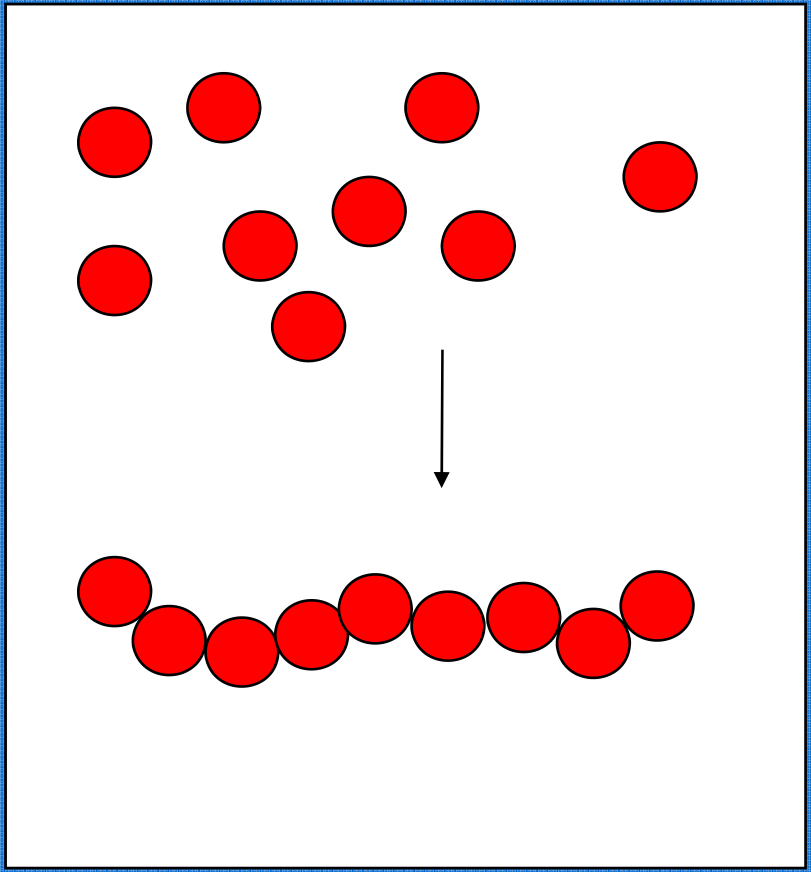
UNIT 5 POLYMERS AND CRYSTALS

POLYMERS



- A long molecule made up from lots of small molecules called *monomers.*

Monomers

- Monomers all same type (A)
- A + A + A + A →
- -A-A-A-A-
- *Eg: poly(ethene) polychloroethene PVC*

