An Introduction to Materials: Nature and Properties (Part 1: Structure of Materials)
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Lecture – 30
Structure of Polymers

So, we now begin with lecture 30 in which we will continue talking about the Structure of Polymers.

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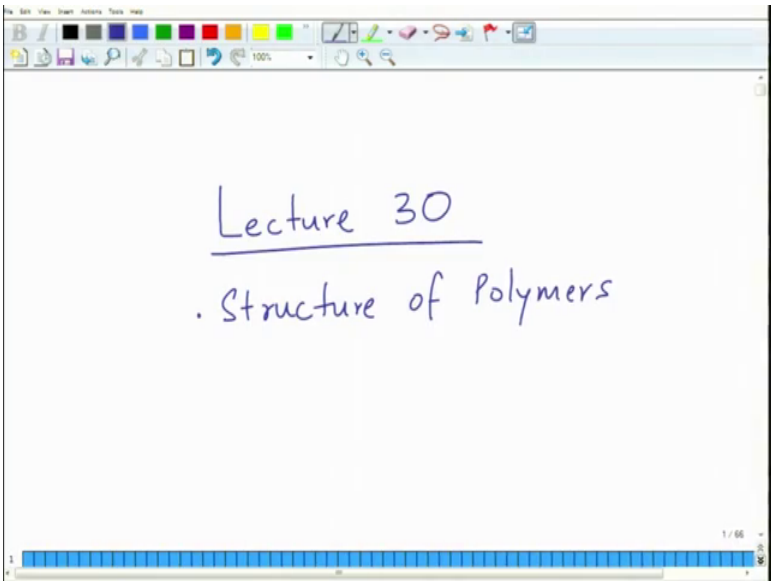

So, in the last lecture we talked about remaining glass related things. So, mainly we looked at the fused silica and composition of various glasses in which elements like sodium, potassia, sodium, potassium, calcium, and boron are added typically to lower the class transition temperature of the of the of the glasses glass transition temperatures. Basically that temperature at which glasses are too soften before it completely melts.

So, there is a there is a slight difference between glass transition and melting temperature, softening temperature is typically loosely talked off as transaction in picture same is true for plastics as well. And then we started with discussion on polymers, polymers are other category of non crystalline solids.

We looked at the category of two materials thermoplastic and thermosets, thermoplastics are the once which show a melting kind of behavior, thermosets are the once which show at the composition kind of behavior. Thermoplastics are typically ductile they can be shaped easily thermoplastic from the other hand are not very ductile they are hard and brittle. And it depends upon the molecular weight of the polymers how will they behave as a function of temperature when we want to use them.

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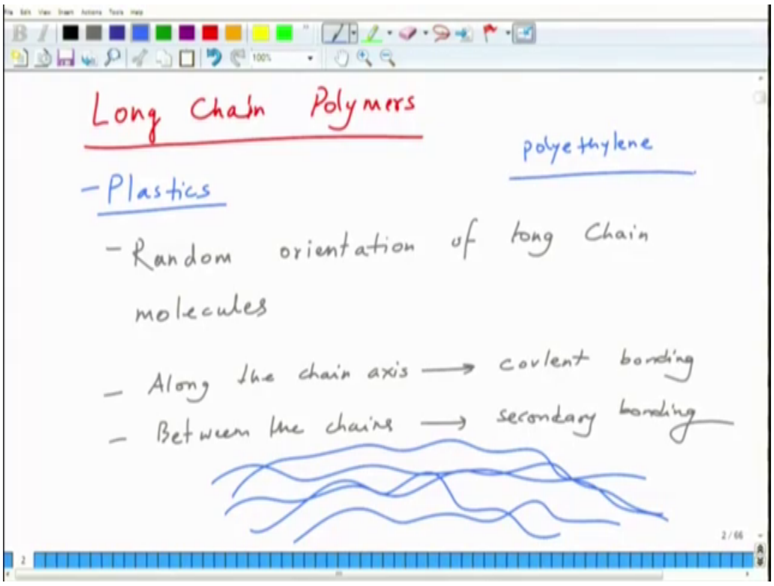

So, if I now first start with long chain polymers, there are three categories of long chain polymers that we typically go ahead with, first is called as plastics ok, plastics typically tend to have they have a random orientation of long chain molecules. So basically the there are long chains of molecules the polymer chains which are randomly oriented with respect to each other and the bonding as I said along the chain, chain axis let us say it is covalent. So, if you have thrilling molecules these are thrilling molecules will be covalently bonded with respect to each other, and then between the chains we have secondary bonding ok.

