COMPOSITES

- Composite material- material system composed of two or more macro constituents that differ in shape & chemical composition, mutually insoluble.

- It contains two or more physically distinct and mechanically separable materials (metal, ceramic and polymer)

- It is made by dispersing one material in the other in a controlled way to achieve optimum properties

Many composite materials are composed of two phases

- matrix phase and dispersed phase.

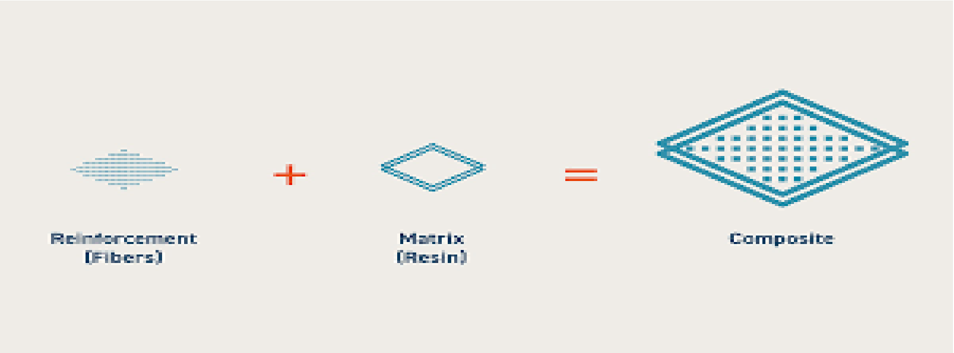
Matrix

It is a continuous phase in composite which completely surrounds the other phase (or dispersed phase)

Ex: metal (M Matrix Composites), polymer (PMC), ceramic (CMC)

Function of matrix phase:

- Binds dispersed phase
- Acts as medium to transport and distribute the load to dispersed phase
- Protect the dispersed phase from chemical action and keep in proper position and orientation along the direction of applied load



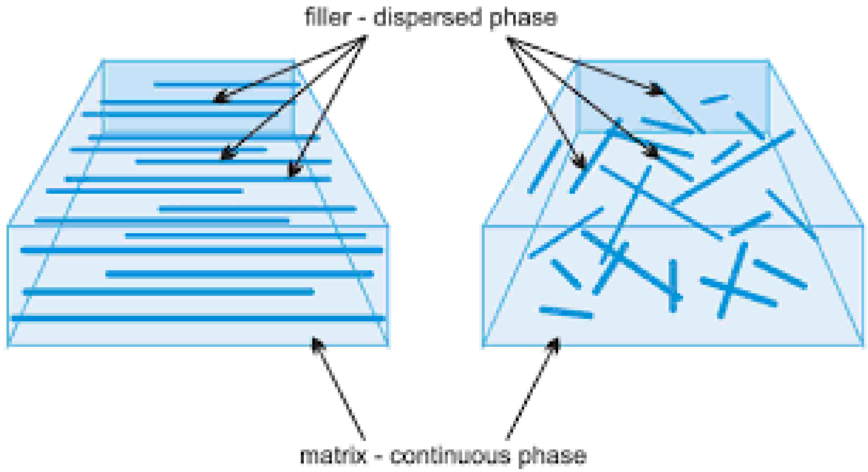
Dispersed phase or reinforcing phase

- It is a discontinuous phase that is surrounded by the matrix phase.
- It is the structural constituent which determines the internal structure of the composite

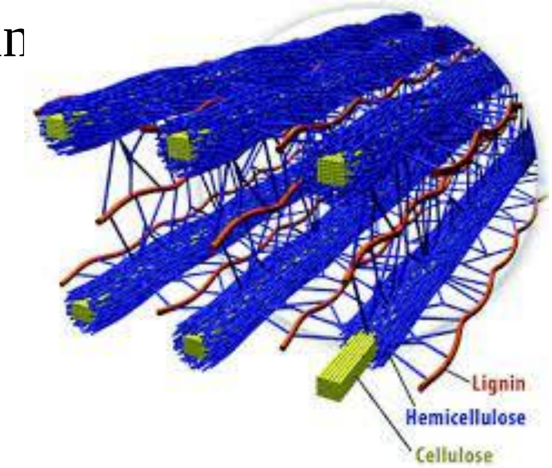
Ex: fibers (glass or carbon), particulates (small pieces of solid material)

Function of dispersed phase:

- To enhance matrix properties
- Increases the strength, used at elevated temperature



Ex: i) **Wood** consists of strong and flexible cellulose fibers surrounded and held together by a stiffer material called lignin



Synthetic composite: ii) fiberglass, in which small glass fibers are embedded within a polymeric material (epoxy or polyester).

Properties of composite materials are determined by three factors.

i) The materials used as component phases (property of two phases)
ii) Geometry of dispersed phase (particle size, distribution, orientation)
iii) The amount of phase and the way in which the phases interact with one another.