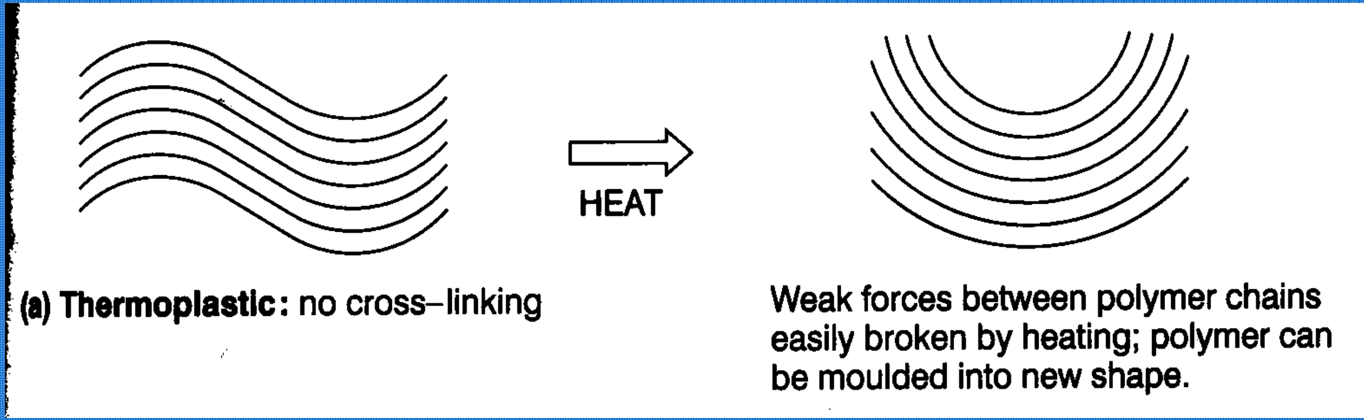
Different monomers

- Monomers of two different types A + B
- A + B + A + B
- → -A-B-A-B-
- Eg: Polyamides,
  Polyesters

Types of Polymers

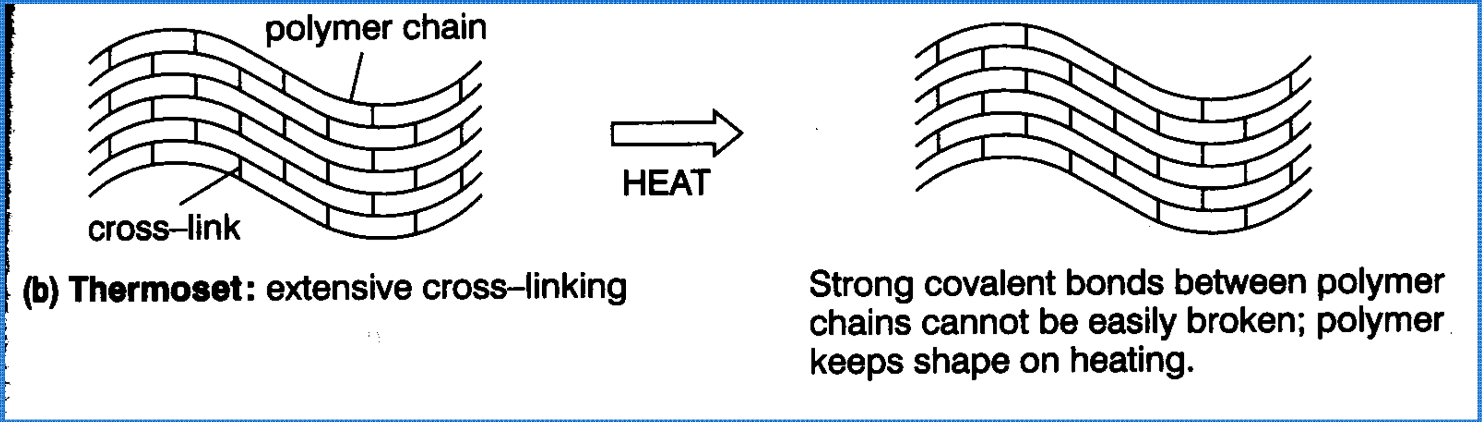
- Thermoplastics
- Thermosets
- Elastomers
- Fibres

Thermoplastics (80%)



- No cross links between chains.
- Weak attractive forces between chains broken by *warming*.
- Change shape - can be remoulded.
- Weak forces reform in new shape when cold.

Thermosets



- Extensive cross-linking formed by covalent bonds.
- Bonds prevent chains moving relative to each other.
- Rigid and not softened by the application of heat.

Elastomers

- Lightly cross-linked polymers.
- They allow considerable extensions which are reversible.
- When stretched, the polymer tends to straighten

Fibres

- Thread forming solids possessing high tensile strength and modulus.
- Strong intermolecular forces like hydrogen bonding
- Eg: Polyamides, Polyesters

Longer chains make stronger polymers.

