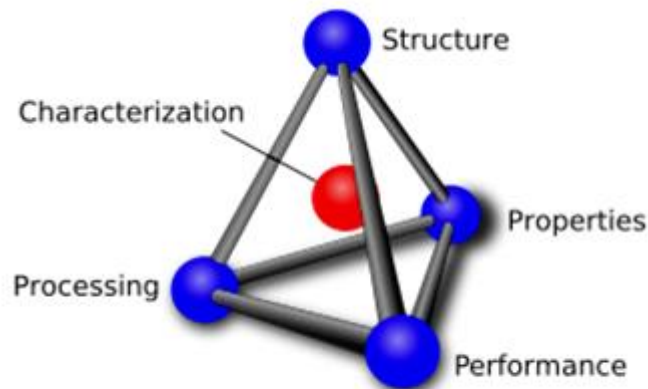


1. Engineering Materials

- ✓ Materials are physical substances used as inputs to production or manufacturing.
- ✓ Raw materials are first extracted or harvested from the earth and divided into a form that can be easily transported and stored, then processed to produce semi-finished materials.
- ✓ An example of raw material is cotton, which can be processed into thread, which can then be woven into cloth, a semi-finished material. Cutting and sewing the fabric turns it into a garment, which is a finished material. Steelmaking is another example—raw materials are mined, refined, and processed into steel, a semi-finished material. Steel is then used as an input in many other industries to make finished products.
- ✓ Materials science or materials engineering is an interdisciplinary field involving the study of materials or matter and its applications to various areas of science and engineering.
- ✓ **Matter** is the substance of the universe that has mass, occupies space, and is convertible to energy.
- ✓ Science is the systematic and formulated knowledge gained through principles of observation.



(The Materials Science Tetrahedron)

- ✓ The term **composition** means the chemical make-up of a material. The term **structure** means a description of the arrangement of atoms. Materials scientists and engineers not only deal with the development of materials but also with the synthesis and processing of materials and manufacturing processes related to the production of components. The term **processing** means how materials are shaped into useful components. The term **synthesis** refers to how materials are made from naturally occurring or man-made chemicals.
- ✓ In materials science, the emphasis is on the underlying relationships between the synthesis and processing, structure, and properties of materials. In materials engineering, the focus is on how to translate or transform materials into a useful device or structure.

It is very important that every engineer must study and understand the concepts of Materials Science and Engineering. This enables the engineer

- To select a material for a given user based on considerations of cost and performance.
- To understand the limits of materials and the change of their properties with use.
- To be able to create a new material that will have some desirable properties.
- To be able to use the material for different applications.

2. Engineering Materials Classification

Most engineering materials are classified into one of the following types:

- a) Metals (ferrous, non-ferrous) and Alloys**
- b) Ceramics**
- c) Composites**
- d) Organics**
- e) Semiconductors**
- f) Advanced and Biomaterials**

a) Metals and Alloys:

- These are the materials used widely in the industries. metal (Greek: Metallo)
- These are extracted mainly from the ores of oxides, sulphides, chlorides, carbonates, silicates, phosphates, nitrates and sulphates.
- Metals are element substances which readily give up electrons to form metallic bonds and conduct electricity.
- Metals are of two types: ferrous (major constituent is iron and carbon such as iron, steel, nickel, etc.), non-ferrous (do not contain carbon or iron such as copper, aluminium).
- Non-Ferrous Metals: These substances are composed of metals other than iron. These are aluminium, tin, copper, nickel, zinc and magnesium. Some other non-ferrous metals, about fourteen in number, are produced in relatively small quantities but these are of vital importance in modern industry. These includes, chromium, mercury, cobalt, tungsten, vanadium, molybdenum, antimony, cadmium, zirconium, beryllium, niobium, titanium, tantalum and manganese.
- Metals generally have the following characteristics: luster, hardness, ductility, strength, malleability, high density, good thermal & electrical conductivity, high melting point, machinability, castability, dimensional stability, and stiffness.
- Examples: Al, Cu, Fe, Zn, Mg, etc.

