Introduction to Materials Science and Engineering

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Lecture – 37
Polymers

Let us now discuss polymers, polymers are a very important class of materials and is very different from other classes of materials like metals and ceramics.

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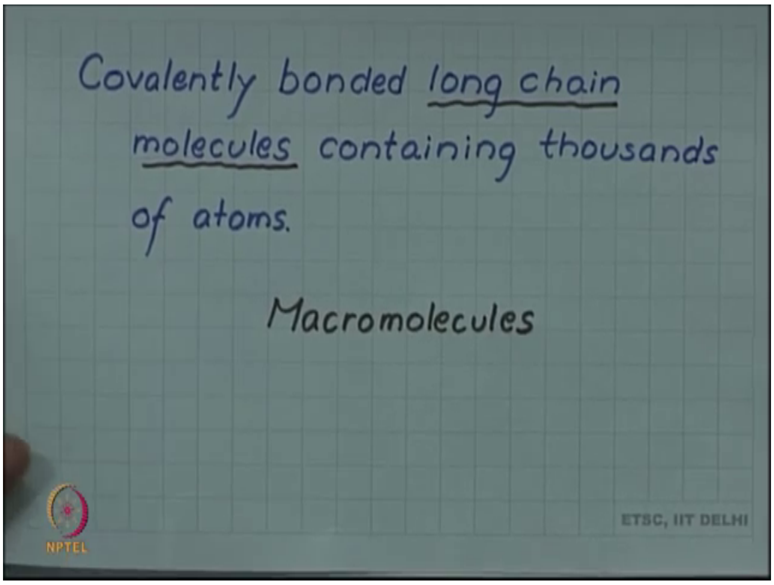

The difference mainly comes from a very special structure which they have, they are covalently bonded long chain molecules this is a particular speciality of polymers, that they consist of long chain molecules long chain molecules, sometimes this is also called macro molecules, they may contain 10,000 or 100,000 atoms in 1 molecule. So, these molecules are really very large.

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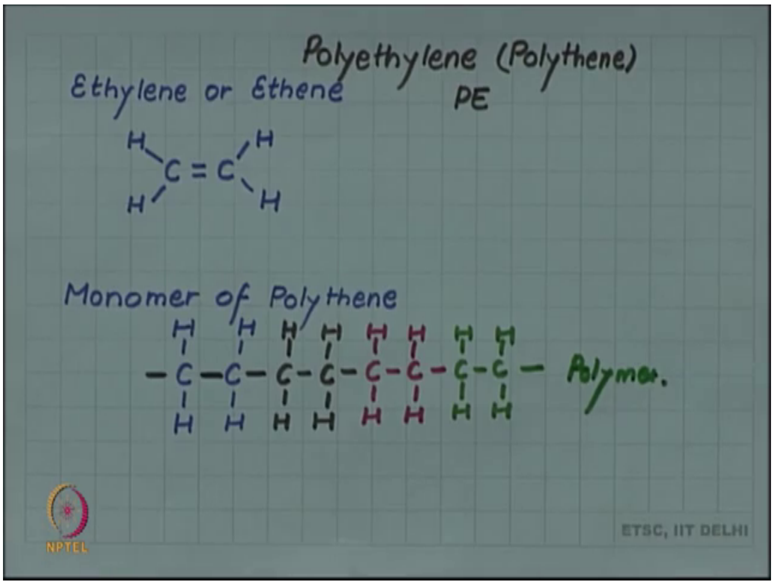

Let us look at an example of poly polythene or polyethylene, or sometimes also called polythene, abbreviated as PE. So, this polymer is made of ethylene or a ethane gas, in the gas you have a doubly bonded pair of carbon with 2 hydrogen attached to each of these carbon, but when this gas is polymerized, you get a monomer in which this double bond transforms now to a single bond, thus satisfying the 4 bonds of carbon you now have 2 free bonds, which can join with other monomer or other molecules of ethylene.