So, this is first form of long chain polymers which is called as plastics which are essentially long chain molecules which are randomly which are long chains of polymers, but are randomly oriented with respect to each other.

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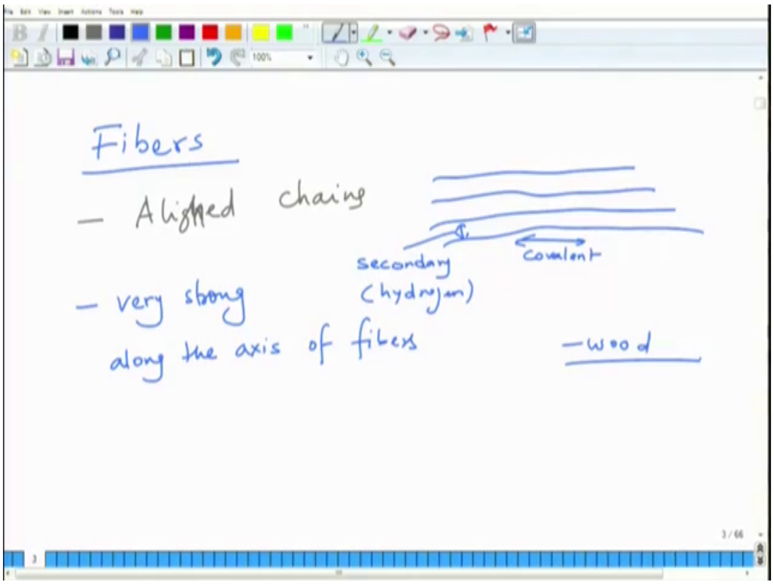

The second category is called as fibers. Fibers are basically aligned chains the chains. So, in this case the previous case the chains would be like this. So, there would be they are long chains, but they are random with respect each other ok. They can be some cross linking, but they are random with respect each other, in the in the in the fiber case the chains would be quite a line like this ok. So, these are chained lined structure.

Again the bonding is similar so, these are along this is covalent and between these is secondary which tends to be typically hydrogen which is slightly stronger than the Van der Waals type of bond ok. And it is very strong along the fiber its extremely strong. So, it is like a tree you if look at the structure of tree right tree is a tree has a fibers structure in which you have molecules..

The chains of tree along the bark axis they are all aliened in one direction and they do not go crossing. As a result tree is very strong along in that direction. So, you need to cut it. So you can rupture the tree along this very easily, but cutting perpendicular to the axis takes a lot of so lot of effort.

So, they are very strong along the axis of fibers. So, wood for example, is a it has a fiber fibers structure in this case it would be plastics would be you know polyethylene for example.

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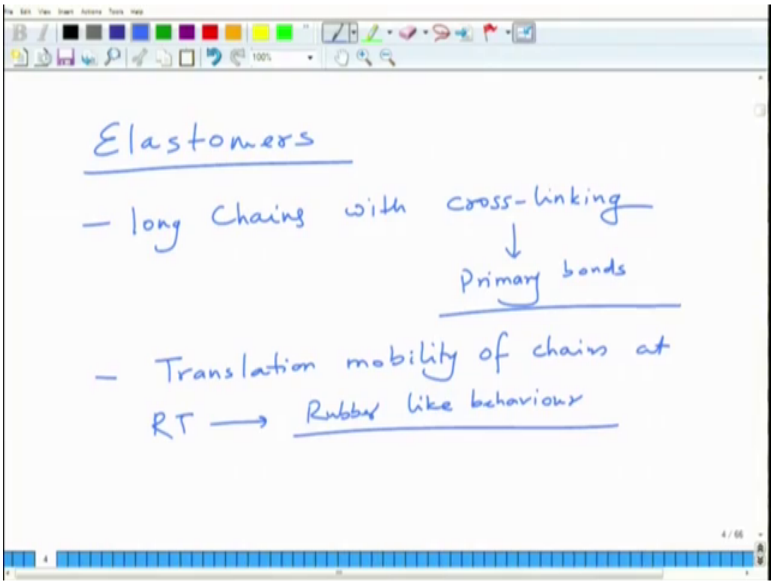