- Metals and alloys have relatively high strength, high stiffness, ductility or formability, and shock resistance. They are particularly useful for structural or load bearing applications.
- Although pure metals are occasionally used, combinations of metals called alloys provide improvement in a particular desirable property or permit better combinations of properties.

b) Ceramics (Greek *keramos*, "potter's clay", or burnt stuff)

- Ceramic materials are non-metallic, inorganic compounds found primarily in the form of oxides, but also carbides, nitrides, borides, and silicates.
- Ceramics are probably the most "natural" materials. Beach sand and rocks are examples of naturally occurring ceramics.
- Advanced ceramics are materials made by refining naturally occurring ceramics and other special processes. Advanced ceramics are used in substrates that house computer chips, sensors and actuators, capacitors, spark plugs, inductors, and electrical insulation.
- In general, due to the presence of porosity (small holes), ceramics tend to be brittle. These are the substances strong in compression but weak in tension.
- We normally prepare fine powders of ceramics and convert these into different shapes.
- Ceramics have the following characteristics: rock like appearance, brittleness, poor conductor of heat & electricity, hardness, high temperature resistance, resistance to corrosion, exceptional strength under compression.
- Examples: Sand, brick, cement, glass, silicon carbide, tungsten carbide, etc.

c) Organic Materials

- Organic materials are carbon compounds and their derivatives. They are solids composed of long molecular chains.
- These materials are carbon compounds in which carbon is chemically bonded with hydrogen, oxygen and other non-metallic substances. The structure of these compounds is complex.
- Common organic materials are plastics and synthetic rubbers which are termed as organic polymers. Other examples of organic materials are many types of waxes and petroleum derivatives.

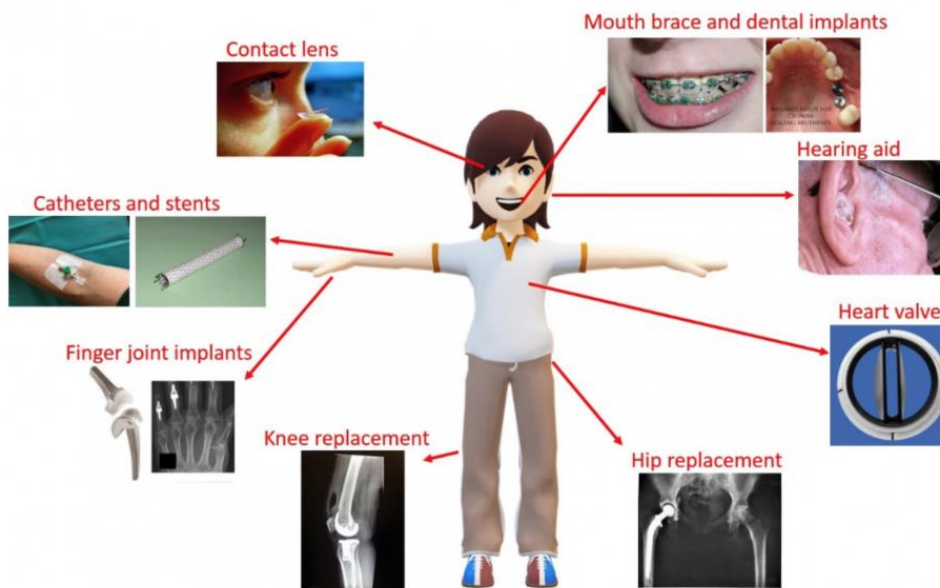
d) Semiconductors

- These are the materials which have electrical properties that are intermediate between the electrical conductors and insulators. The electrical characteristics of semiconductors are extremely sensitive to the presence of minute concentrations of impurity atoms.
- Semiconductors form the backbone of the electronic industry. The semiconductors have made possible the advent of diodes, transistors, and an integrated circuit that has totally revolutionized the electronics and computer industries.
- Some examples of semiconductors are silicon, germanium, gallium arsenide, and elements near the so-called "metalloid staircase" on the periodic table. After silicon, gallium arsenide is the second-most common semiconductor and is used in laser diodes, solar cells, microwave-frequency integrated circuits, and others.

