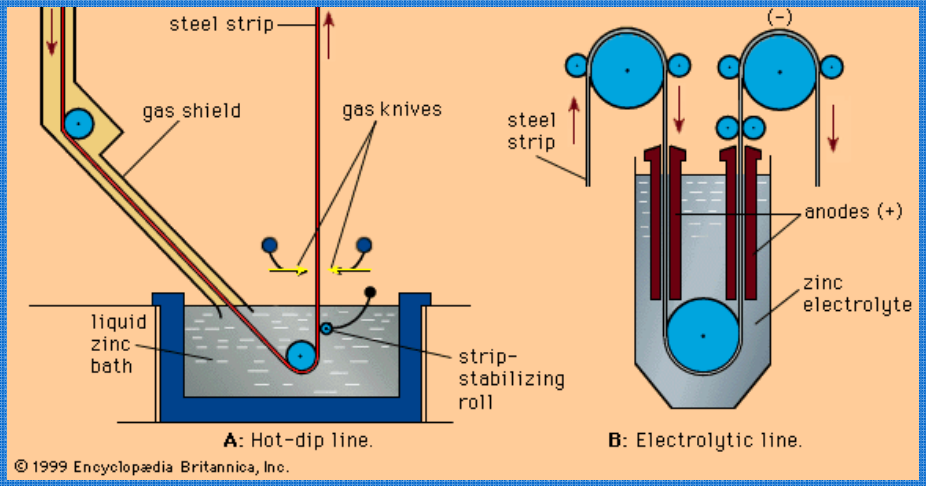
CHAPTER 5 : METALLIC MATERIALS

Forming techniques of fibers

- The process by which fibers are formed from bulk polymer material is called as **spinning**.
- Most often the fibers are spun from the molten state in a process called melt spinning.
- The material to be spun is initially heated until it forms a relatively viscous liquid.
- Next it is pumped through a plate called as the **spinneret** , which contains many small and round holes.
- As the molten liquid passes through each hole the fiber is formed which solidifies immediately upon passing into the air.
  The strength of the fiber is usually increased by a post forming process called as drawing.
- Drawing is simply the mechanical elongation of the fiber in the direction of its axis.
- During this process the molecular chains become oriented in the direction of drawing such that the tensile strength, modulus of elasticity, and toughness are improved.

- **Coatings :** It is a layer of an inert substance relatively, on the surface of the component , and it usually minimizes the chemical or electrochemical attack (on the component material) by the service environment.
- Some of the functions of Coatings are listed down as follows :
- To protect the item from the environment that may produce corrosive or deteriorative reactions.
- To improve the item's appearance
- To provide electrical Insulation
- Coatings can be applied on the component depending on its type :
- **A)Metallic coatings** :
- **Hot dipping** : Involves immersing the product in the molten bath of the coating metal

Hot dipping



Spray coating

- **Metal Spraying** :The surface to be coated is exposed to a fine spray of coating metal from a filler wire (or powder) volatized in a high temperature flame or ar with the help of a spray gun.
- **Electroplating** : It means electrodepositing the protective metal on the surface to be protected.
- **Inorganic Coatings** :
- **Chemical or electrochemical conversion coating**
- They are inorganic barriers produced by chemical or electrochemical reactions with the surface of the metal to be protected.
- Other types of coatings that are applied are vitreous coating, organic coatings, etc.

- **Adhesives:** An adhesive could be defined as any substance capable of holding materials together by surface attachment.
- They are basically used to join two solid materials , as a thin uniform layer.
- They have the advantage over the other joining methods in that they can be applied for any surface of material.
- Some of the various types of adhesives are as follows :
- **Contact adhesives:** Contact adhesives are used in strong bonds with high shear-resistance like laminates, such as bonding Formica to a wooden counter, and in footwear, as in attaching outsoles to uppers.
- Contact adhesives must be applied to both surfaces and allowed some time to dry before the two surfaces are pushed together. Some contact adhesives require as long as 24 hours to dry before the surfaces are to be held together.
- **Hot adhesives:** Hot adhesives, also known as hot melt adhesives, are thermoplastics applied in molten form (in the 65-180 °C range) which solidify on cooling to form strong bonds between a wide range of materials.