The third category is elastomers. So, basically these are long chain molecules with cross linking across the chains. So, long chains with cross linking and the cross links are not secondary bonds, they could be primary bonds.

So, these cross links could be proper primary bonds as a result they have higher strength, they have the chains have mobility at high temperature, they have translational mobility at of chains at room temperature which provides them a rubber like behavior so that is why elastomers are basically they have a rubbery behavior they act like a rubber. So, these are three categories of a long chain polymers. Let us see the example of to begin with polyethylene structure.

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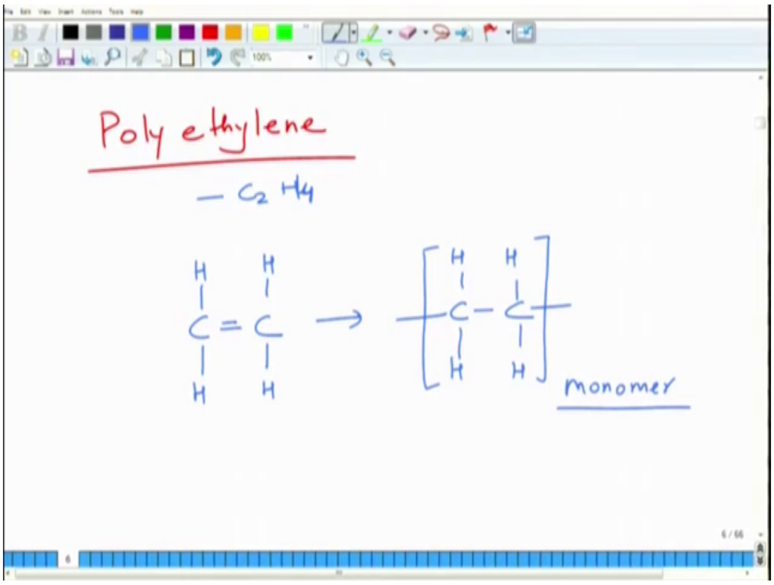

So, we start with the poly polyethylene structures. So, polyethylene to the polyethylene is it is basically molecules C 2 H 4, and it can be represented as you have C all the 4 bonds are satisfied. When it makes a mar it becomes C C H H H and now it can it is open to react on both the sides it is happened it is open to accepting a neighbor on the each side, and this is called as a monomer or a mer mer unit of polymer.

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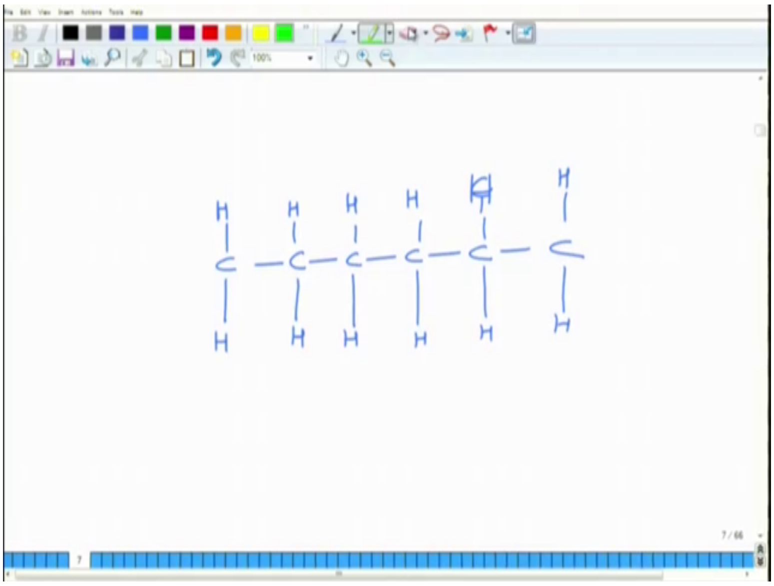