So, this is the basis of having long chain. So, once these will connect now, with the next carbon atom from a neighboring monomer, then what we have a we can say a dimer, then yet another next third molecule can come and join with this, we have a trimer, and if this process continues you can see, that you can have many, many monomers attached to a single chain and that is what you have then a polymer, this will be a polymer.

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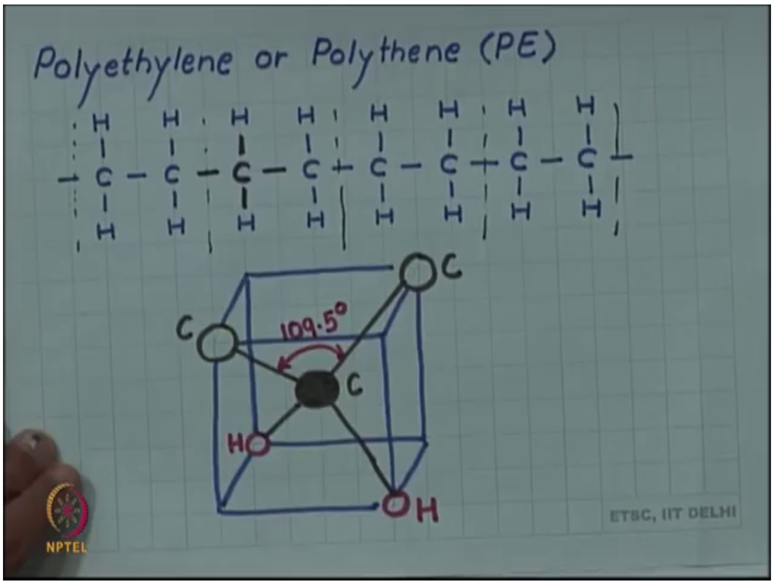

So, polyethylene or polythene is a long chain molecule with many monomers, many monomers of each of these each pair of carbon atom is defining a monomer. So, you have several monomers here which are connected to give you a macro molecule or a chain of polythene, I have drawn it here in a planar way, which is a simple way of drawing, but one should recognize that the bonds of carbon, if I take a single carbon the 4 bonds of carbon are not in a plane, they are directed from vertices to the corners of a tetrahedron. So, they are tetrahedral bonds, one way to think about these tetrahedral bond is to place a carbon atom in the cube in the center of a cube, and then draw these bonds as diagonals body diagonals of the cube.

So, 2 bonds are connected to carbon atoms. So, I connect them to carbon atoms, and 2 are connected to hydrogen atoms, let me show the hydrogen atoms in red, these 2 are connected to hydrogen atoms, and let me complete the outline of the reference cube. So, this is the reference cube, 4 corners of a cube appropriately selected 4 corners, or you can say alternating 4 corners of a cube define a tetrahedron. So, if a central carbon atom, which I now say dark, has it is bond directed towards these corners and you have carbon at 2 of these corners and hydrogen at 2 others.

So, in reality the this model is not planar, but will have a 3-dimensional configuration.

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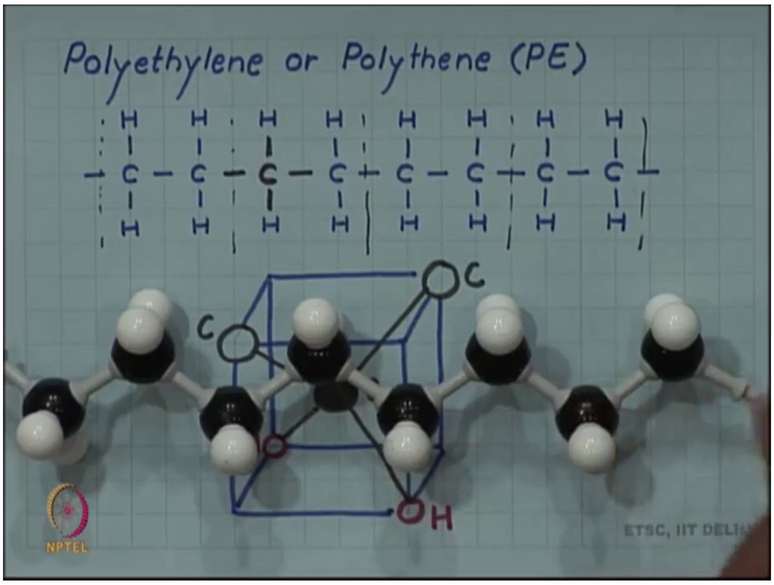