e) Biomaterials & Advanced materials

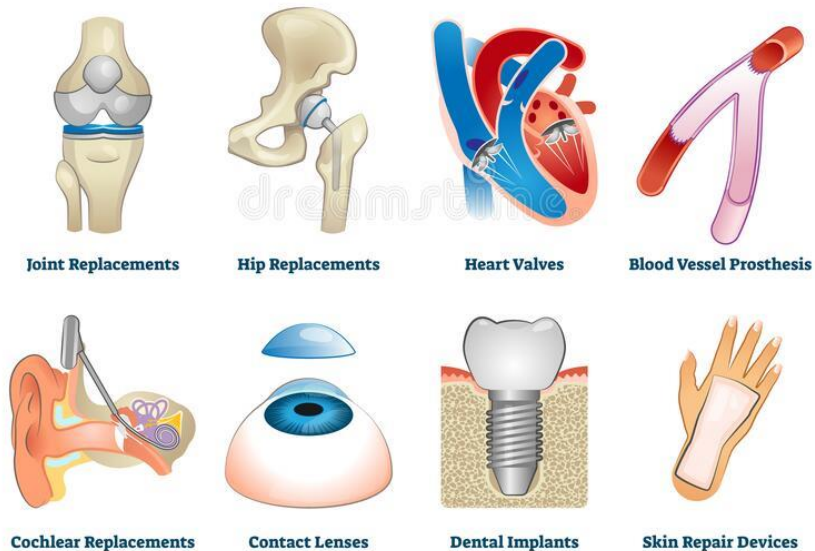
- Biomaterials are employed in components implanted into the human body for the replacement of diseased or damaged body parts. Biomaterials must not produce toxic substances and must be compatible with body tissues (i.e., these materials must not cause adverse biological reactions). All the above materials, i.e., metals, ceramics, polymers, composites, and semiconductors—may be used as biomaterials.
- Common applications- Bone grafts, Hip replacement Heart valve, and skin repair.

Biomaterials



BIOMATERIALS

Substance that has been designed to interact with biological systems for a medical purpose