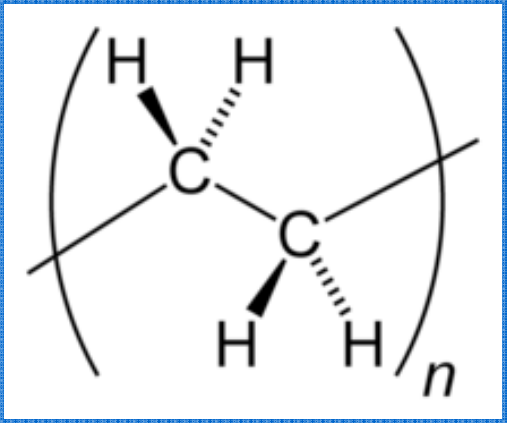
- **Multi-part adhesives:** Multi-component adhesives harden by mixing two or more components which chemically react. This reaction causes polymers to cross-link into acrylics, urethanes, and epoxies.
- There are several commercial combinations of multi-component adhesives in use in industry. Some of these combinations are:
- Polyester resin – polyurethane resin
- Polyols – polyurethane resin
- Acrylic polymers – polyurethane resins

- **Foams:**
- Very porous materials are produced in a process called foaming.
- Both thermoplastic and thermosetting materials may be foamed by including in the batch a lowing agent that upon heating, decomposes with the liberation of a gas.
- Gas bubbles are generated throughout the non-fluid mass, which remain as pores upon cooling and give rise to a sponge-like structure.
- The same effect is produced by bubbling an inert gas through a material while it is in a molten state.
- Some of the commonly foamed polymers are polyurethane, rubber, polystyrene, and PVC (Poly-vinyl Chloride)
- Foams are used as cushions in automobiles and furniture as well as in packaging and thermal insulation .

Wood being foamed

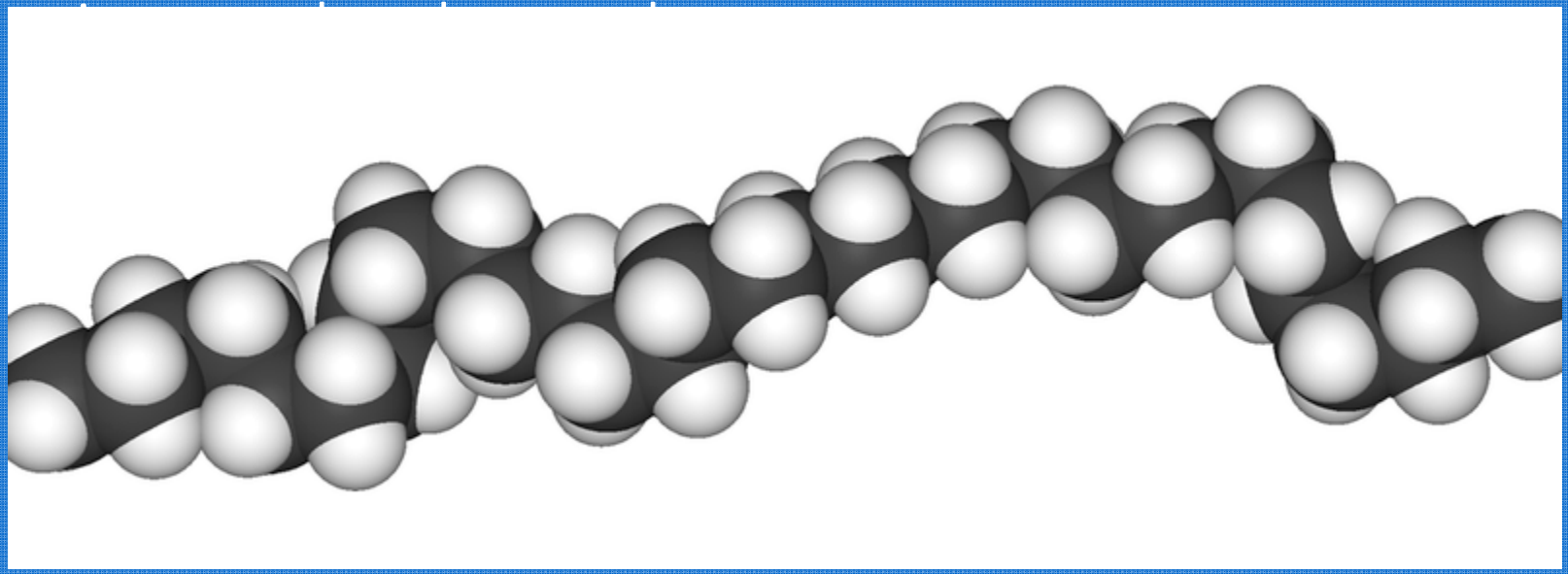
Various Polymers

- **Polythene** :
- Polyethylene (abbreviated PE) or polythene (IUPAC name polyethene or poly(methylene)) is the most common plastic. Many kinds of polyethylene are known, but they almost always have the chemical formula $(C_2H_4)nH_2$.
- **Properties** :
- Polyethylene is a thermoplastic polymer consisting of long hydrocarbon chains.
- Have excellent chemical resistance.
- It is also resistant to gentle oxidants and reducing agents.
- The melting point for average, commercial, low-density polyethylene is typically 105 to 115 °C (221 to 239 °F).



