Lecture (10)

Materials Science and Engineering

Semiconductors Materials

Semiconductors have electrical properties that are intermediate between the electrical conductors (Viz. metals and metal alloy) and insulators (Viz. ceramics and polymers). Furthermore, the electrical characteristics of these materials are extremely sensitive to the presence of minute concentrations of impurity atoms, for which the concentrations may be controlled over very small spatial regions. Semiconductors have made possible the advent of integrated circuitry that has totally revolutionized the electronics and computer industries (not to mention our lives) over the past three decades.

Organics Materials

The materials, which are derivatives of carbon, chemically combined with hydrogen, oxygen or any other non-metallic substance, are known as organic materials. The organic materials may be natural or synthetic (i.e. manufactured artificially). The natural organic materials include wood, cotton, natural rubber, coal, Petroleum and food products etc. The synthetic organic materials include synthetic rubber, plastics, lubricants, soap oils, synthetic fibres etc. It has been observed that the organic materials, consists of very large molecules. In natural organic materials, the molecules are readymade. But in synthetic materials, the molecules are built up by joining simpler molecules by some chemical reactions.

Organic Compounds

All the compounds, which essentially contain carbon atoms along with other non-metal atoms such as hydrogen, nitrogen, oxygen, chloride etc. in each molecule, are known as organic compounds.

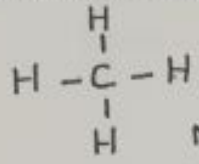
Types of Organic Compounds

There are a number of organic compounds, yet the following are important from the subject point of view:-

1) Saturated organic compounds.
2) Unsaturated organic compounds.
3) Aromatic organic compounds.

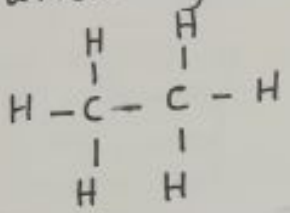
Saturated Organic Compounds

Sometimes, the compounds in the carbon atoms, present in each molecule, are jointed by single covalent bonds. And the remaining bond is completed by the atoms of carbon and hydrogen. All the carbon atoms may be either in a single chain or side branching. The simplest member of the saturated organic compound series is methane (CH_4).

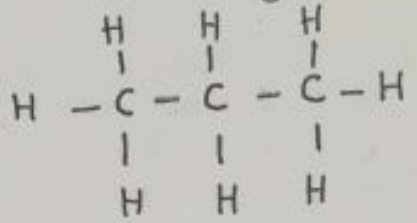


Methane

Similarly, other two members of the series are ethane (C_2H_6) and propane (C_3H_8) which may be represented as shown in figure.



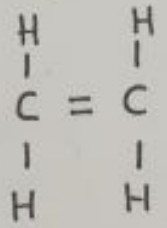
Ethane



Propane

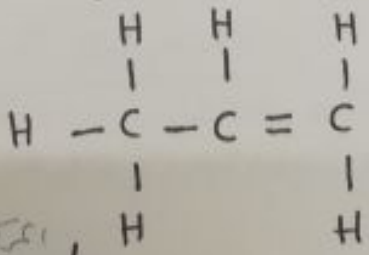
Unsaturated Organic Compounds

The compounds in which any two carbon atoms, present in a molecule, are joined by double covalent bonds and the remaining carbon bonds completed by hydrogen atoms are known as unsaturated organic compounds. The simplest member of this series in ethylene (C_2H_4). The two dimensional formula for ethylene is given in figure.



Ethylene

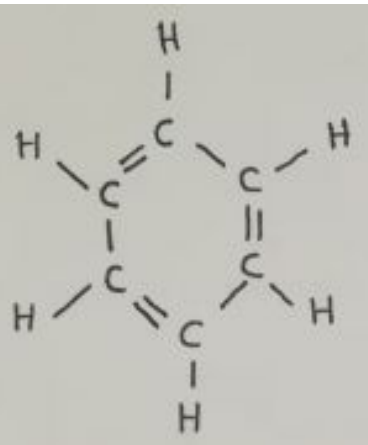
The next member of this series is propylene or propene (C_3H_6). Its two dimensional formula is given in figure.



Propylene (propene)

Aromatic Organic Compounds

The organic compounds, which are derived from benzene (C_6H_6) by replacing the hydrogen atom with other groups of atoms are known as aromatic organic compounds. The structure of benzene is in the form of a ring in which the carbon atoms are arranged in a regular hexagon with the hydrogen atoms attached to each carbon atom outside the ring as shown in



Benzene C_6H_6

Polymers

A polymers is composed of a large number of repetitive called monomers or simple molecules. Thus a polymer is made up of thousands of monomers joined chemically together to form a large molecule. It has been observed that each molecule of a polymer, is either a long chain or a network of repetitive units or monomers. The following terms regarding polymers are important from the subject point of view :-

1) Polymerization : It is process of forming a polymer.
2) Degree of Polymerization : It is the number of repetitive units (or mers) present in one molecule of a polymer.
3) Linear polymer : It is a polymer, which is obtained by simply adding the monomers together to form long chains.
4) Copolymer : It is a polymer, which is obtained by adding different types of monomers.
5) Thermoplastics : These are linear polymers, whose plasticity increases with the rise in temperature.
6) Thermosets : These are the polymers, whose plasticity does not change with the rise in temperature.