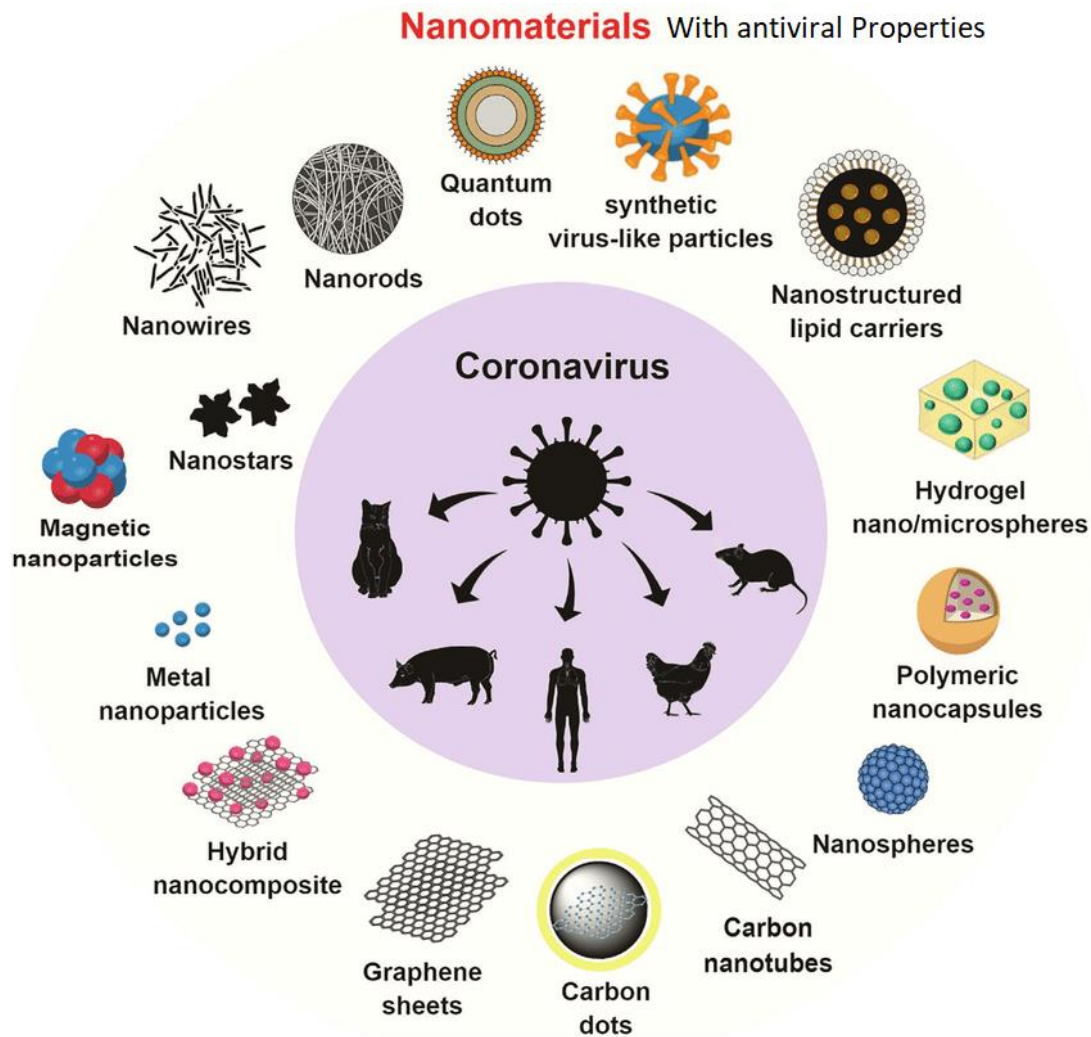
Module I: Classification of Materials

- Advanced materials that are utilized in high-technology (or high-tech) applications are sometimes called advanced materials. By high technology we mean a device or product that operates or functions using relatively intricate and sophisticated principles; for example: electronic equipment (VCRs, CD players, etc.), computers, fiber optic systems, spacecraft, aircraft and military rocketry. These advanced materials are typically either traditional materials whose properties have been enhanced or newly developed high-performance materials. Furthermore, advanced materials may be of all material types (e.g., metals, ceramics, polymers) and are normally relatively expensive. In subsequent chapters are discussed the properties and applications of a good number of advanced materials—for example, materials that are used for lasers, ICs, magnetic information storage, liquid crystal displays (LCDs), fiber optics, and the thermal projection system for the space shuttle orbiter.
- Smart or intelligent materials form a group of new and state-of-the-art materials now being developed that will have a significant influence on many of our technologies. The adjective “smart” implies that these materials are able to sense changes in their environments and then respond to these changes in predetermined manners—traits that are also found in living organisms.

SMART MATERIAL FUNCTION	DEFINITION	SMART MATERIAL EXAMPLE	EXAMPLE OF THE CURRENT APPLICATION
Actuators	Moves in response to an external stimuli	Shape-memory alloy	Arterial stents
Colour changing	Changes colour in response to an external stimuli	Photochromic materials	Glasses that change colour when in direct sunlight
Self-healing	A material that can repair itself without human influence	Self-healing paint	Kawasaki motorcycles repairing certain types of paintwork scratches
Temperature-responsive	Materials that adapt to changes in temperature	Thermochromic thermometers	Identifies whether a specific part of a machine is too hot to touch
Magnetorheological fluids	Changes viscosity with the application or removal of magnetic fields	(MR) Magnetorheological fluid	Reinforcing Kevlar armour

- Nanomaterials describe, in principle, materials of which a single unit is sized (in at least one dimension) between 1 and 100 nm. Materials with structure at the nanoscale often have unique optical, electronic, thermo-physical or mechanical properties.

- Nano materials are used in a variety of, manufacturing processes, products and healthcare including paints, filters, insulation and lubricant additives.



Summary

1. Material: Materials are physical substances used as inputs to production or manufacturing.
2. Material Science: Systematic Study of Materials. Systematic study: Study of their structure, properties, characterization, processing, performance
3. Metallurgy: Study of metals
4. Difference between Ferrous and Non-ferrous Materials

Ferrous metals	Non-ferrous metals
✓ Iron content is more.	✓ Iron content is missing.
✓ Melting point is high	✓ Melting point is low.
✓ They are of brown & black color	✓ They are of different colors.
✓ They catch rust.	✓ They don't catch rust
✓ They can be magnetized.	✓ They can't be magnetized.
✓ They are brittle in cold state	✓ They are brittle in hot state.