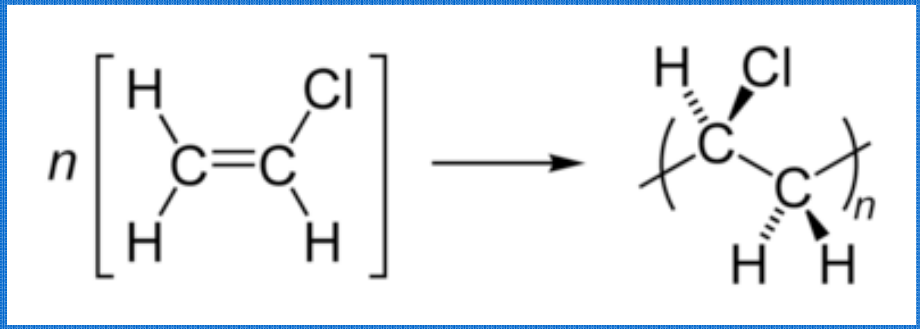
Repeating unit in PE

- Applications :
- In its foam form, polyethylene is used in packaging, vibration damping and insulation, as a barrier or buoyancy component, or as material for cushioning.
- Many types of polyethylene foam are approved for use in the food industry. Found in all types of packaging, polyethylene foam is used to wrap furniture, computer components, electronics, sporting goods, plants, frozen foods, clothing, bowling balls,



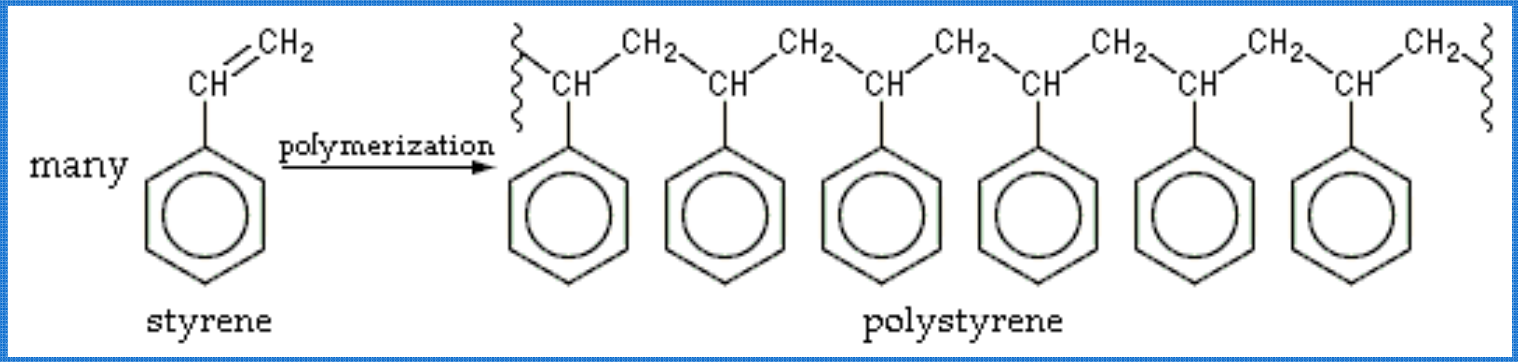
Space filled model of PE

- **Poly vinyl Chloride (PVC) :**Polyvinyl chloride, commonly abbreviated PVC, is the third-most widely produced plastic, after polyethylene and polypropylene.
- **Properties :**
- PVC is a thermoplastic polymer.
- PVC is a useful material because of its inertness and this inertness is the basis of its low toxicity
- PVC is a material resistant to ignition due to its chlorine content.
- PVC products can last up to 100 years and even more.
- **Applications :**
- It is used for sewerage pipes
- PVC is commonly used as the insulation on electrical cables
- PVC has become widely used in clothing, to either create a leather-like material or at times simply for the effect of PVC.