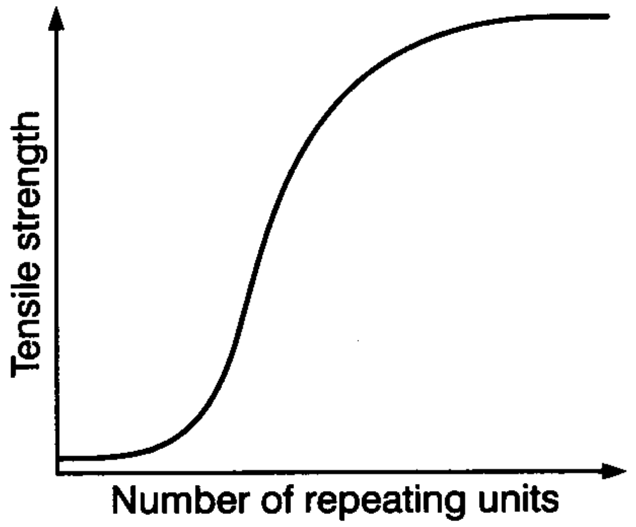


Figure 31 The relationship between tensile strength and chain length for a polymer.

- Critical length needed before strength increases.
- Hydrocarbon polymers average of 100 repeating units necessary but only 40 for nylons.

Polymerization Processes

- Addition Polymerization
- Condensation Polymerization

Addition polymerisation

- Monomers contain C=C bonds
- Double bond opens to (link) bond to next monomer molecule
- Chain forms when same basic unit is repeated over and over. Eg: Ethylene
- Also known as chain growth or chain reaction polymerization.
- No reaction byproducts in general.

Copolymerisation

- When more than one type of monomer is used, it is called copolymerisation.
- Heat and pressure are applied in the presence of a catalyst.
- Here condensation reaction takes place and loss of a small molecule of water is often accompanied. Eg: Terylene, Nylon

CERAMICS

- A wide-ranging group of inorganic materials whose ingredients are clays, sand and feldspar.
- Traditionally, moulded from silicate materials, then dried and fired.

Classification based on Microstructure

- Single Crystals of appreciable size Eg: Ruby laser Crystal
- Glass of appreciable size
- Crystalline or glassy filaments
- Polycrystalline aggregates bonded by a glassy matrix.
- Glass-Free polycrystalline
- Polycrystalline aggregates

General Properties

- Very strong interatomic bonding exists in ceramics which may ionic, covalent or a mixture of the two.
- Properties are mainly affected due to this strong bonding.

General Properties

- Very high melting point
- Low electrical and thermal conductivity. This enables them to be used in furnace as refractory material
- High compressive strength
- Low bulk density typically about 2000-4000 kg per m^3. (Metals such as Iron are as high as 8000).
- Low resistance to crack propagation. Impact conditions must be avoided.

Properties and Applications of Selected Engineering Ceramics

- Alumina
- Tungsten Carbide
- Cubic Boron Nitride
- Diamond

Properties of alumina

- High melting point of 2050^{o}C.
- Resistant to heat, i.e. shows refractoriness.
- Interatomic bonding forces, partly ionic and partly covalent are very strong and the structure of alumina is physically stable upto a temperature of 1500-1700^{o}C.

- Alumina is used in coarse grain size as refractory material in the form of slabs, shapes and bricks for furnace construction.
- Due to stability in elevated temperatures it is used as a protective sheath for temperature measuring thermocouples.
- The coefficient of expansion of Alumina is 3.5 x 10^{-6} K^{-1}.
- Used extensively in electrical and electronics industry as substrates and packing material.
- Alumina components are frequently quite small but affect vital functioning of system Eg: Spark Plug insulators.

COMPOSITES

- A broad definition of composite is: Two or more chemically distinct materials which when combined have improved properties over the individual materials. Composites could be natural or synthetic.
- Wood is a good example of a natural composite, combination of cellulose fiber and lignin. The cellulose fiber provides strength and the lignin is the "glue" that bonds and stabilizes the fiber.
- The ancient Egyptians manufactured composites! Adobe bricks are a good example. The combination of mud and straw forms a composite that is stronger than either the mud or the straw by itself.
- Bamboo is a very efficient wood composite structure. The components are cellulose and lignin, as in all other wood, however bamboo is hollow. This results in a very light yet stiff structure. Composite fishing poles and golf club shafts copy this natural design.