Classification of composites

i) **Particle reinforced:**

- Large particle
- Dispersion strengthened

ii) **Fiber reinforced:**

- Continuous (aligned)
- Discontinuous(short)-Aligned and Randomly oriented

iii) **Structural:** Based on build-up of sandwiches in layered form

- Laminates
- Sandwich panels

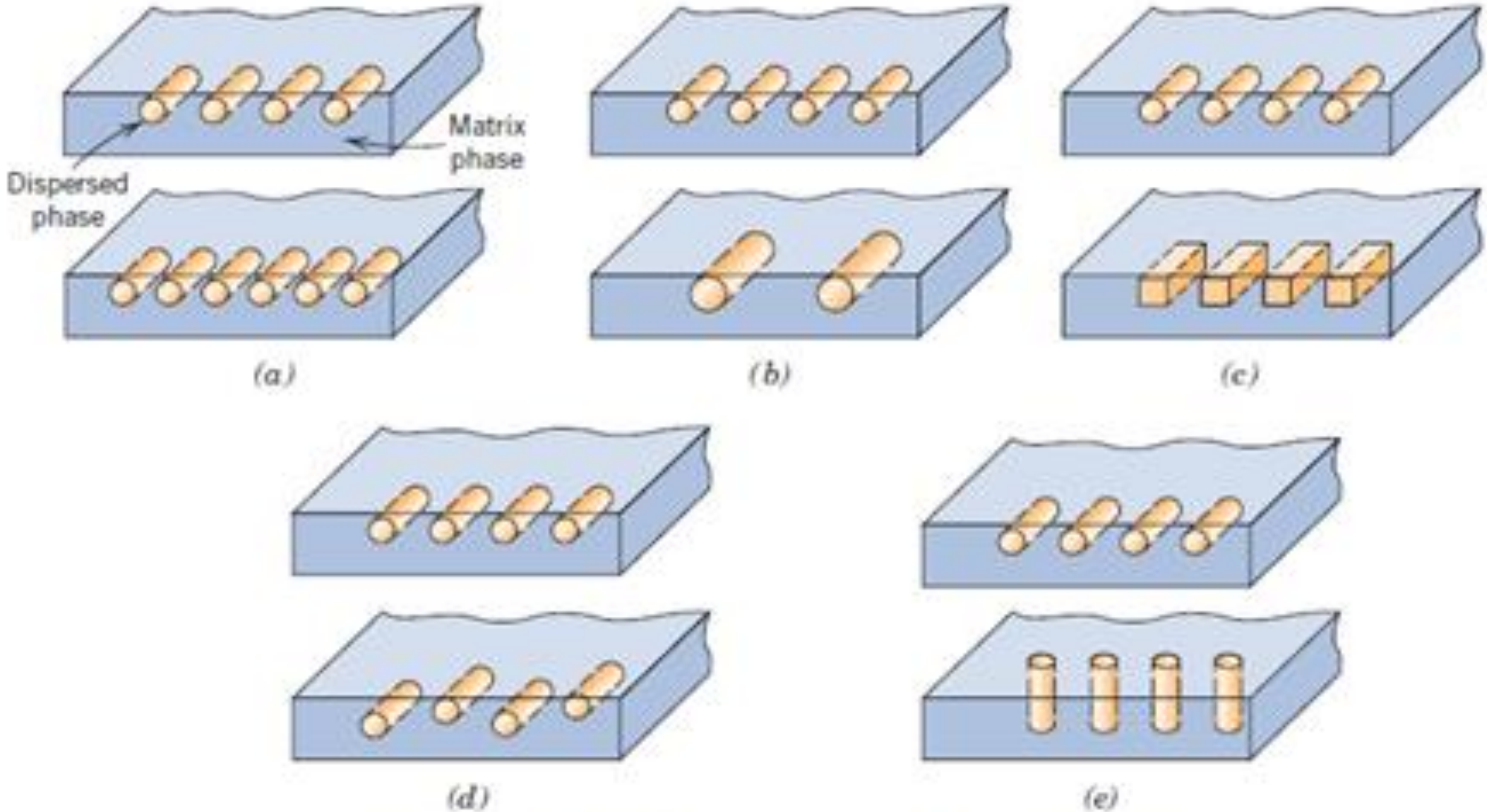
Particle reinforced

Based on reinforcement and strengthening Mechanism

i) Large particle:

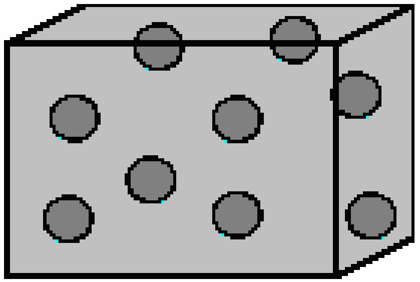
- The dispersion phase (particulate) should be harder and stiffer than matrix phase
- The matrix transfer some stress to the particulate, which bears the major portion of the applied load
- Particles can have quite a variety of geometries, but they should be of approximately the same dimension in all direction.
- Particle size is large and present in large concentration.

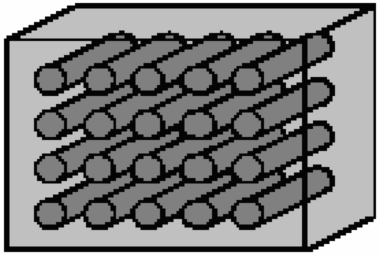
Ex: concrete where the aggregates (sand and gravel) are the particles and cement is the matrix.



Schematic representations of the various geometrical and spatial characteristics of particles of the dispersed phase that may influence the properties of composites: (*a*) concentration, (*b*) size, (*c*) shape, (*d*) distribution, and (*e*) orientation.

i) Dispersion strengthened





- Strengthening materials which are very small and hard (usually less than 0.1 μm) are uniformly dispersed within the matrix phase
- The matrix bears the major portion of an applied load and the small dispersed particles hinder the motion of dislocations.
- Thus material deformation is restricted and hardness and strength increases
- Particle size is small and present in small concentration.
- The dispersed phase may be metallic or nonmetallic materials

- **Example**: thoria (ThO_2) dispersed Ni-alloys.

ii) Fiber-reinforced composites

Dispersed phase : fiber (long length to diameter ratio)
Matrix phase: metal, polymer or ceramic

- The primary functions of the matrix are to Transfer stresses between the reinforcing fibers (hold fibers together)
- To protect the fibers from mechanical and/or environmental damages.

<u>Fibre phase:</u>

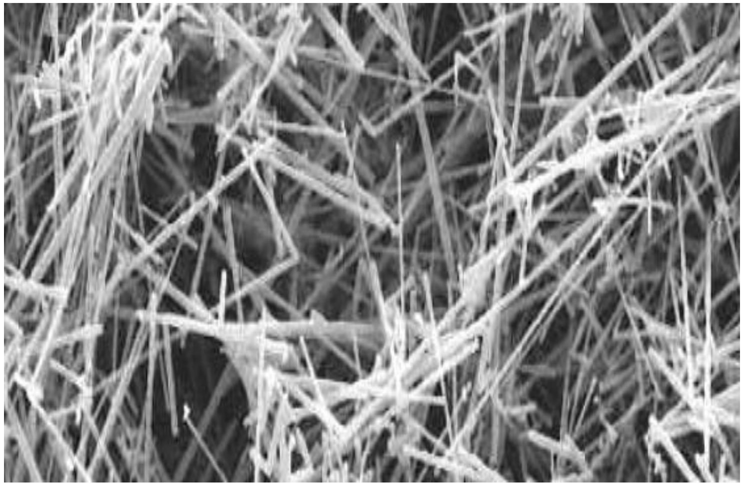
On the basis of diameter and character, fibres are grouped into three different classifications as

- Whiskers
- Fibres
- Wires.

Whiskers

- Thin single crystals that have large length to diameter ratios (lower than fiber)
- Posses high strength due to its small size that have extremely high degree of Crystallinity
- they are very expensive and difficult to incorporate into matrix.

Ex: graphite, silicon carbide, silicon nitride.