So, here I have molecule to show you, you can have you can see here we have 1 2 3 4, 4 monomers are there, and I have put them in a straightest possible configuration, and we are looking from the top along this axis with the 2 hydrogen atom associated with each carbon, you can see that these 2 hydrogen atoms the first 2 hydrogen atoms here are on the down side of this chain whereas, the other 2 are pointing up. So, they are really not in the plane, they are pointing either down or up depending upon the location of the carbon atom.

The carbon atoms themselves are forming a zigzag formation, as shown here we are having a zigzag of carbon atoms, this is the straightest possible chain this configuration for this chain.

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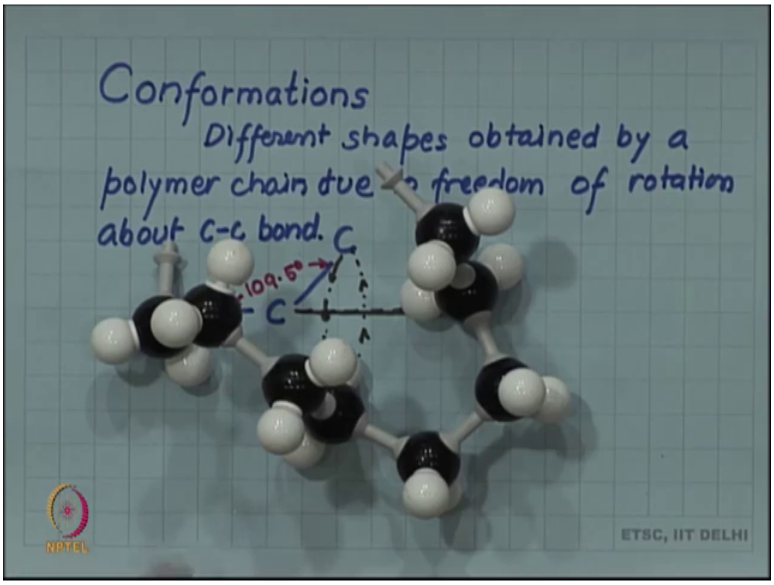

But the polymer like this has a degree of freedom of rotation about every bond, keeping that angle. So, this angle will be the tetrahedral angle tetrahedral angle of 109.5. So, that is the angle between the body diagonals of a cube.

So, keeping this carbon carbon bond angle as 109.5 there is possible to rotate any given bond about the other bond. So, here I have shown that possible rotation. So, I can take this carbon atom, and I can rotate it in this manner about the axis defined by the other bond. So, if I rotate it about the axis defined by the other bond, this angle 109.5 degree will be preserved, but then the carbon carbon structure will be taking different shapes in 3 dimensions.

So, these different shapes are called conformations. So, confirmations are different shapes obtained by a polymer chain, due to freedom of rotation about carbon carbon bond. We can see this from again from our molecule here so, this is a very straight chain although it is zigzag this is the straightest possible, why I am saying this? That there is a freedom of rotation about every bond.

So, let me use that freedom and start rotating. So, let us say I am rotating about this bond about this bond. So, if I rot start rotating about this bond, I can flip this segment of the molecule out of the plane of the paper. So, and if I keep using rotations about other bond, I can have a molecule which is no more a straight and is going in 3 dimension in a different conformation. So, this is different conformation. So, what I have is the same molecule, but in a different conformation, each bond angle if one carefully looks at each bond angle is a still 109.5, but the shape of the molecule in the 3 dimension is very, very different from the straight chain I started with.

