - in context of manufacturing processes, perocity of a liquid vs a solid.
- Crystalline and amorphous solids - materials which are one or the other, both or both in different capacities, look into molecular structure of each, crystallinity is a degree of structure which affects its properties.
- Plasticity and deformations in metals and other materials.

Structure - Property Relationship at the heart of all Material Science.

Manufacturing (Processing)	
Structure	Property

Categories of materials - these all have different structures and hence properties.

- Metals
- Ceramics
- Polymers
- Composites - a mix of the other three above (physical mix), provides an extra level of structure for scientists to work with.

Chapter 2

Properties of materials

2.1 Metals

2.1.1 General Properties

- High electrical conductivity - "thermal".
- Heavy and plastically deformable.
  - Plastic - permanent change in dimension.
- Shiny when polished.

All of these properties are a function of the atomic bonding ("metallic bond"). A metallic bond is traditionally thought to be a sea of delocalised electrons "orbiting" a *regular* array of ions. A regular array is known as a *crystal*. In this structure, we see repulsive and attractive forces from the atoms and subatomic particles. These are all balanced and thus in *equilibrium*. The interatomic distance can be defined as a_0. The interatomic distance can be modelled as a spring. Initially a tensile (or a compressive) force will generate deformation and thus a_0 but will attempt to restore to its original shape; i.e. the deformation is recoverable. This is the definition of *elastic* behaviour.

Beyond a certain deflection/deformation, *permanent* deformation is achieved. When the deforming force is removed, only some of the deformation is recovered (the elastic portion) and the plastic deformation remains.

2.1.2 Mechanisms of plastic deformation in metals

Slip

this is where planes of atoms (ions) slip/slide past each other. Planes orientated at 45°to the tensile of compressive load will slip first. Slip (under tension) generates lengthening of the specimen. However, the *volume* of the specimen does not *change* i.e. the intermolecular distance stays the same. This means that under a tensile force, the specimen becomes *thinner*. Under compression, metals become *shorter/fatter*.

2.2 Polymers

2.2.1 Thermoplastics and Thermosets

General Properties

- Thermally and electrically poor conductors.
- Low density.
- Poor reflectors.
- Often flexible (low stiffness).
- Often deformable.
    - "Slip" is possible.
    - Behave plastically.

These properties (including the mechanical properties) are due to the *bonding* occurring in polymers. These bonds are *covalent* within a polymer molecule but the existence of secondary bonding (e.g. Van der Waals and H bonding) are very influential on the properties.

Polyethene (or PE) is a chain structure molecule made up of carbon and hydrogen atoms. This structure is *thermoplastic* or *thermopolymer*. Often these chains can be 100,000 carbon atoms long. The carbon-carbon bond is tetrahedral in reality. If such a polymer was to be stretched out linearly, its length would be approximately 20 µm. Each molecule is *stable* i.e. all the covalent bonds are satisfied but there must be interaction between molecules; else PE would have no physical strength. Hence, intermolecular bonding *must* be present. There will be a degree of mechanical interaction with such "massive" molecules but secondary bonds (dipole interactions) dominate.

Not all polymers have this structure e.g. *thermosets*. Epoxy resin such as ureaformaldehyde are thermosetting. The molecular structure of thermosets are similar to thermoplastics. However, there are *real* covalent bonds between the chains instead of secondary bonding. These are called *crosslinks*. Crosslinks are created through chemical reaction during the *polymerisation* process. This creates a new substance and have no chemical formula. Thermoplastics are polymerised at the factory. Thermosets are sold as two products (*pre-polymers*), which are to be reacted together to make the thermoset. As a consequence of the crosslinks, the properties differ to those of thermoplastics such as being stiffer, harder and they can also be stronger. They are also brittle (which can lead to weak behaviour).

2.2.2 Elastomers

General Properties

- Massive elastic deformation.
- No plastic deformation.
- Non recyclable (by melting).

Elastomers are effectively a subset of thermosets; they contain covalent crosslinks (not as many) and thus cannot be melted once formed. The crosslinks permit *freedom* of deformation (movement) of the carbon chains but ultimately restrict it and thereby stop *plastic* deformation. The degree of crosslinking *strongly* affects the stiffness of the elastomer. The stiffness increases with the number of crosslinks.

2.2.3 Ceramics

General Properties

- Inorganic compounds, usually between a metallic and non metallic element.

Alumina (Al_2O_3), silica (Quartz) (SiO_2) and silicon carbide (SiC) (hard, abrasive) are all examples of ceramics.