Silicon carbide whiskers

Fibres : They are either polycrystalline or amorphous and have small diameters (ex: like glass, ceramic)

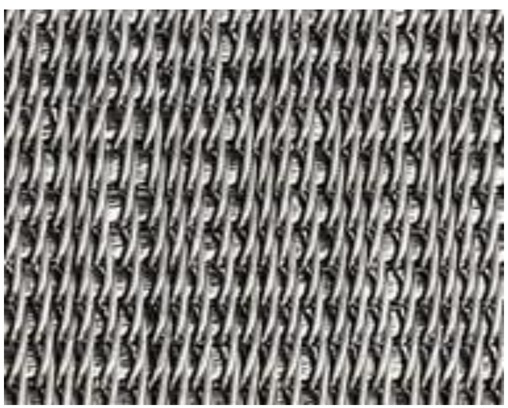
High length to diameter ratio

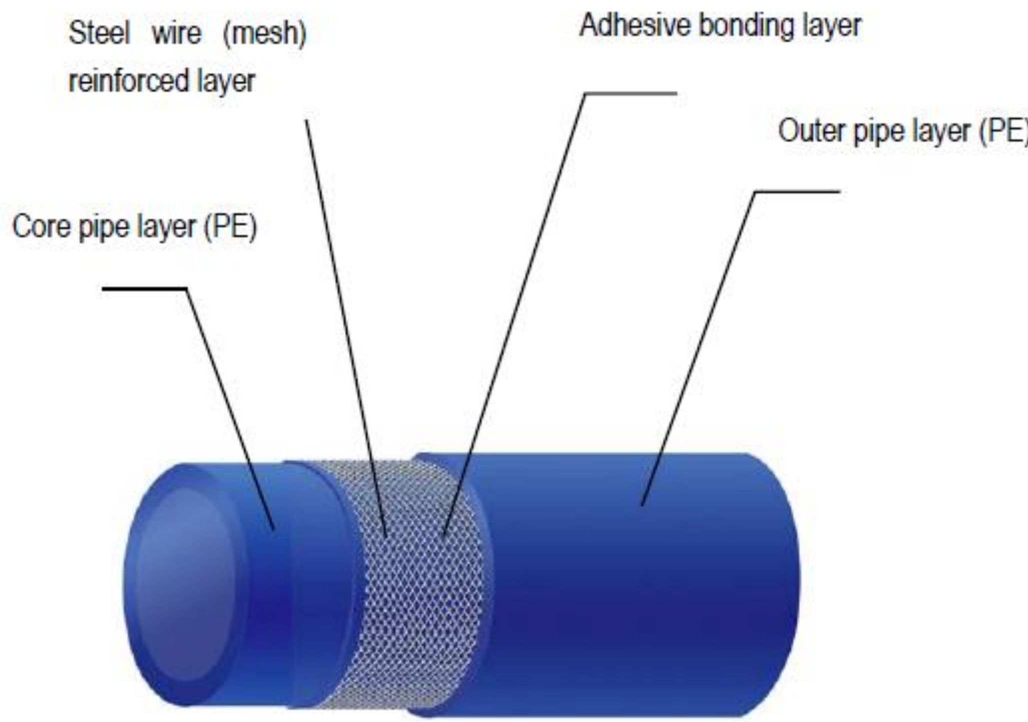
The stiff reinforcing fibres are responsible for carrying load and ductility, toughened

Glass fiber and glass fiber mat carbon fiber mat

Wires: Fine wires have relatively large diameters. Typical material include steel, molybdenum, tungsten.