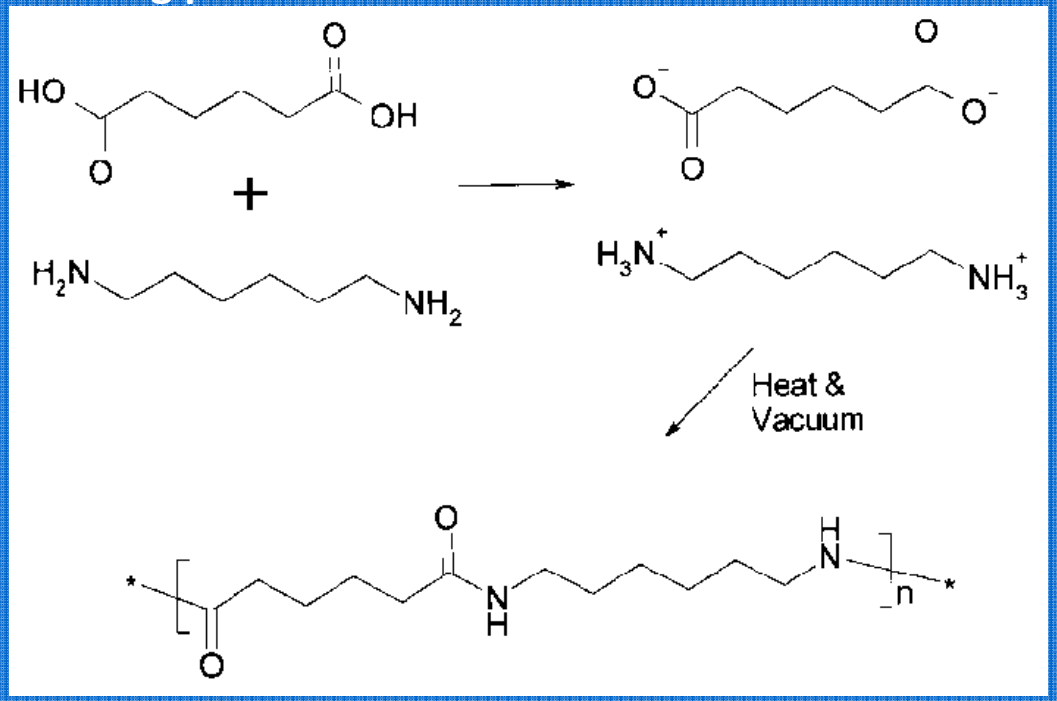


Polymerization reaction for PVC from vinyl chloride

- **Polystyrene :**
- Polystyrene (PS) also known as Thermocole, abbreviated following ISO Standard PS, is an aromatic polymer made from the monomer styrene.
- **Properties :**
- Polystyrene is hard and brittle
- Polystyrene is chemically nonreactive
- Polystyrene is flexible and can be made into moldable solid or thick viscous solids
- It is highly flammable and burns with an orange yellow flame, giving off soot
- **Applications :**
- Used to make containers for other chemicals, solvents and even food items
- Is used in casting and moulding

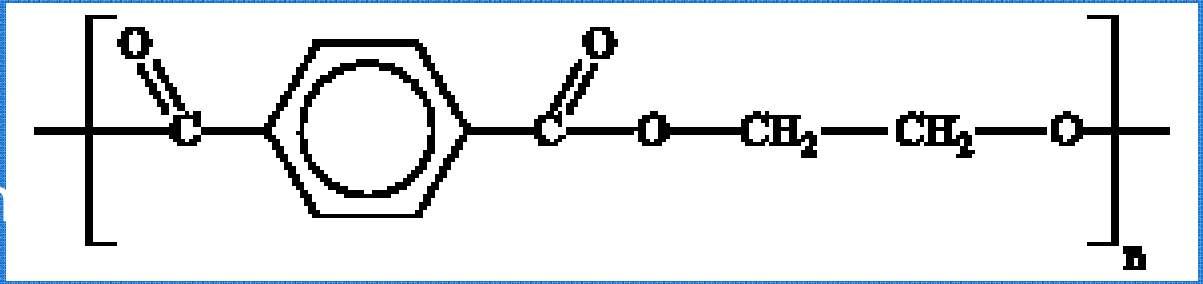


- **Nylon 6,6** :
- Nylon 6,6 is made of hexamethylenediamine and adipic acid, which give nylon 6,6 a total of 12 carbon atoms in each repeating unit, and its name.
- **Properties :**
- Nylon 6,6 has a melting point of 265°C, high for a synthetic fiber, though not a match for polyesters or aramids such as Kevlar. This fact makes it resistant to heat and friction.
- Its long molecular chain results in more sites for hydrogen bonds, creating chemical "springs", making it very resilient.
- **Applications :**
- **It is used for manufacturing the following products :**
- Carpet fiber
- Airbags
- Tires
- Ropes



- **Teflon :**
- Polytetrafluoroethylene (PTFE) is a synthetic fluoropolymer of tetrafluoroethylene that finds numerous applications.
- **Properties :**
- PTFE is a thermoplastic polymer
- It has a low coefficient of friction
- PTFE has excellent dielectric properties
- It has a high melting point .
- **Applications :**
- Used in those components where sliding or action occurs such as plain bearings, gears, slide plates
- They are used in solid rocket fuel propellants
- PTFE membrane filters are among the most efficient used in industrial air filtration applications

- **Dacron / Terylene** :
- Polyethylene terephthalate commonly abbreviated PET, PETE, or the obsolete PETP or PET-P, is a thermoplastic polymer resin of the polyester family.
- **Properties :**
- It is strong and im
resistant.
- It is light weight .
- **Applications :**
- It is used as a fiber.
- It can be used in bottle making