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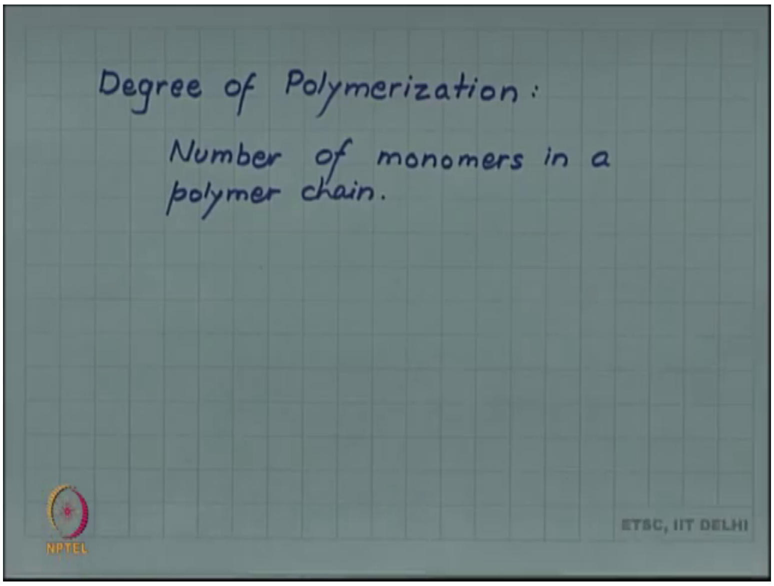

There is also a term degree of polymerization, which is number of monomers in a polymer chain, this tells us how long the polymer edge many of the properties of polymer depends upon the length of the polymer chain or the degree of polymerization. So, of course, every chain every single chain will have a degree of polymerization, and degree of polymerization of a polymer sample will be an average of the degree of polymerization of different chains within that polymer, macromolecules was originally proposed by Hermann Staudinger in about 1920.

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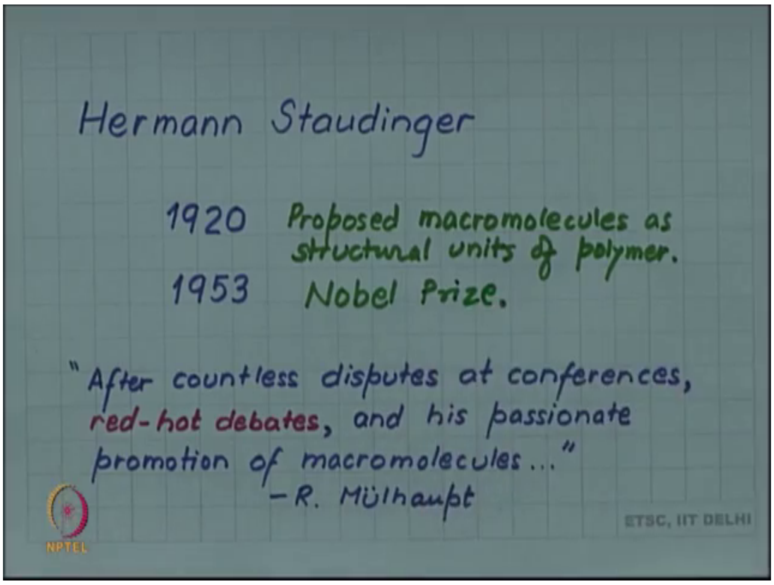

So, 1920 the proposal proposed macromolecules as a structural unit of polymers, this was not easily accepted this was not really easily accepted by the scientific community, there was opposition to this thinking and they were there was disbelief that, a single molecule in a polymer may contain such large number like 10,000 carbon atoms. So, after countless disputes at conferences red hot debates and his passionate promotion of macromolecules, this is how one author puts it in 1953 he was awarded the Nobel Prize.