Ex: wire mesh

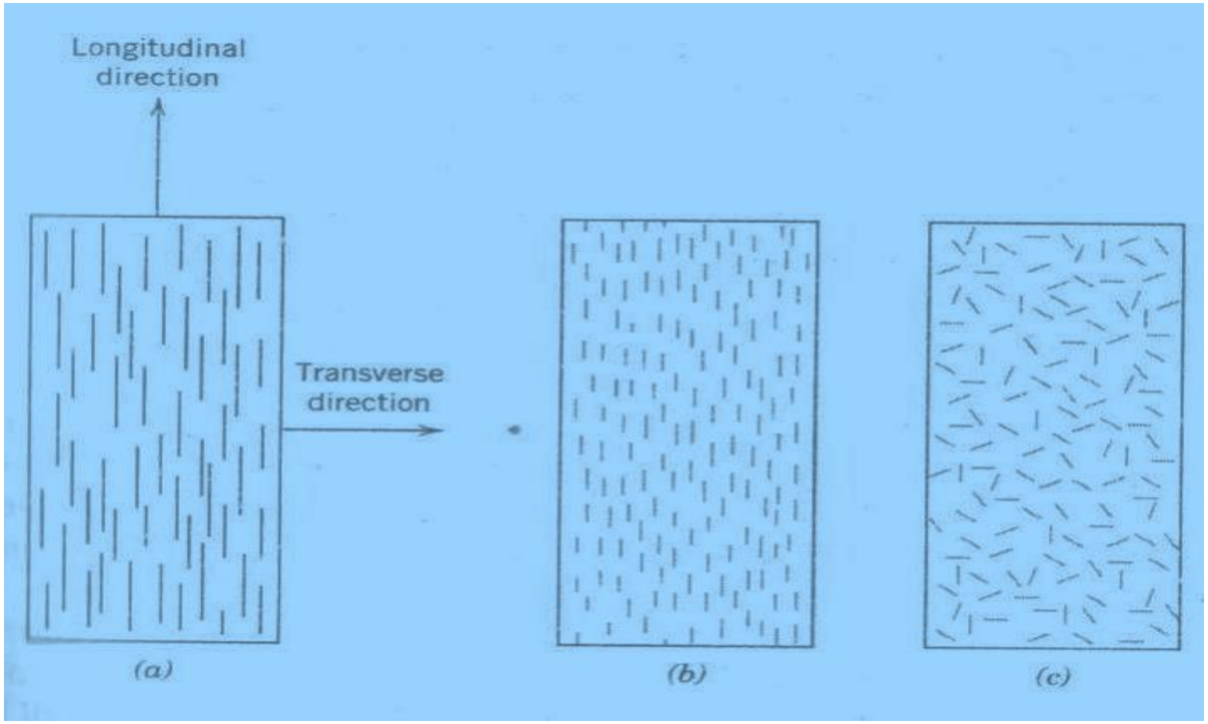


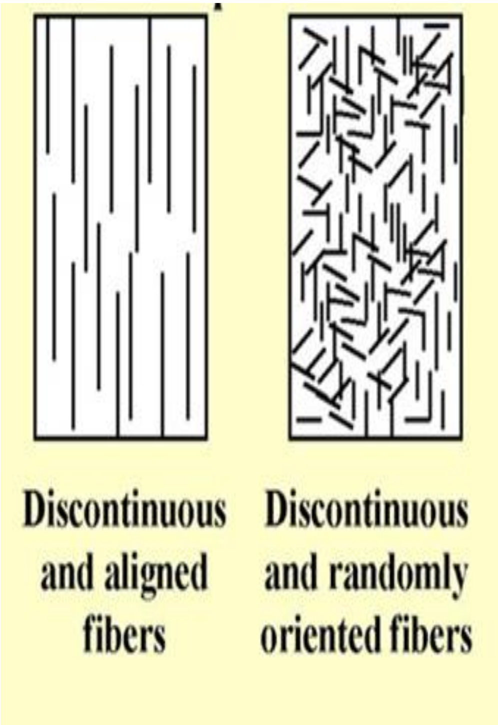


The strength of fiber-reinforced composite depends on fiber orientation and its concentration

a) Parallel alignment of the longitudinal axis of the fibers in a single direction

c)Totally random alignment





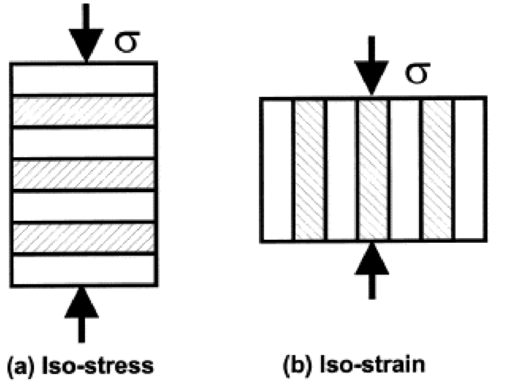
Elastic Behavior—Longitudinal Loading

When the load is applied on the composite in the direction of the orientation of continuous fiber, then its modulus of elasticity is equal to the summation of the products of the modulus of elasticity (E) and volume fraction (V) of the respective phases.

i.e., Modulus of elasticity of composite, $E = (EV)_{matrix} + (EV)_{fiber}$

When the load is applied on the composite perpendicular to the orientation of continuous fiber, the inverse of the modulus of elasticity is equal to the summation of the ratio of volume fraction (V) and modulus of elasticity (E) of the respective phases.

i.e., $\frac{1}{E} = \left(\frac{V}{E}\right)_{matrix} + \left(\frac{V}{E}\right)_{fiber}$

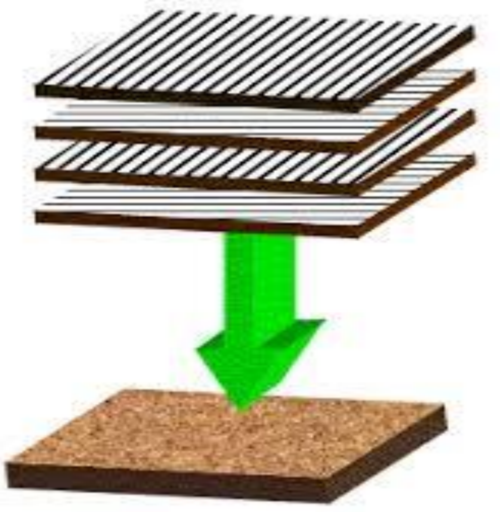


Structural composites

- It is composed of composite and homogenous materials.
- The properties depend on properties of constituent materials and on the geometrical design of various structural elements.

Laminar composites:

- It is made of two dimensional sheets or panels that have a preferred high strength direction
- Layers are stacked and subsequently cemented together such that the orientation of high strength direction varies with each successive layer. Ex: Ply wood



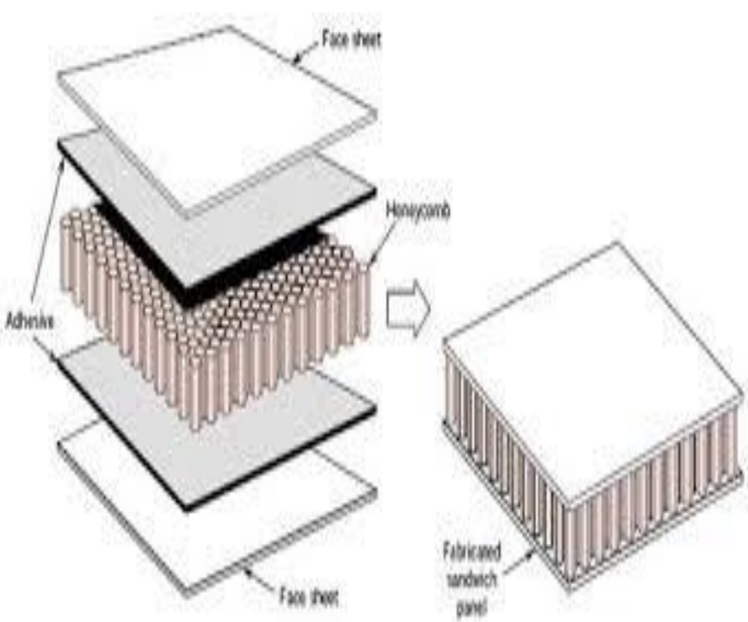
Sandwich panels

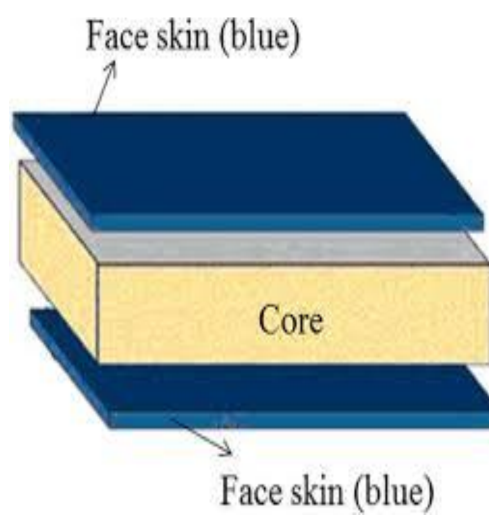
Consists of two strong outer sheets, or faces separated by a layer of less dense material or core which has lower stiffness and lower strength