And when you put many of these together or he put them. So, so you can see the top, and bottom are long and short, but they are unintentional. So, basically let me just I think to avoid the confusion.

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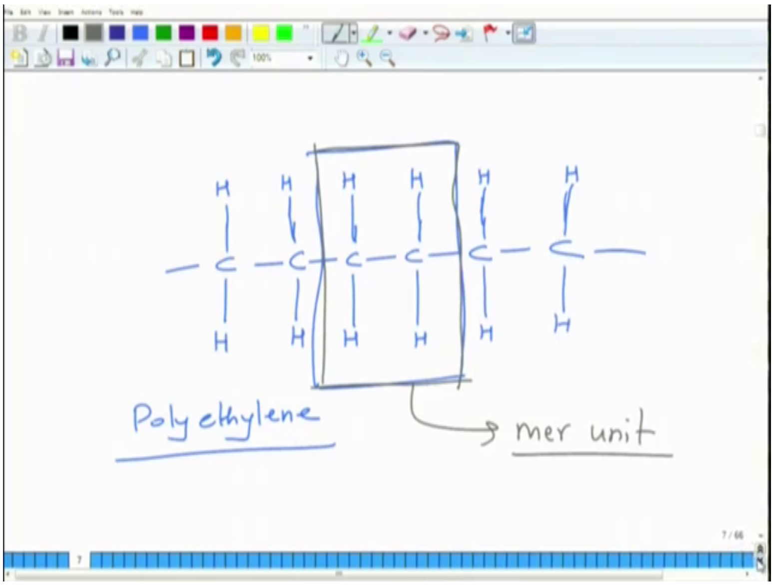

So, that you do not think of it as a intentional long and short bonds. They are basically bonds of same length ok. So, these are all single bonds, so this will make a polymer. So, this is called as poly ethylene and the basic unit of this is the one shown here in this box, this is the mer unit or the monomer.

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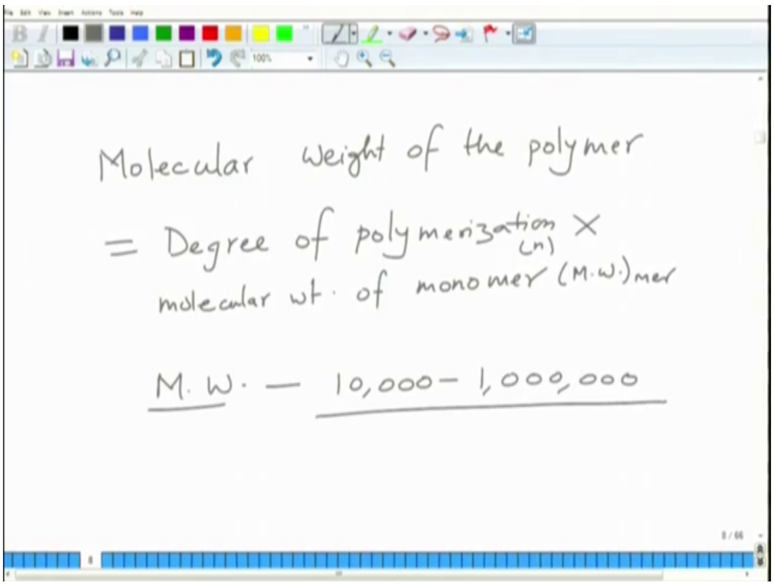

So, for a polymer you can define the molecular weight of the polymer can be defined as degree of polymerization, multiplied by the molecular weight of monomer ok. So, how many so basically this is n this is M. W. Mer and this is molecular weight of the polymer. Typically the molecular weights range between 10000 to a million ok. So, they can contain from low to high molecular weight, but these molecular weights are significantly higher.