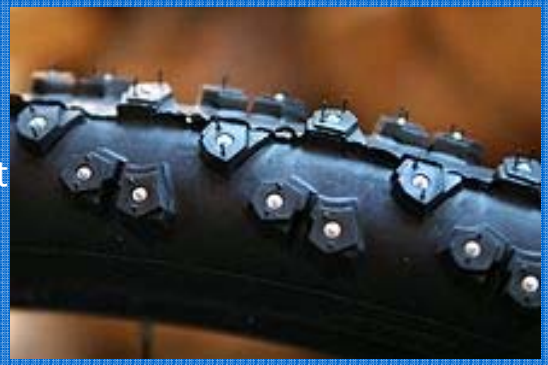
Structure of Dacron/PET

Advanced structure ceramics

- Ceramics comes from the Greek word Keramos which refers to burnt stuff.
- Ceramics are basically defined as inorganic, non-metallic materials that are processed and/or at high temperatures.
- They have been subject to a heat treatment.
- They are generally brittle materials that withstand compression very well but do not hold well under tension when compared to metals.
- The nature of the chemical bonds in ceramics are ionic in character , and the anions help in determining the properties of the ceramic material .
- Ceramics are broadly classified as follows :
  - White ware , which includes china and porcelain
  - Structural clay products
  - Glass
  - Refractory Materials which are capable of withstanding very high temperatures.

Tungsten carbide

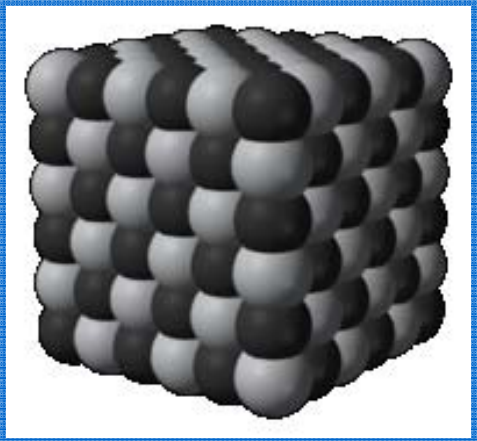
- Tungsten carbide (WC) is an inorganic chemical compound (specifically, a carbide) containing equal parts of tungsten and carbon atoms
- In its most basic form, tungsten carbide is a fine gray powder, but it can be pressed and formed into shapes for use in industrial machinery, cutting tools, abrasives, other tools and instruments, and jewelry.
- **Properties:**
- Tungsten carbide is high melting
- It is extremely hard
- It has two structures, the alpha and the beta structures.
- **Applications :**
- Hard carbides, especially tungsten carbide, are used by athletes, generally on poles which strike hard surfaces.
- It is also used for making surgical instruments meant for open surgery
- Tungsten carbide, also called cemented carbide, has become a popular material in the bridal jewelry
- Tungsten carbide is sometimes used to make the rotating ball in the tips of ballpoint pens



A tire with tungsten carbide spikes

Titanium Carbide

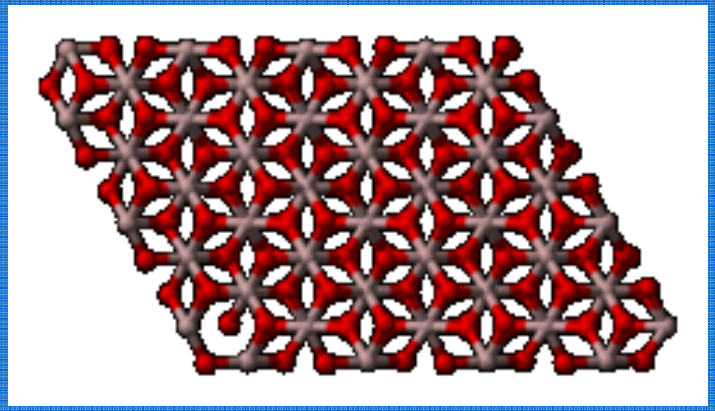
- Titanium carbide, TiC, is an extremely hard (Mohs 9-9.5) refractory ceramic material, similar to tungsten carbide.
- **Properties :**
- The resistance to wear, corrosion
- It is used as a heat shield in space crafts
- **Applications:**
- Is used to make tool bits
- It is used in cermet preparation.
- It is used in scratch proof watches.



Structure of TiC

Aluminium Oxide

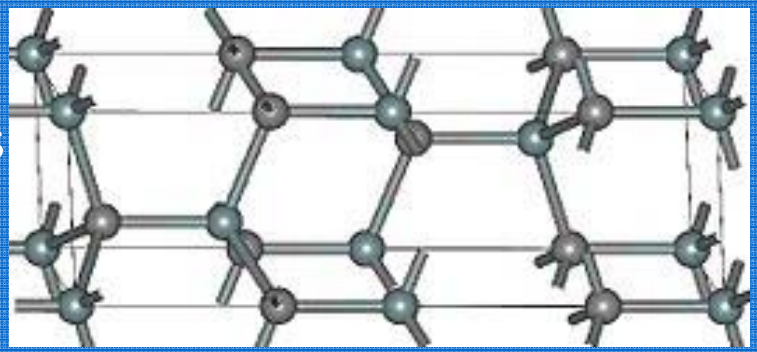
- Aluminium oxide is an amphoteric oxide with the chemical formula Al_2O_3. It is commonly referred to as alumina (α-alumina), aloxide, or corundum in its crystalline form.
- **Properties:**
- Aluminium oxide is an electrical insulator .
- It can react with both acids and bases
- **Applications :**
- Being fairly chemically inert and white, alumina is a favored filler for plastics
- Alumina catalyses a variety of reactions that are useful industrially.
- Alumina is widely used to remove water from gas streams.
- Used as an abrasive