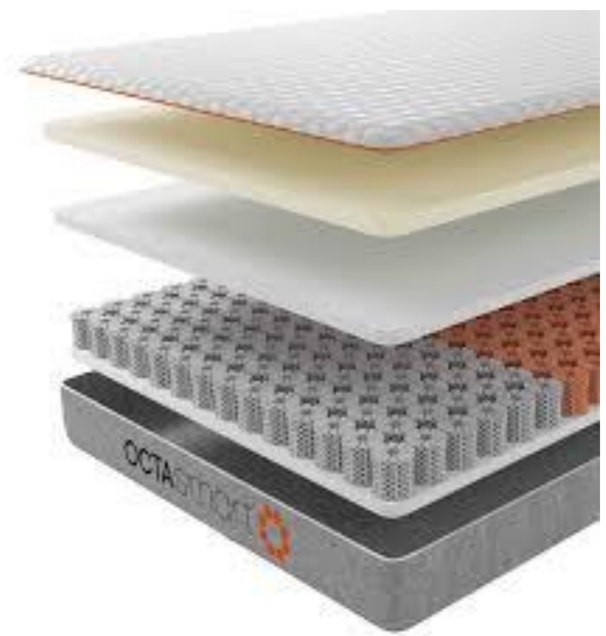
Faces or skin: Laminates of glass or carbon fiber-reinforced thermoplastics or mainly thermoset polymers

Core:

Polymeric foams like PVC, Polyurethane, PE, PS and synthetic rubber

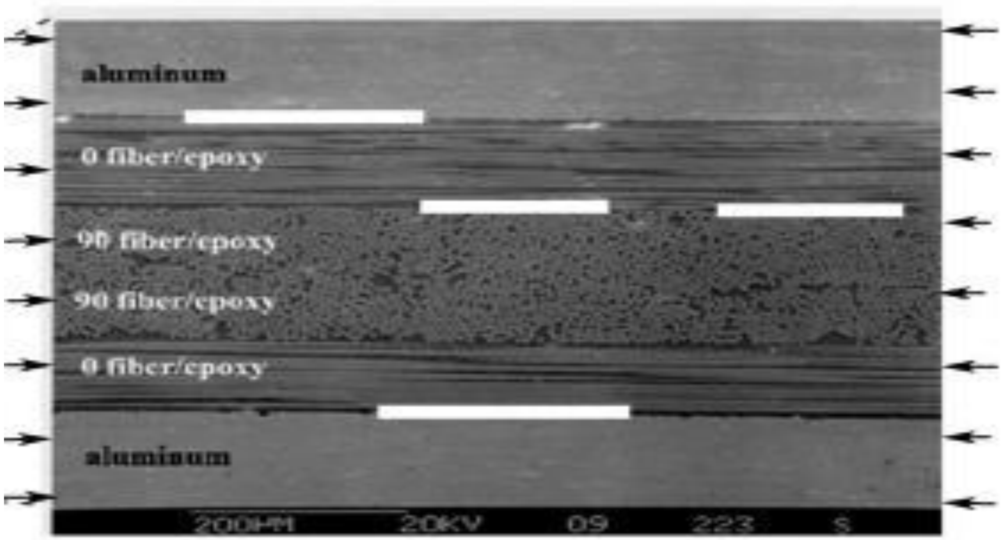


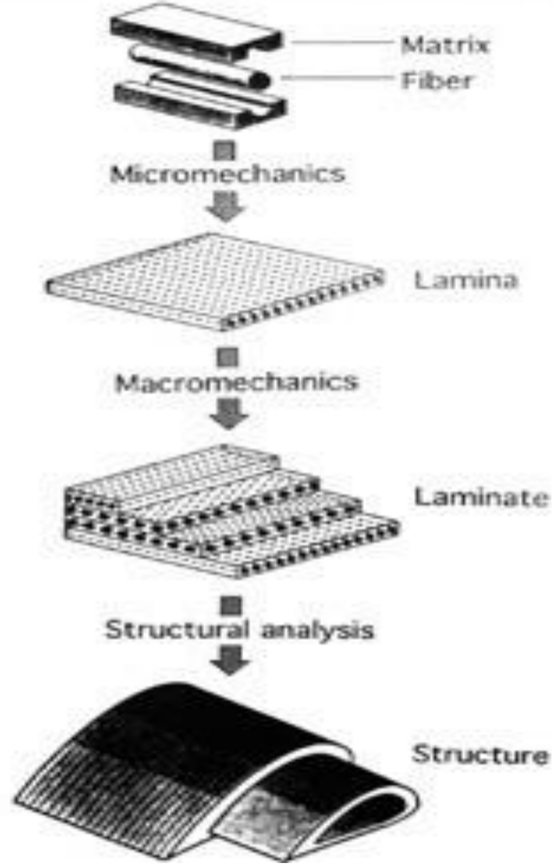




Foam

Fig. 2. Configuration of continuous fiber/metal/epoxy hybrid composite (3/2 lay-up).





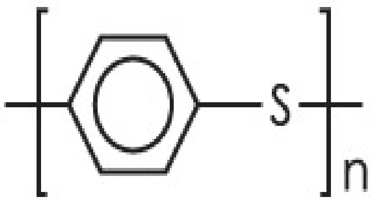
POLYMER COMPOSITES

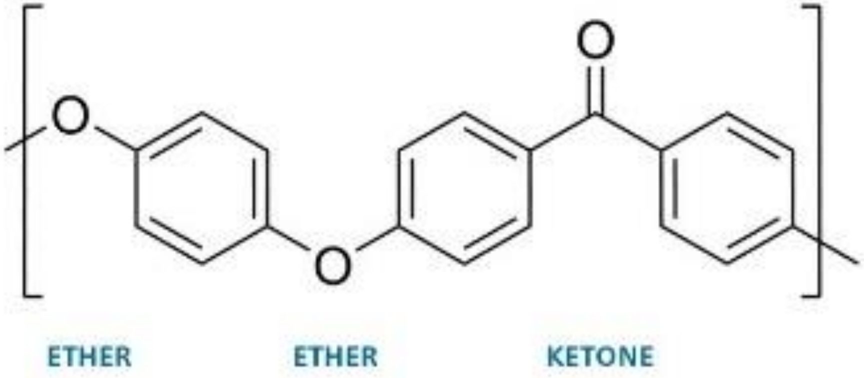
- Combination of two material- reinforcing material usually in the form of fiber, sheet or particles,
- Matrix is made of polymeric material

- Materials used :Fiber- glass, carbon
- Matrix: thermoplastic(polyolefines, vinylic polymers) and thermosetting resines (polyester and epoxides)

Polymer matrix materials:

- The matrix materials used in composites are polyesters, vinyl esters, epoxies, polyetheretherketone (PEEK), polyphenylene sulfide (PPS), and polyetherimide (PEI).
- PEEK, PPS and PEI are the polymeric resins with potential aerospace applications.





i) Glass Fiber-Reinforced Polymer (GFRP) Composites,
ii) Carbon Fiber-Reinforced Polymer (CFRP) Composites, and
iii) Aramid Fiber-Reinforced Polymer Composites.