- Composites are combinations of two materials in which one of the material is called the reinforcing phase, is in the form of fibers, sheets, or particles, and is embedded in the other material called the matrix phase.
- Typically, reinforcing materials are strong with low densities while the matrix is usually a ductile or tough material. If the composite is designed and fabricated correctly, it combines the strength of the reinforcement with the toughness of the matrix to achieve a combination of desirable properties not available in any single conventional material.

Components of composite materials

- Reinforcement fibers
  - Glass
    Carbon
    Organic
    Boron
    Ceramic
    Metallic

- Matrix materials
  - Polymers
    Metals
    Ceramics

Composites – Polymer Matrix

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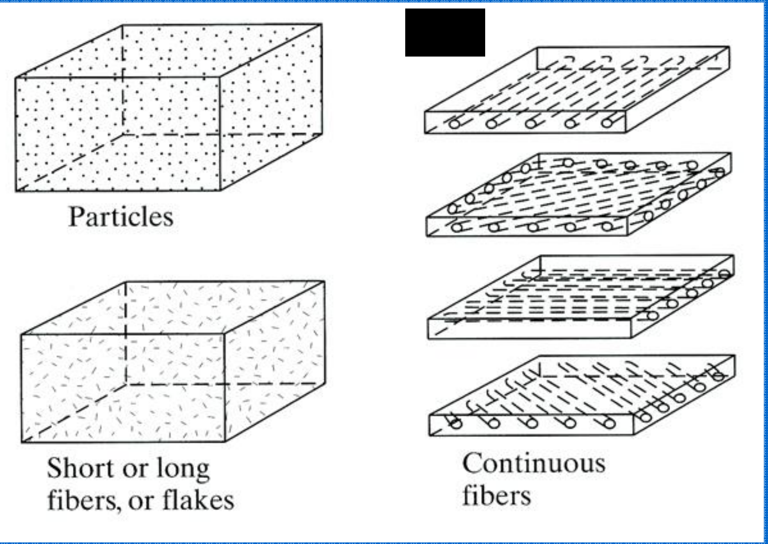
- Polymer matrix composites (PMC) and fiber reinforced plastics (FRP) are referred to as ***Reinforced Plastics.*** Common fibers used are glass (GFRP), graphite (CFRP), boron, and aramids (Kevlar). These fibers have *high specific strength* (strength-to-weight ratio) and *specific stiffness* (stiffness-to-weight ratio)



Reinforcing fibers

Glass – most common and the least expensive, high strength, low stiffness and high density. GFRP consists 30-60% glass fibers by volume.

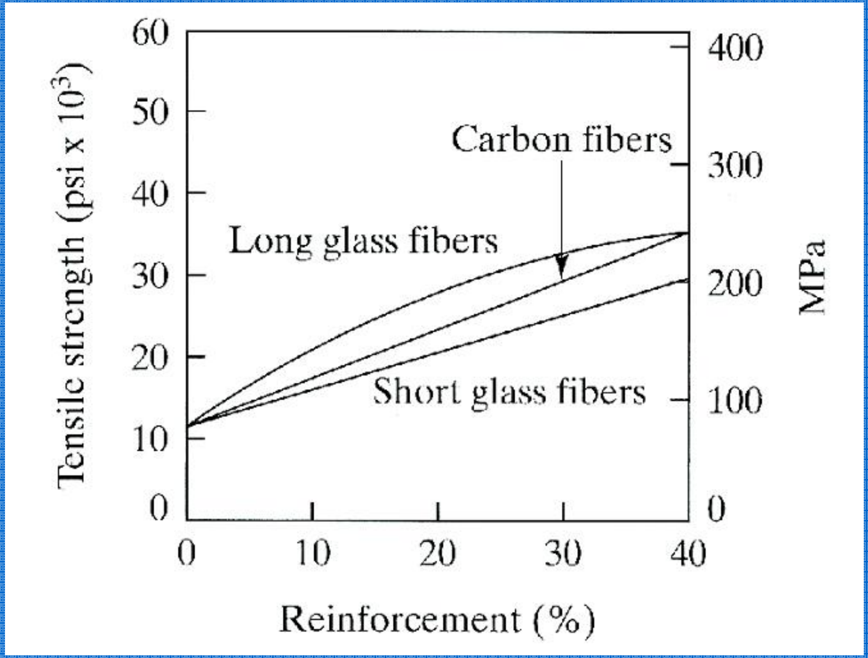
Graphite (99% carbon) or Carbon (80-95% carbon) – more expensive than glass fibers, but lower density and higher stiffness with high strength. The composite is called carbon-fiber reinforced plastic (CFRP).