Structure of Aluminium Oxide

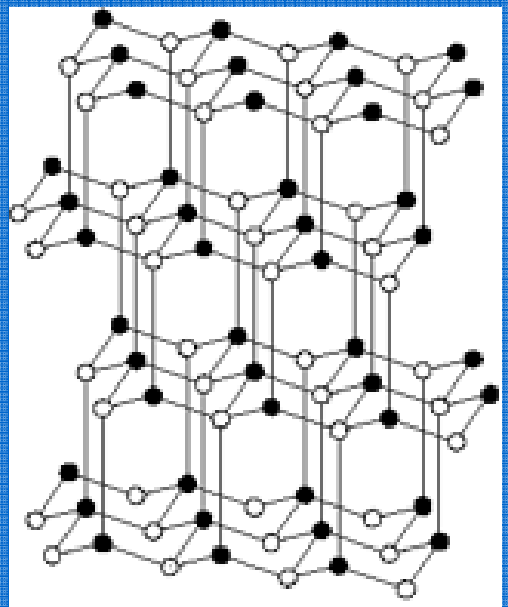
Silicon Carbide (SiC)

- Silicon carbide (SiC), also known as carborundum, is a compound of silicon and carbon with chemical formula SiC.
- It occurs in nature as the extremely rare mineral moissanite.
- **Properties:**
- Pure SiC is colorless
- Silicon carbide does not melt at any known pressure.
- It is also highly inert chemically. There is currently much interest in its use as a semiconductor material in electronics, where its high thermal conductivity, high electric field breakdown strength
- Has a low coefficient of thermal expansion
- **Applications:**
- Used in Abrasive and cutting tools
- Used to manufacture automobile parts
- Used in lightning arresters



Cubic Boron Nitride

- Cubic Boron Nitride (cBN) is second in hardness only to diamond.
- **Properties:**
- Its usefulness arises from its insolubility in iron, nickel, and related alloys at high temperatures, whereas diamond is soluble in these metals to give carbides.
- Has the highest thermal conductivity
- Has the highest electrical conductivity
- **Applications :**
- It is used an abrasive
- It is used for machining steel specifically
- Are used to form the tool bit for cutting tools