Advantages of polymer composites:

- Light weight.
- High strength to weight ratio.
- More durable than conventional materials like steel and aluminium.
- Good corrosion resistance.
- High fatigue strength.
- High temperature resistance.

Applications:

-Composites of phenolic resins and nylon are used in heat shields for space crafts.

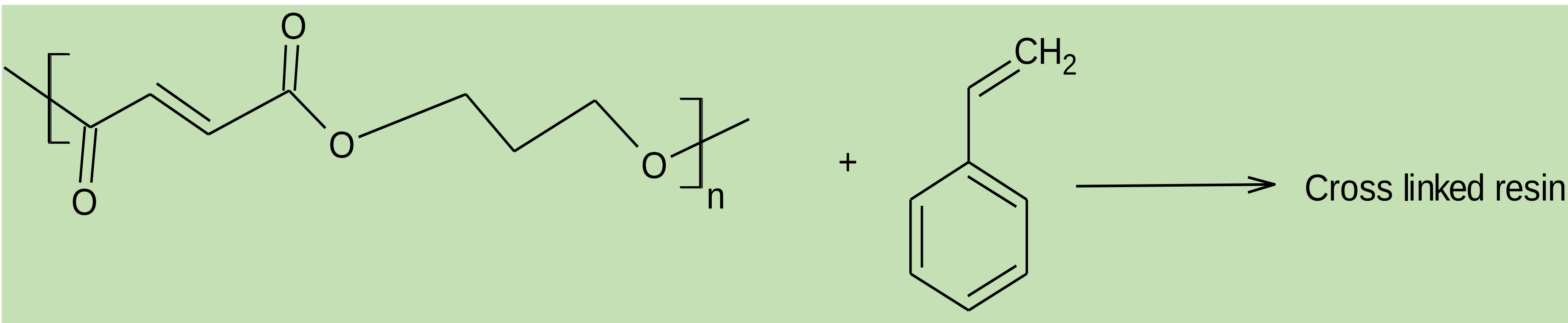
-Which are used in automotive and railway applications.

-As structural material in construction industries.

Fibre glass or glass-reinforced plastic (GRP)

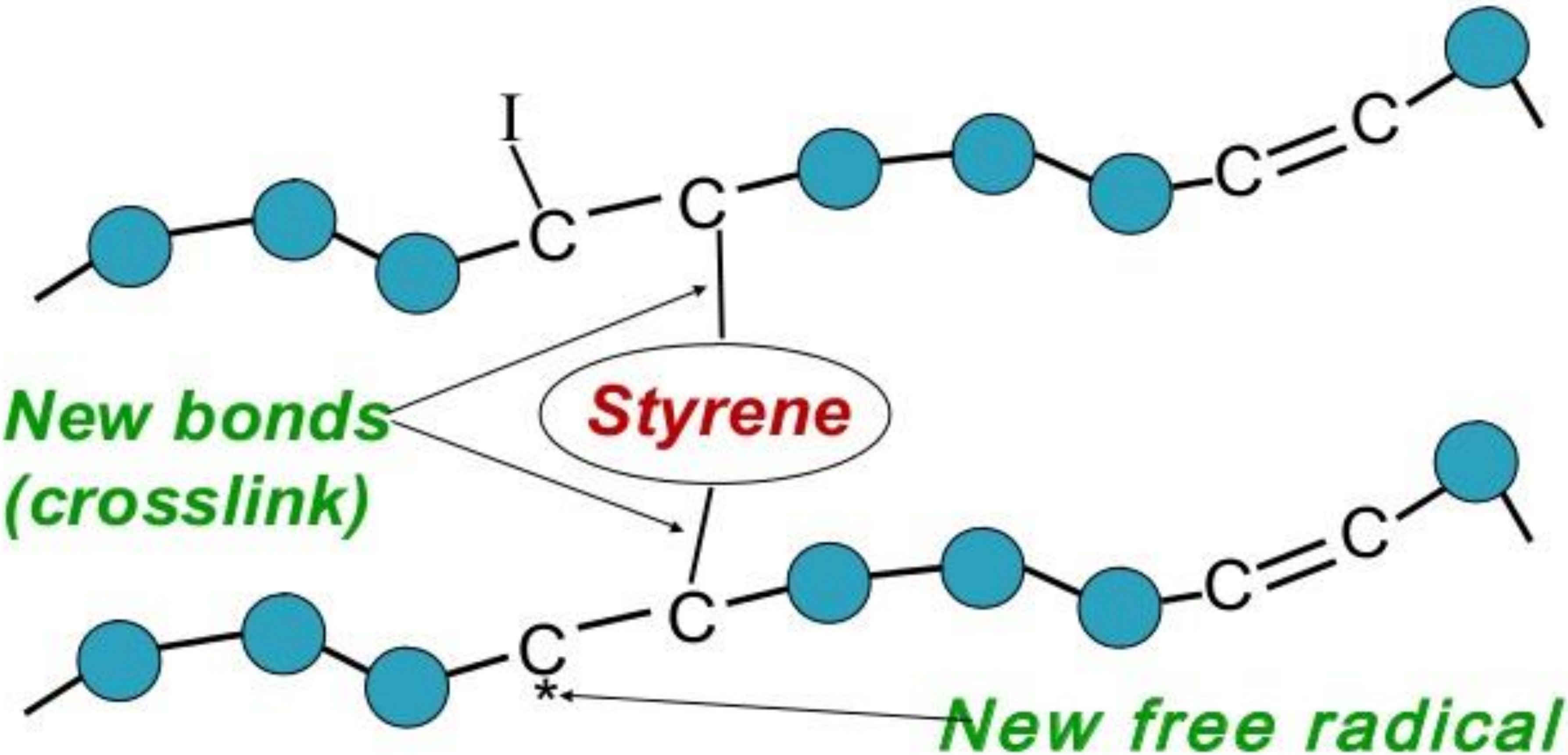
Matrix: Made by reacting a polyester with carbon-carbon double bonds in its backbone and styrene- a mix of the styrene and polyester