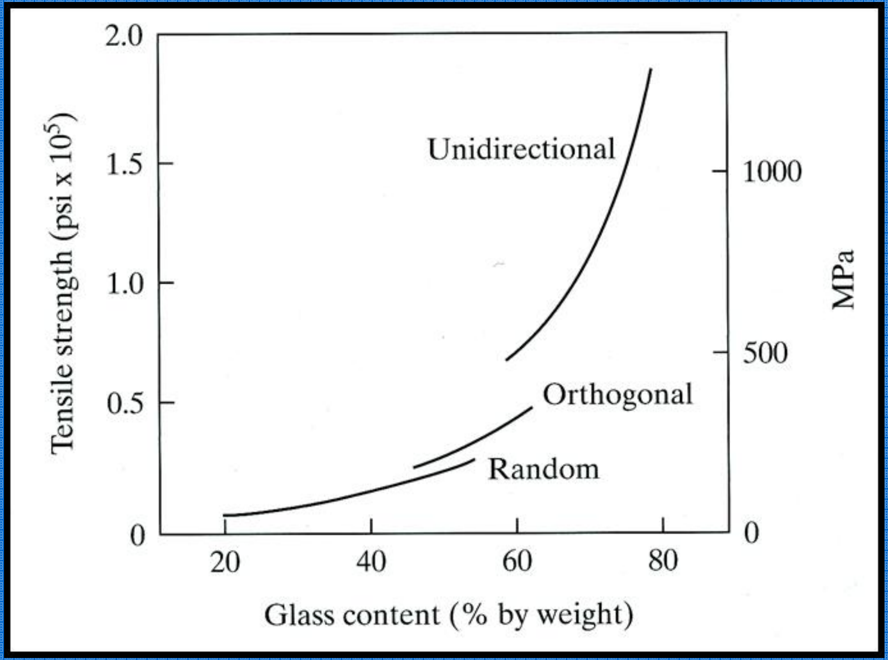
Boron – boron fibers consist of boron deposited on tungsten fibers, high strength and stiffness in tension and compression, resistance to high temperature, but they are heavy and expensive.

Aramids (Kevlar) – highest specific strength, toughest fiber, undergoes plastic deformation before fracture, but absorbs moisture, and is expensive.

Properties of Reinforced Plastics

The mechanical properties of reinforced plastics vary with the kind, shape, relative volume, and orientation of the reinforcing material, and the length of the fibers.





Effect of type, length, % volume, and orientation of fibers in a fiber reinforced plastic (nylon)

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(Under section 3 of UGC Act 1956)

Composites – Ceramic Matrix

Matrix materials are usually silicon carbide, silicon nitride and aluminum oxide, and mullite (compound of aluminum, silicon and oxygen). They retain their strength up to 3000 ^{o}F.

Fiber materials used commonly are carbon and aluminum oxide.

Applications are in jet and automobile engines, deep-see mining, cutting tools, dies and pressure vessels.