Crystal structure of the cubic boron nitride
● = Boron atom
○ = Nitrogen atom

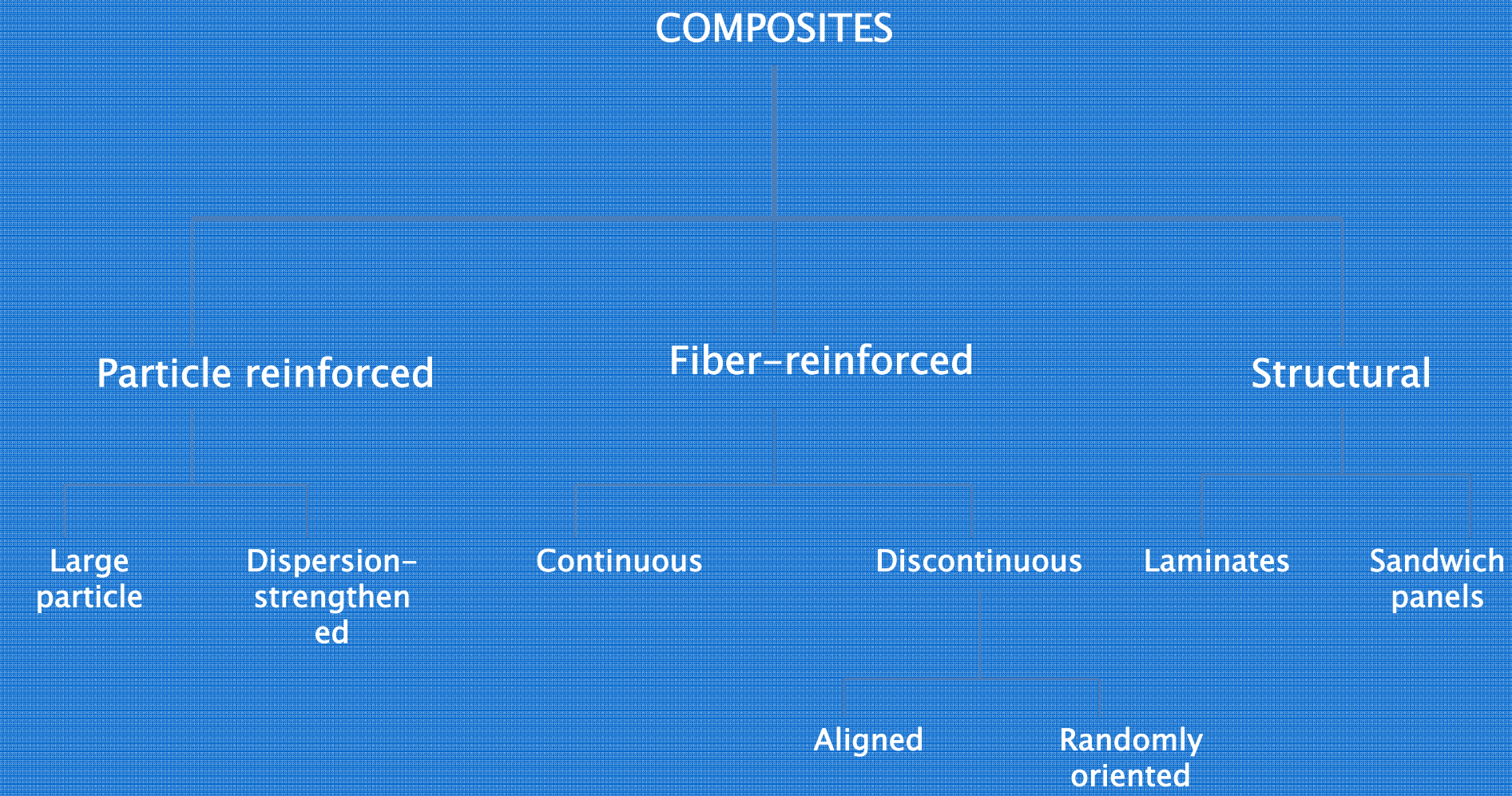
Diamond

- In mineralogy, diamond is an allotrope of carbon, where the carbon atoms are arranged in a variation of the face-centered cubic crystal structure called a diamond lattice
- Diamond is less stable than graphite, but the conversion rate from diamond to graphite is negligible at ambient conditions
- Most natural diamonds are formed at high temperature and pressure at depths of 140 to 190 kilometers (87 to 120 mi) in the Earth mantle
- **Properties:**
- Has extremely high hardness
- Has a high thermal conductivity
- Has good optical characteristics
- Diamond is chemical non-reactive
- They form excellent insulators
- **Applications :**
- It is mainly used in jewelry.
- Can be used in making Diamond blades.

Composite Materials

- Composite materials, often shortened to composites or called composition materials, are engineered or naturally occurring materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct within the finished structure.
- Metals, ceramics, glasses, polymers and cement can be combined in composite materials to produce unique characteristics such as toughness and high temperature strength and so on .
- A very common example of a composite material would be the fiber-glass-reinforced plastic which is commonly used for the household goods and in many industrial applications.
- Many composite materials are composed of just two phases; one is termed as the **matrix** and the other is termed as the **dispersed phase.**

Classification of composite materials

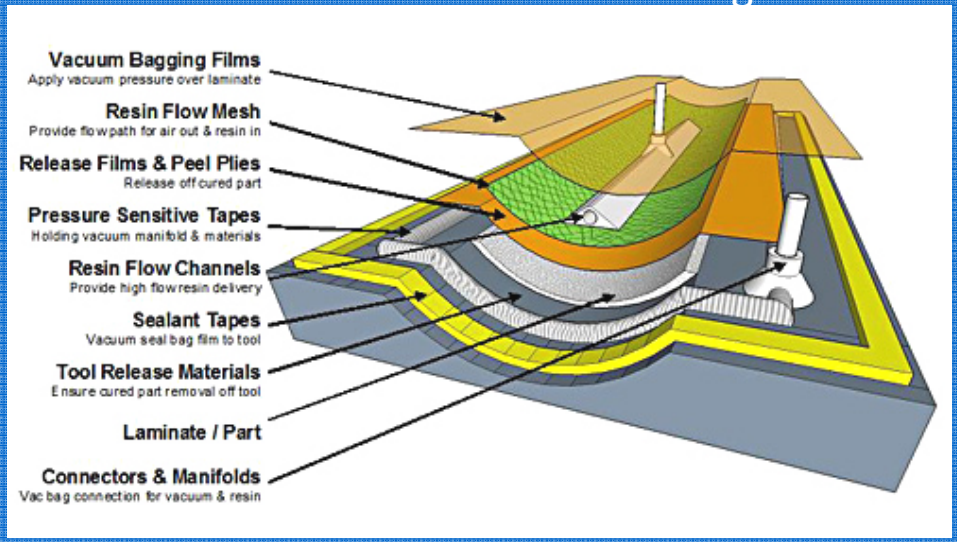


Production techniques

- In general, the reinforcing and matrix materials are combined, compacted and processed to undergo a melding event.
- Some of the moulding methods are as follows
- **Vacuum bag moulding**
- **Pressure bag moulding**
- **Resin transfer moulding (RTM)**