Fibre: glass fibre



Ex: Used car engines components aeroplane parts and boat hulls

Polyester – forming the crosslink

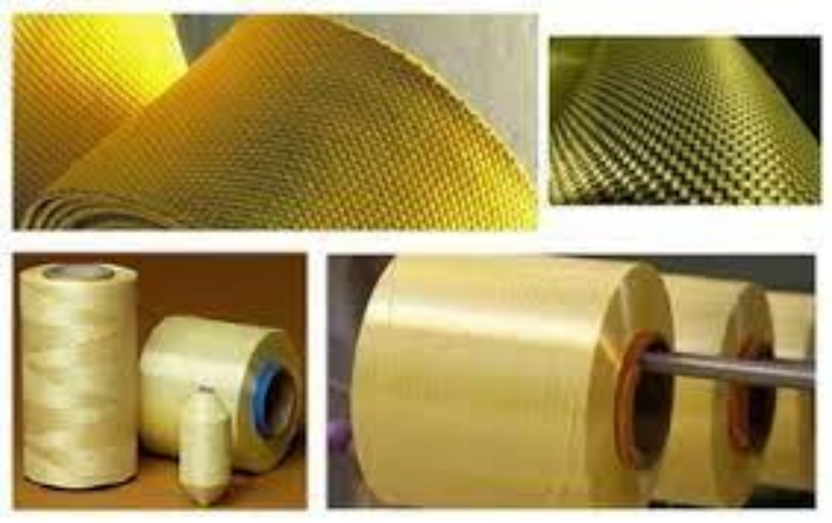


The styrene is a bridge molecule between the polyester polymers

The new free radical is available to react with another styrene

Aramid Fiber-Reinforced Polymer Composite:

- Aramid fibers - high-strength, high-modulus materials
- desirable for their outstanding strength-to-weight ratios, which are superior to metals.
- Materials is known as poly(paraphenylene terephthalamide).
- Most common are Kevlar™ and Nomex™.

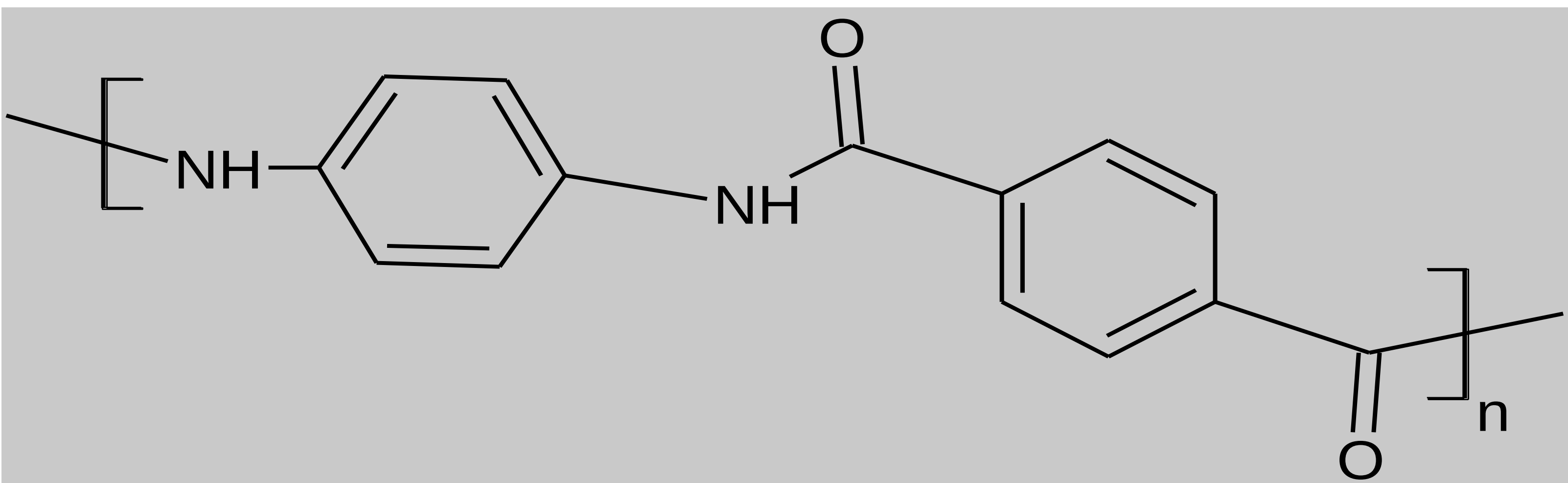


Kevlar composites

Kevlar is an aromatic polyimide. Chemically it is poly(para phenyleneterephthalamide).

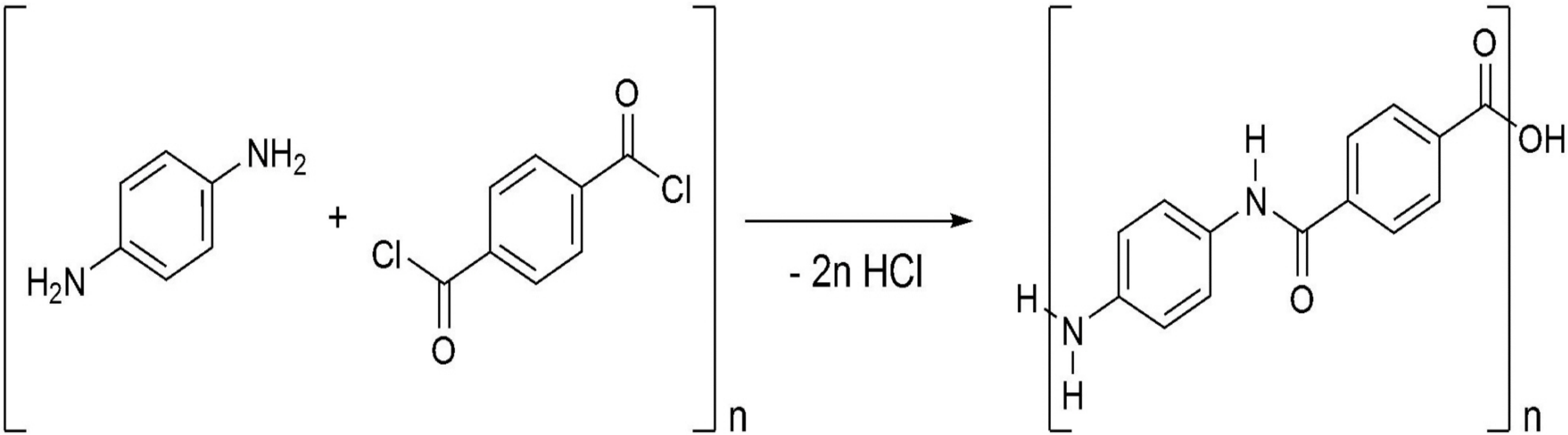
Matrix: Kevlar

Fibres: carbon fibre or glass fibre as reinforcing agent.