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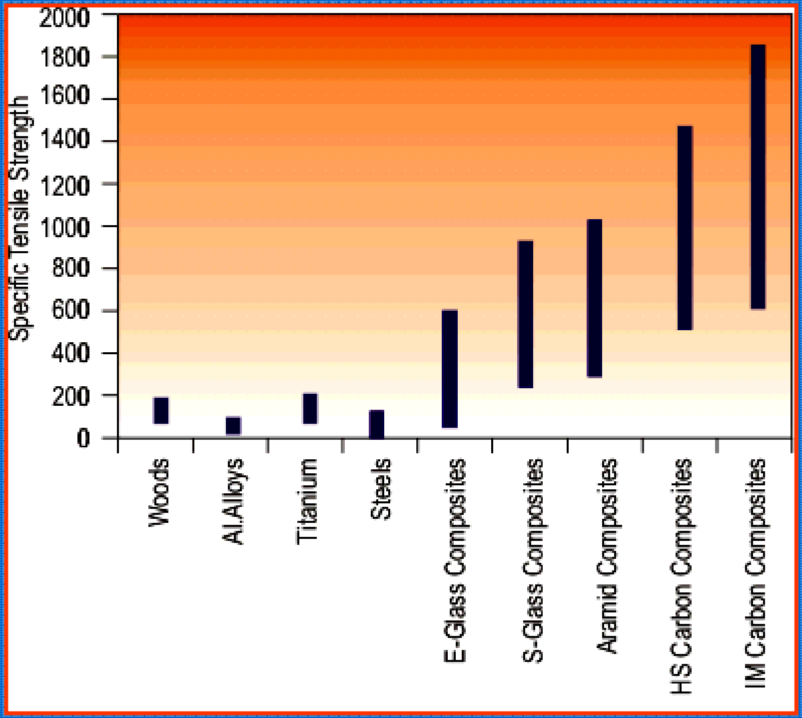
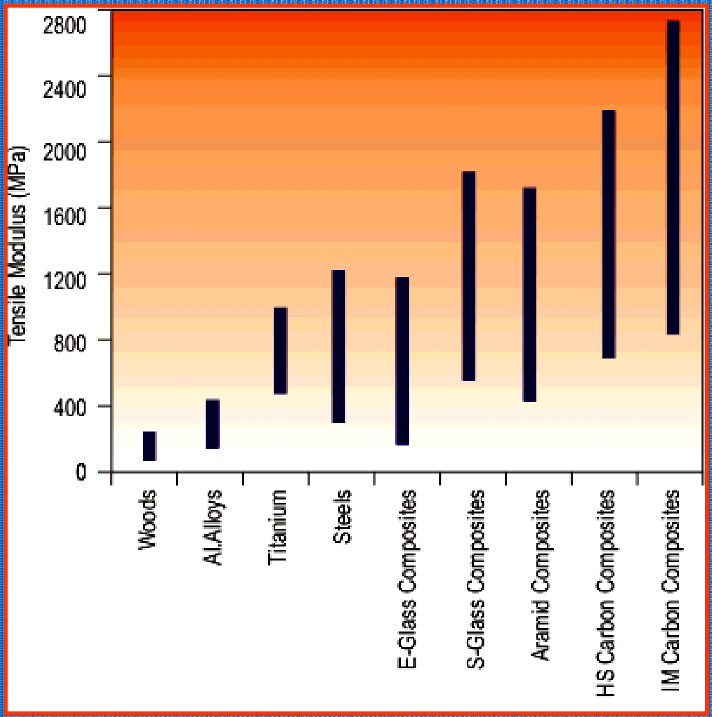
Advantages of Composites

Higher Specific Strength (strength-to-weight ratio)

Composites have a higher specific strength than many other materials. A distinct advantage of composites over other materials is the ability to use many combinations of resins and reinforcements, and therefore custom tailor the mechanical and physical properties of a structure.





The lowest properties for each material are associated with simple manufacturing processes and material forms (e.g. spray lay-up glass fibre), and the higher properties are associated with higher technology manufacture (e.g. autoclave moulding of unidirectional glass fibre), the aerospace industry.

Advantages of Composites

Design flexibility

Composites have an advantage over other materials because they can be molded into complex shapes at relatively low cost. This gives designers the freedom to create any shape or configuration. Boats are a good example of the success of composites.

Corrosion Resistance

Composites products provide long-term resistance to severe chemical and temperature environments. Composites are the material of choice for outdoor exposure, chemical handling applications, and severe environment service.