5. Difference Between Metals & Non-metals

Metals	Non-metals
✓ In normal temperature, they are solids except mercury.	✓ They are found in solid or gaseous state except Bromine.
✓ They have luster	✓ They have no luster except iodine & graphite.
✓ These are ductile	✓ Brittle
✓ Hard in solid state.	✓ Soft in solid state except Diamond & Iodine.
✓ High melting point.	✓ Low melting point except carbon.
✓ Good conductor of heat & electricity.	✓ Poor conductor of heat & electricity.
✓ Fe, Al, Cu, Au, Mg, Mn, Ni, K, Ag, Zn, etc.	✓ B, C, N, O, Si, P, S, As, I, Graphite, Diamond, etc.

3. Crystal Geometry

1. What is a crystal?

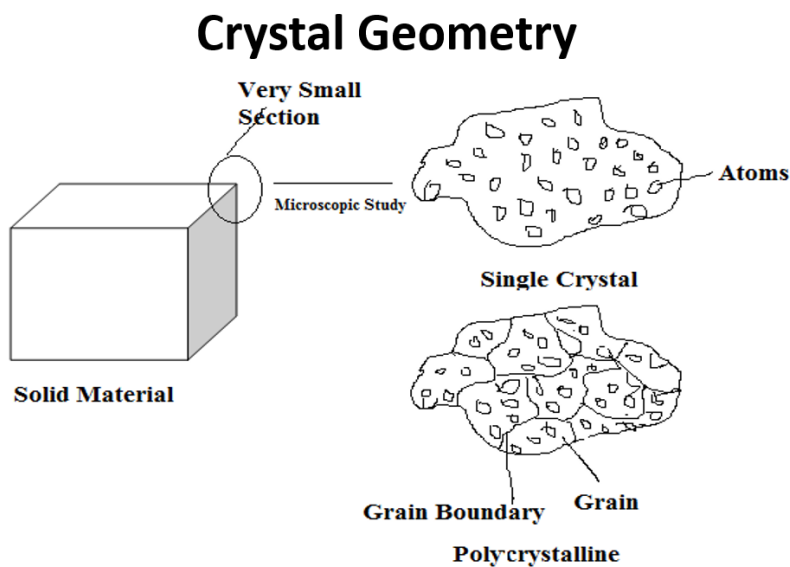
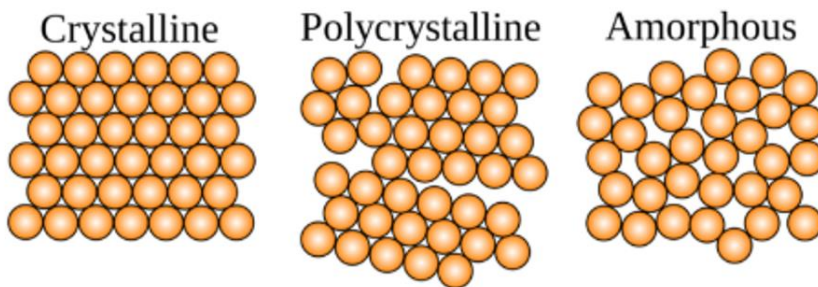
Crystal is a small part of a material/solid having regular atomic, molecular or ionic arrangement over the entire volume, bounded by smooth surfaces called grain boundaries. The crystal is also called grain.

2. How solids are classified on the basis of crystal structure?

Two types- crystalline solid and non-crystalline solids.

crystalline solid (atomic arrangement is regular); non-crystalline solids(atomic arrangement is irregular)

How solids are classified on the basis of crystal structure?



What is Lattice?

A collection of points. A lattice is a hypothetical regular and periodic arrangement of points in space. It is used to describe the structure of a crystal.

What are Lattice points?

Points that make up the lattice. The lattice points are separated by an equal distance.

What are Lattice parameters?

Parameters describe the lattice structure.

What is a crystal structure?

Crystal structure is a description of the ordered/regular arrangement of atoms, ions or molecules in a crystalline material.

What is Crystallography

Study of crystals or study of the arrangements of atoms in solids.

What are Lattice points?

Points that make up the lattice.

What are Lattice parameters?

Parameters describe the lattice structure.

What is a crystal structure?

Crystal structure is a description of the ordered/regular arrangement of atoms, ions or molecules in a crystalline material.