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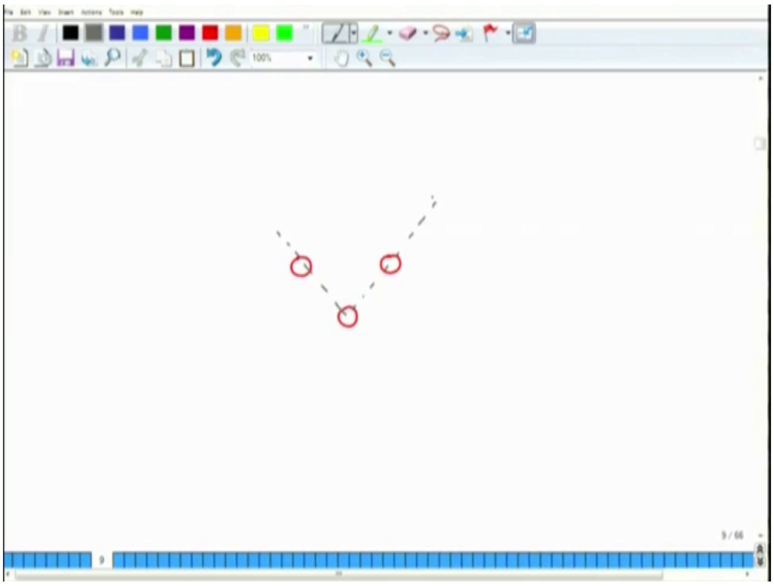

The structure looks something like this if I so you have there is a there is a angle between so there is a angle or relation between the mole molecules. So, you have let us say this is a carbon atom, this is a carbon atom, and you have a carbon item here ok. The angle between these two typically it is not drawn very correctly it looks like as a fixed oblique angle, it is not a oblique angle let me first draw the angle. So, the angle is something like this ok.

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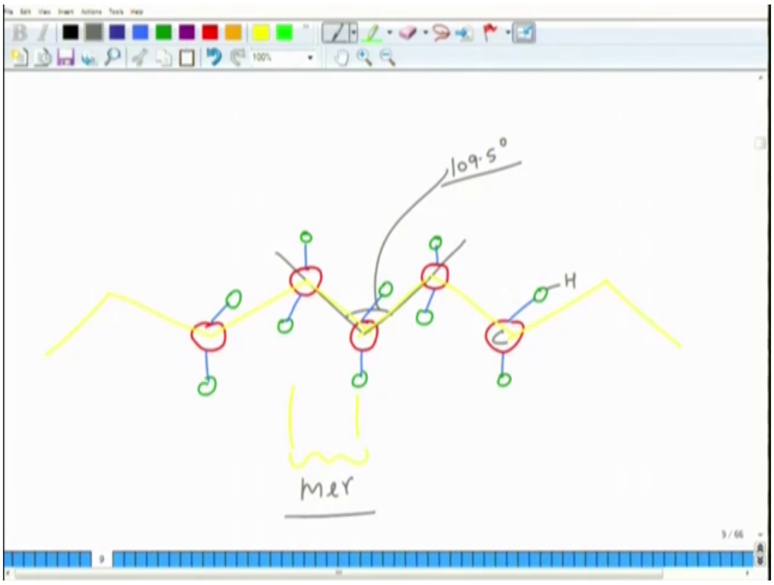

So, now I put the carbon atom, the first carbon atom is here, second one is somewhere here, third one is somewhere here. Now if I so this angle is approximately 109.5 degree ok, in the way hydrogen atoms are attached to it is like this. So, you have these so hydrogen atoms are attached as of so little this kind of fashion.

So, sorry so the first one is like this, the second one would be would be like that something like that cress cross. So, this is how you then proceed and the next one will again go here, and the next one will again go here, and this will be like this look like this, so these are all hydrogen ok.

