Introducing modern materials

Since prehistoric times humans have used naturally found materials such as wood, stone and bone as both tools and construction materials, and natural plant and animal fibres have been used for producing clothes and other textiles.

The *Stone Age* refers to the period when the predominant material used by humans and our predecessors for making tools was stone. It lasted for more than 3 million years up until about 5000 years ago. Stone in fact is not as simple a material as you might think. It can range from the very soft (such as Talc that is used in powder and cosmetics) to very hard (such as Granite used in building and road construction).

Natural, and processes materials

Following the stone age came the Bronze Age (bronze is a relatively soft metal which is a mixture of copper and tin) and then the Iron Age, when these metals were dominant in making weapons, tools and other products. A key difference between stone and metals such as bronze and iron is that bronze and iron are hardly ever found naturally occurring, but need to be recovered from 'ores' that contain them in chemical form such as iron oxide. The reason the Iron Age came later is that iron is a more difficult metal to recover from its naturally occurring form, and more difficult to shape than bronze.

New materials we take for granted

Iron is a very flexible element to use. Pure iron is relatively soft, and while cast iron is hard, it is also brittle and can fracture. Iron can be smelted (mixed with carbon in a high temperature furnace) and further processed to remove most impurities, and with the addition of small quantities of other elements, an iron "alloy" (mixture) called steel can be made. There are many different forms of steel.

While stone and timber are still commonly used naturally occurring materials, most of the materials that you see around you today are artificial, produced by humans in industrial processes using natural raw materials, scientific knowledge and engineering know-how. Glasses, plastics, paper, many fibres and fabrics, concrete, most metal alloys, most dyes and colours, and ceramics are all common materials that are made by people because they have properties that make our lives easier, safer, longer and more enjoyable.

Scientists and engineers invent new materials

Research by scientists leads to the discovery and creation of new materials, and engineers design the processes which produce these materials, and many of the products which are made from them. In designing new products, engineers constantly look for ways to improve performance. This might include lower weight, lower cost, higher strength, increased safety, lower impact on the environment, and other desirable aims. The search for, and application of, new materials is a joint scientific and engineering endeavour.

Research to improve existing materials

Natural fibres such as wool, cotton and silk, and metal alloys such as steel are materials that have been used for thousands of years. Never-the-less, scientific research still goes on today to refine the properties of these materials and to find new uses for them. For steel, there is an on-going quest to produce lighter, stronger steels to make cars weigh less and use less fuel while still maintaining passenger safety, and to reduce the time and energy needed to produce them, to make cheaper and have less environmental impacts. The processing of natural fibres uses large amounts of water and energy, and there is a desire to lower the environmental impact and cost of using them. Fabrics made from natural fibres have a range of desirable features, including being light weight, thermally insulating and in some cases water resistant. Research continues into how to mimic these desirable properties in fabrics made from synthetic materials.

Nanotechnology

Small amounts of elements are added to some pure metals to control their internal structure to create alloys that have new and more desirable properties. An important goal of materials science and engineering is to be able manipulate individual atoms or molecules to construct new materials. Operating on materials at very small scales is known as nanotechnology. Developments in nanotechnology are driven in part by the desire for more powerful computers, which requires more and tinier electronic devices to be placed in computer chips. This challenges our engineering ability to make these devices, and also how to connect to them with tiny nanowires so they can be assembled into computer products.

The other exciting thing about nanotechnology and nanomaterials research is that materials constructed at the nanoscale often exhibit new and unexpected properties. A sheet of single carbon atoms connected in a hexagonal pattern and rolled into a tube (‘nanotube’) is the strongest and stiffest material known. Many materials are used as catalysts, because they promote useful chemical reactions to occur – for example, platinum is used in the catalytic converter in most modern cars, to convert the toxic exhaust fumes into carbon dioxide and water. By chopping a single 1 cm cube of platinum into one nanometer size cubes, the surface area on which this reaction occurs is increased by a factor of ten million! On-going research into nanotechnology continues to reveal new properties of materials and new ways to engineer at very small scales.

Composite materials and carbon fibre

High strength materials, like metals and concrete, are typically heavy. Increasingly we need lighter weight materials to replace these for construction of buildings and vehicles, that require less fuel to process and move them around, but which also offer the same or better levels of protection and strength. Composite materials are one approach to achieving lower weight and higher strength combination. A composite material is one that is ‘composed’ of two or more separate components. By carefully combining two or more materials that have different desirable characteristics, such as lightness, and strength, it can be possible to create a new ‘composite material’ that combines these separate properties.

For instance lightweight strands of carbon fibre have very high strength when stretched in tension, but crumple if pushed from the sides or ends. However, if these fibres are set ('cured') into a hard plastic resin, the resultant carbon fibre composite material is lightweight and combines the tensile strength of the fibres with the rigid structure of the solid resin.

Carbon fibre composites are light and strong, but the raw materials used are expensive and a lot of energy is required for their production, and the curing process to produce a carbon fibre product takes a long time compared to the manufacture of similar products made from metals. Carbon fibre composites are used in applications where weight is more critical than cost, such as aircraft. Scientific research continues to find cheaper and more sustainable raw materials from which to make carbon fibres, and engineering efforts are directed at minimising the energy needed to produce the fibres and the time required to curing of products made from carbon fibre composites.

Questions

1. Imagine everything that you and your family own, that is not made of naturally found materials, suddenly disappeared. What would be left?
2. What are the advantages of metals like bronze and iron for human use, compared to stone?
3. Think about the production of a car, or of a piece of specialised clothing such as a wetsuit or sportswear. What are some of the ways in which modern materials production and design can contribute to low environmental impact?
4. What is the difference between 'science' and 'engineering' in inventing, designing and producing products made from modern materials?

Activities

1. Ask your parents about how some of the common objects round the house have changed, since they were your age. How many of these changes involve new materials? (Think for instance of phones, kitchen cupboards and benches, utensils, electrical goods, clothes, furniture).
2. We tend to take these modern materials for granted. Look around you, in the room you are in. How many of the materials in the room are natural, or processed? Can you recognise the difference between:
    - Stone and stone products
    - Wood and wood products
    - Natural fibres such as cotton and wool
    - Synthetic, or composite fibres.
    - Metals (What sorts, and what properties do that have? Strength? Rigidity? Lightweight? Flexible?)
    - Plastics (what sorts of different properties do they have that suits them to the particular use?)
    - Composite materials composed of different parts.