Vacuum bag moulding

- A process using a two-sided mould set that shapes both surfaces of the panel.
- On the lower side is a rigid mould and on the upper side is a flexible membrane or vacuum bag.
- The flexible membrane can be a reusable silicone material or an extruded polymer film. Then, vacuum is applied to the mould cavity.
- A vacuum bag is a bag made of strong rubber-coated fabric or a polymer film used to or laminate materials.
- The open end is sealed and the air is drawn out of the bag through a nipple using a vacuum pump.
- As a result, uniform pressure approaching one atmosphere is applied to the surfaces of the object inside the bag, holding parts together while the adhesive cures
- Vacuum bagging is widely used in the composites industry as well. Carbon fiber fabric and fiberglass, along with resins and epoxies are common materials laminated together with a vacuum bag operation.



Pressure bag moulding

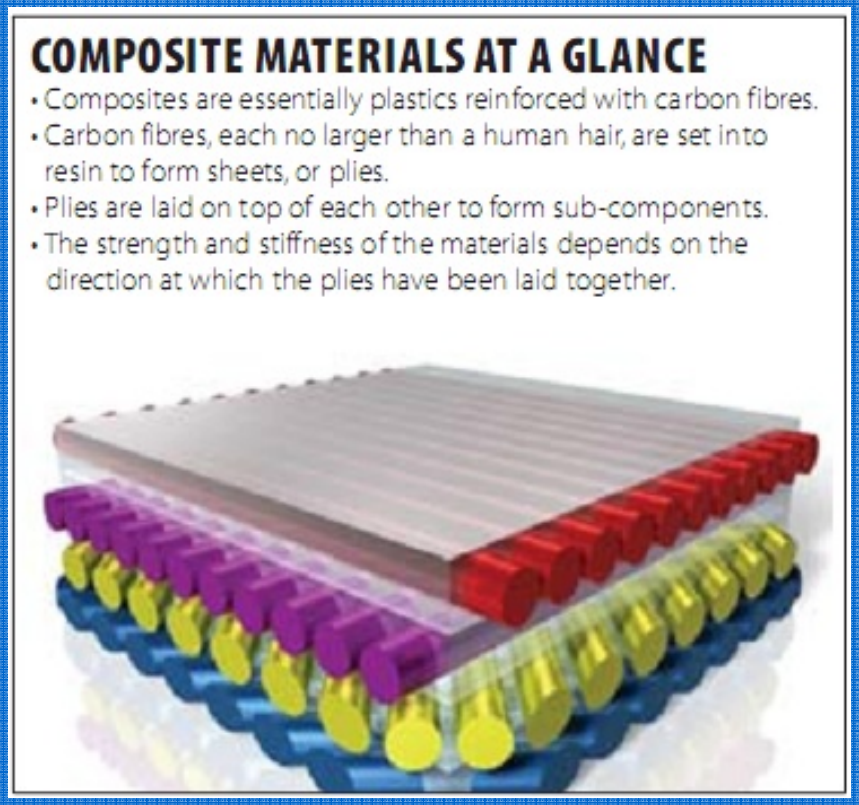
- This process is related to vacuum bag moulding in exactly the same way as it sounds.
- A solid female mould is used along with a flexible male mould.
- The reinforcement is placed inside the female mould with just enough resin to allow the fabric to stick in place (wet lay up).
- A measured amount of resin is then liberally brushed indiscriminately into the mould and the mould is then clamped to a machine that contains the male flexible mould.
- The flexible male membrane is then inflated with heated compressed air or possibly steam.
- The female mould can also be heated. Excess resin is forced out along with trapped air. This process is extensively used in the production of composite helmets due to the lower cost of unskilled labor.
- Cycle times for a helmet bag moulding machine vary from 20 to 45 minutes, but the finished shells require no further curing if the moulds are heated.

Resin transfer moulding

- A process using a two-sided mould set that forms both surfaces of the panel. The lower side is a rigid mould.
- The upper side can be a rigid or flexible mould.
- Flexible moulds can be made from composite materials, silicone or extruded polymer films such as nylon.
- The two sides fit together to produce a mould cavity.
- The distinguishing feature of resin transfer moulding is that the reinforcement materials are placed into this cavity and the mould set is closed prior to the introduction of matrix material.
- Resin transfer moulding includes numerous varieties which differ in the mechanics of how the resin is introduced to the reinforcement in the mould cavity.
- These variations include everything from vacuum infusion (for resin infusion see also boat building) to vacuum assisted resin transfer moulding (VARTM). This process can be performed at either ambient or elevated temperature.

Structure and Properties and Applications

- **Properties:**
- Improves the following properties
  - Ultimate tensile strength
  - Temperature resistance
  - Flexural modulus
  - Offer generally a high performance



- **Applications:**
  - Carbon fibers are used in the sole of sport shoes.
  - Used in aircraft manufacturing
  - Are used for reinforcing structures in the field of civil engineering

SRM UNIVERSITY

Thank You