Mechanical Behaviour of Polymers

There are a number of factors which affect the mechanical behavior of polymers, yet the following are important from the subject point of view:

1) Shape of the polymer.
2) Degree of polymerization.
3) Temperature of Polymer.
4) Crystallinity of Polymer.

Shape of Polymer

The shape of a polymer affects, to a great extent, the resistance to its plastic deformation.

Degree of Polymerization

The number of repetitive units (or mers) present in one molecule of a polymer is known as degree of polymerization.

Temperature of Polymer

It has been observed that at very low temperature, the polymers are hard, rigid and glass like materials. They give limited elastic deformation and fracture in a brittle manner. But as the temperature of polymer is increased, above the room temperature, it gradually deforms under the applied load.

Crystallinity in Polymers

As a matter of fact, the polymer are rarely crystalline in structure. It has been observed that the behaviour of Partially crystalline polymers is intermediate between those for crystalline and amorphous polymers.

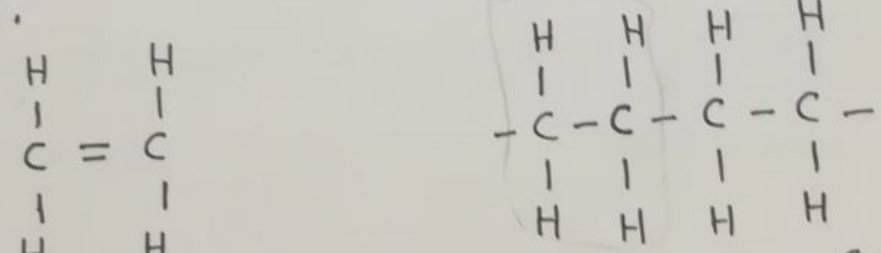
Types of Polymerizations

We have already discussed that the polymerization in the process of forming a polymer. This process is of the following two types:-

1) Addition polymerization.
2) Condensation Polymerization.

Addition Polymerization

These compounds are, relatively, unstable as compared to the saturated organic compounds.

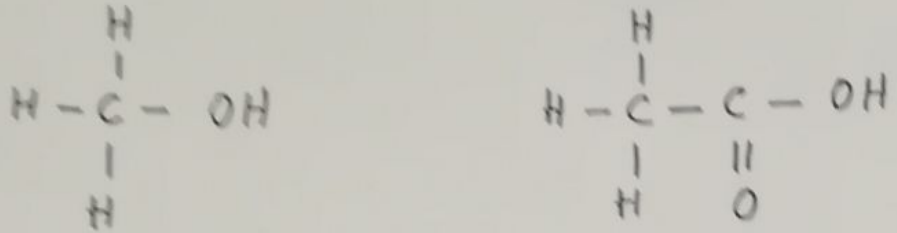


a) Ethylene b) Polyethylence (Polythene)

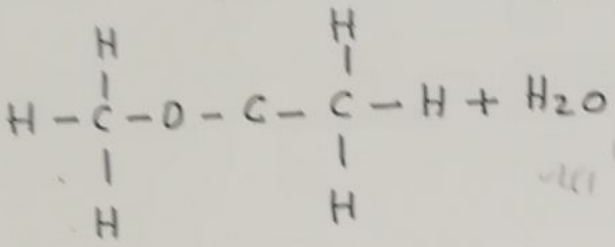
Addition polymerization

Condensation Polymerization

The process in which two or more chemically different monomers are polymerized to form a cross-link or linear polymer, along with a by product such as water or ammonia, is known as condensation polymerization.



a) Monomers of methyl alcohol and acetic acid.



b) Ester.

Condensation Polymerization

Crystalline Ceramics

The term (ceramics) is used to denote those products which are made from inorganic materials and have non-metallic properties. Ionically, bonded magnesia (MgO) and covalently bonded Silicon carbide (SiC) are the simple examples of ceramics. The traditional ceramic materials are stone, brick, concrete, clay, glass, Vitreous enamel and refractories. Majority of these are composed of silicates. New ceramic materials includes oxides, carbides, borides and other similor compounds which are being developed. Such materials have properties of special advantage in particular applications such as high temperature work, solid-state electronics and in nuclear reactors

Classification of Ceramics on the Basis of Application

Fig. shows the classification of ceramic materials on the basis of application. As seen from this diagram, the ceramic materials can be classified into the following six groups:

1. Glasses
2. Clay products
3. Refractories
4. Abrasives
5. Cements
6. Advanced materials.

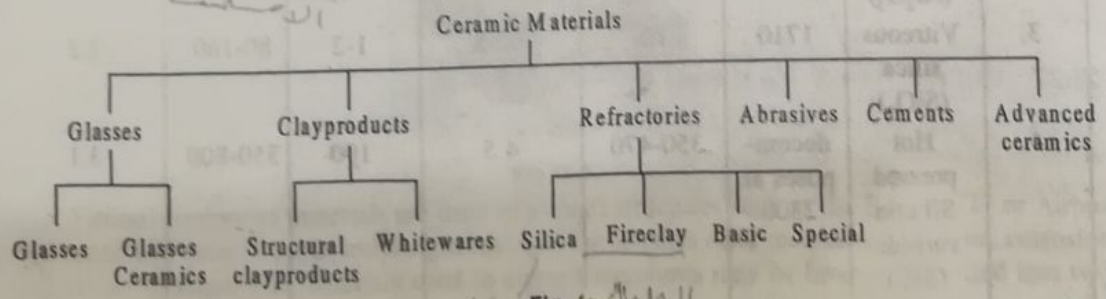


Fig. 1: