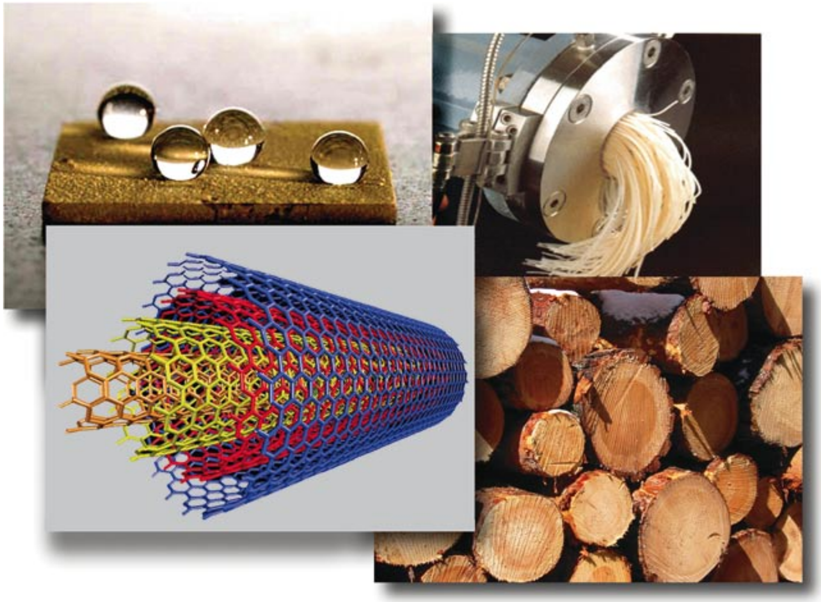
# 1 MATERIALS AND COMPONENTS



The development of civilisation is shaped by materials and their use. Whether wood, stone or ceramic – for centuries people have used the materials provided by nature. Whole epochs of human history have been defined according to the material dominant at the time, such as the Bronze Age or the Iron Age. In these periods, knowledge was acquired about the pertinent material and how to process it. With the discovery of ore smelting, mankind was no longer restricted to using materials as found in their natural state.

It is now customary to classify materials in three main groups:

- *metals* (e.g. steel)
- non-metallic inorganic materials (e.g. *ceramics*)
- organic materials (e.g. plastic)

There are also materials in the transitions between these categories: *semiconductors*, for example, are positioned between metals and non-metallic inorganic materials. The enormous variety of modern-day materials results from the vast array of different combinations that are possible using composites. These include fibre reinforced ceramics for high-temperature applications as well as multi-layer films for food packaging.

50 years ago materials research hardly existed as a discipline in its own right. Researchers had to seek out materials from the standard range available on the market and adapt them as far as possible for new purposes. Nowadays material scientists, chemists, physicists and even biologists create their own tailor-made materials. Today´s knowledge of materials has grown exponentially over the past three decades. Around two thirds of all innovations depend on material-related aspects of development. In the western technology-based countries more than 70 % of gross national product derives directly or indirectly from the development of new materials. The main contributors are energy generation, the automotive industry, mechanical engineering, the electrical and electronics industry and chemical production.

Development times for new materials are long. Progressing from the laboratory sample to a finished product can take a decade. Once a new material has been developed and tested, its properties, in particular its amenability to quality-assured and cost-efficient production, have to be verified. It also has to be borne in mind that the way a material is produced can have an influence on its structure and properties. Conversely, to achieve specific properties (e.g. hardness) specific processing methods are required.

Over the past decade nanotechnology has been the main driving force behind innovations in materials science generated from basic research, even though it is not an isolated discipline. The advance into these tiniest dimensions has proved useful in improving the resolution and understanding of material structures. The techniques developed now go beyond observation and facilitate specific processing. With small particle structures, completely new properties can be generated. It is now even possible to manipulate single atoms.

*Lightweight materials* dominate demand as far as the market is concerned, since the need to improve energy efficiency calls for materials that provide the same properties but at lower weight. The transport sector is the dominant player here.