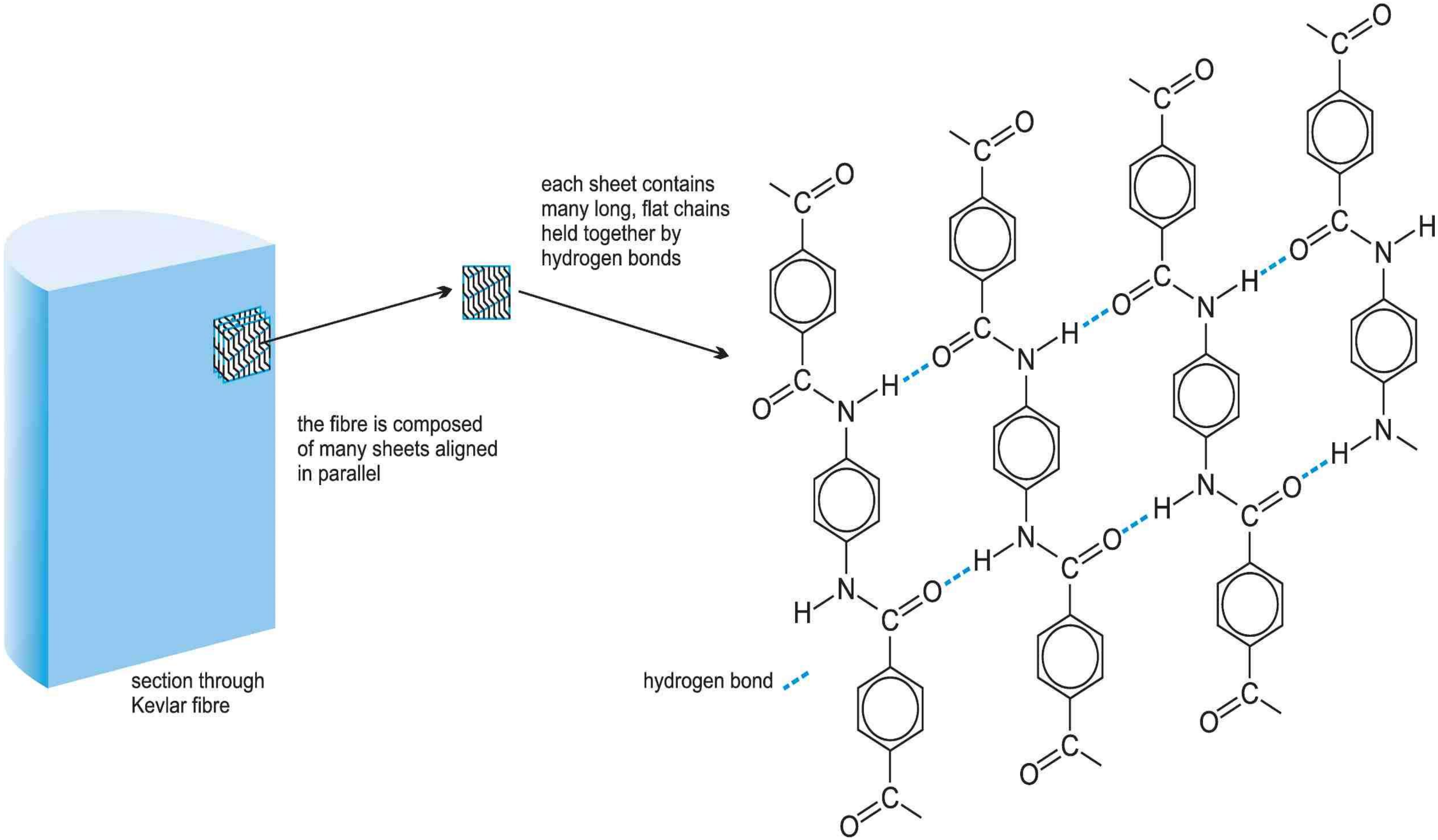


In Kevlar aramid ring provides thermal stability and para-structure provides high strength and modulus

para-phenylenediamine and terephthaloyl chloride



Kevlar® 29 is used in the manufacture of body armour (panels) for lightweight military vehicles. A good example is the US Army's 'Bradley Fighting Vehicle'. This has been used extensively in Iraq and Afghanistan.



each sheet contains many long, flat chains held together by hydrogen bonds
the fibre is composed of many sheets aligned in parallel
section through Kevlar fibre
hydrogen bond

Advantages:
-Light weight, high strength, thermally stable
-Resistant to impact and abrasion damage. It can be used as protective layer on graphite laminates.
-Can be mixed with graphite to provide damage resistance and to prevent failure.

Disadvantages:

-Fibres themselves absorb moisture, so Kevlar composites are more sensitive to the environment than glass or graphite composites.
-Poor compression resistance.

ii) Carbon Fiber Reinforced Polymer (CFRP) Composite:

Carbon is a high-performance fiber material that is most commonly used reinforcement in advanced polymer matrix composites. The reasons for this are as follows:

1. Carbon fibers have the highest specific modulus and specific strength of all reinforcing fiber materials.
2. They retain their high tensile modulus and high strength at elevated temperatures; high-temperature oxidation, however, may be a problem.
3. At room temperature, carbon fibers are not affected by moisture or a wide variety of solvents, acids, and bases.
4. These fibers exhibit a diversity of physical and mechanical characteristics, allowing composites incorporating these fibers to have specific engineered properties.
5. Fiber and composite manufacturing processes have been developed that are relatively inexpensive and cost-effective.

- Carbon-reinforced polymer composites are currently being utilized extensively in sports and recreational equipment (fishing rods, golf clubs), filament-wound rocket motor cases, pressure vessels, and aircraft structural components—both military and commercial, fixed wing and helicopters (e.g., as a wing, body, stabilizer, and rudder components).