4. Scanning Electron Microscopy

- A scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning the surface with a focused beam of electrons.
- The SEM technique can only be used for the evaluation of surface morphology.
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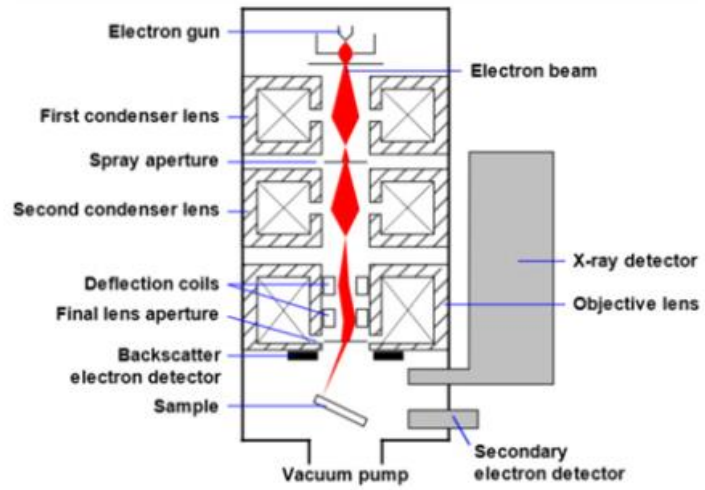
The main [SEM components](#) include:

- Source of electrons
- Column down which electrons travel with electromagnetic lenses
- Electron detector
- Sample chamber
- Computer and display to view the images

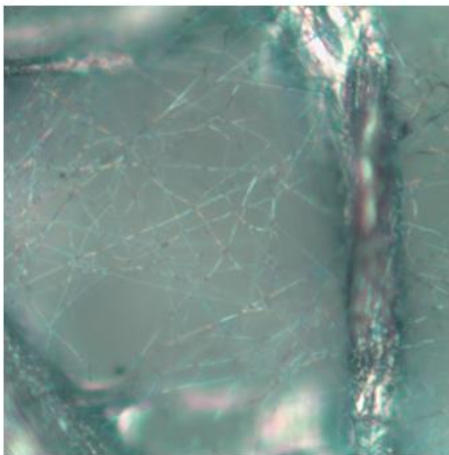
Electrons are produced at the top of the column, accelerated down, and passed through a combination of lenses and apertures to produce a focused beam of electrons which then strikes the surface of the sample. The sample itself is mounted on a stage in the chamber area and (unless the microscope is designed to

operate at low vacuums) both the column and the chamber are evacuated by a combination of pumps. The level of the vacuum will depend on the design of the microscope.

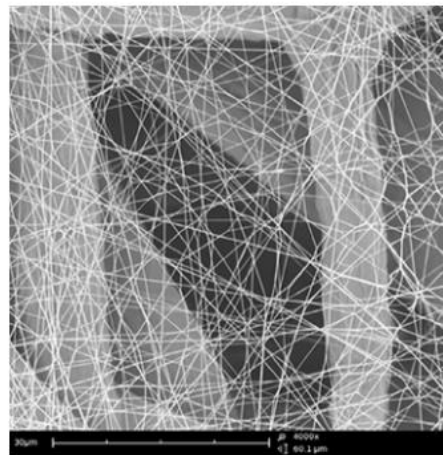
The position of the electron beam on the sample is controlled by scan coils situated above the objective lens. These coils allow the beam to be scanned over the surface of the sample. This beam rastering or scanning enables information about a defined area on the sample to be collected. As a result of the electron-sample interaction, a number of signals are produced. These signals are then detected by appropriate detectors.



Schematic of a scanning electron microscope.



Optical microscope image of nanofibers.



Scanning electron microscope image at 4000x magnification of the same nanofibers.

Scanning electron microscopes (SEMs) have become powerful and versatile tools for material characterization, especially in recent years, as the size of materials used in various applications continues to shrink.

Electron microscopes use electrons for imaging in a similar way that light microscopes use visible light. Unlike transmission electron microscopes (TEMs), which detect electrons that pass through a very thin specimen, SEMs use the electrons that are reflected or knocked off the near-surface region of a sample to create an image. Since the wavelength of electrons is much smaller than that of light, the resolution of SEMs is superior to that of a light microscope.