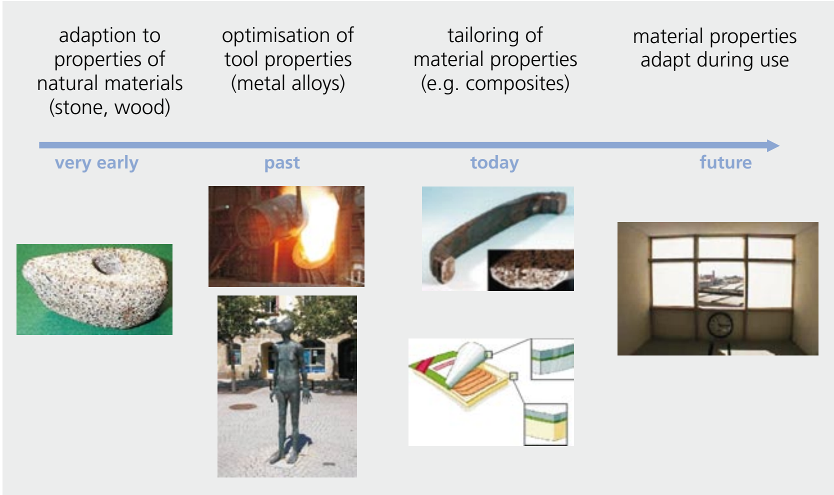
► **The topics**. Around 80 % of chemical elements are metals. Around the world they are the most commonly produced material. Although metals are among the oldest materials, they still require constant research: the sheer number of different alloys, containing various metals and other constituents, extends into the millions of possible combinations.

The Bronze Age was preceded by the Ceramic Age. The firing of clay is one of man's oldest cultural techniques. Today, distinction is made between utility ceramics and high-performance ceramics. The latter perform load-bearing functions such as in implants and technical functions such as in electrodes.

Synthetically produced polymers are relatively new. What started in 1870 with the invention of celluloid now encompasses an immense array of different organic materials. Products range from floor coverings and plastic bags to fishing lines (thermoplastics), from kitchen spoons and power sockets (thermosets) to rubber boots (elastomers). *Polymers* are long-chain molecules built up by multiple repetition of basic units with at least 1,000 atoms. Most polymers are made from mineral oil. In order to conserve this energy resource, sustainable materials are being increasingly used. They are mainly plant-based raw materials and biowaste, which are processed either to generate energy or to manufacture textiles, plastics and other chemical primary materials. The most important sustainable raw material is wood. Annual wood production exceeds that of steel, aluminium or concrete. Wood is relatively easy to process. In recent years technology has focused on how to process the large volumes available more efficiently.

In addition to the pure materials, *composite materials* have become established in a range of applications. A composite consists of two or more materials and possesses properties other than those of its individual components. Fibre composite materials are a dominant group. Polymers, metals or ceramics are used as the matrix and are interlaced with particles or fibres of other materials. The properties of these other components are therefore determined by their volume characteristics. The surface properties of materials are increasingly relevant. Tailor-made surfaces are used nowadays to attain important functions such as the "wettability" of liquids, barriers against gases, reflection of light and electrical conductivity.

*Nanomaterials* are being increasingly used both in the volume as well as in the surface layer. Although nanomaterials have become established in a wide range of applications, such as scratch-resistant car paints (surface) and sun creams (volume), expectations remain high for new applications. In *microelectronics* and *photonics*, major breakthroughs are anticipated from nanostructuring techniques and nanomaterials e. g. carbon nanotubes. Cheaper manufacturing methods will have to be developed, however, if widespread use is to be achieved.




Material epochs: While early man merely processed materials as found in their natural form, the next technological stage of human history was characterised by new combinations of materials, e. g. steel as an alloy of iron and carbon or bronze as an alloy of tin and copper. Today, components or materials are specifically designed to match required applications and functions, e. g. as metal foams or multi-layered films. In the future materials will be endowed with the ability to change according to environmental conditions, e. g. windows will darken automatically depending on the amount of incoming light

*Smart materials* are acquiring a prominent yet not always very clearly defined place in scientific-technical discussions. They incorporate a component system in which materials change their shape or behaviour according to specific environmental conditions and thus appear to react intelligently. To this end, the sensor and actuator materials have to be combined with an electronic control device to create a composite unit. But it will be some time before an airplane can adapt its wings like a bird to match wind conditions.

With the increase in computer power, *material simulation* has also become established as a research field in its own right. Numerical simulation is used in industrial practice to develop new products in a shorter time and at lower cost, to design more-efficient production processes and to ensure the required product quality.

*Self-organising systems* are an area of research that is still in its infancy. Simple building blocks arrange themselves to create units of higher complexity which have different properties and a higher information content than the individual components. As this is the way all natural structures are formed, nature is once again guiding the way. ■