So, this is sort of it will make a you can you can say that this will make a polymer chain if I now connect it, this kind of structure it will make. So, this is the polymer chain and we can see that the, this is the mer unit, this is carbon, this is hydrogen. So, if I want to I will just show you a graphic representation of how it looks like? So, this is the graphic look presentation of how the chain would look like.

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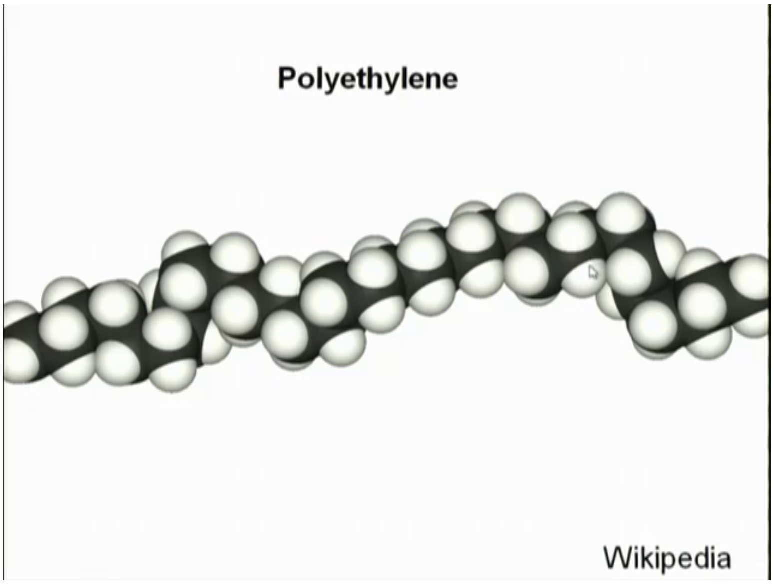

So, you have carbon atoms have in the centre, and then you have these oxygen hydrogen atoms at various angles, so 1, 2, 3, 4 like that right ok.

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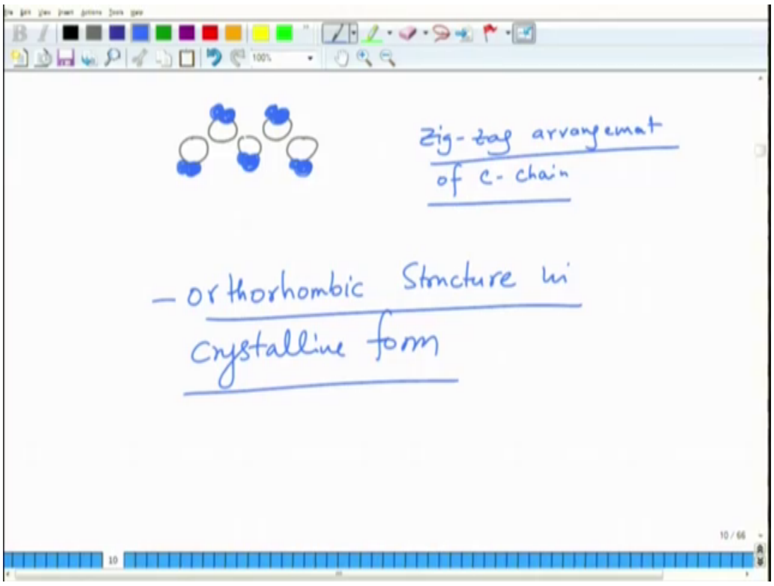

So, now these the alternative view to look at that is you have this as one atom of carbon, this is another atom of carbon, this is another atom of carbon, and these two carbon atoms have the hydrogen atom, one of hydrogen atom sitting on the back, another hydrogen atom sitting on the front.

Similarly on this side one on the back, one on the front one on the back, one on the front, one on the back, one on the front, one on the back, one on the front. So, if I just write this becomes little bit more clearer, like this.

So, on two sides you have a hydrogen atom, so this is a planar sort of zigzag arrangement of arrangement of carbon chain molecules of carbon chain ok. So, these make a structure which looks like orthorhombic structure I will show you here.

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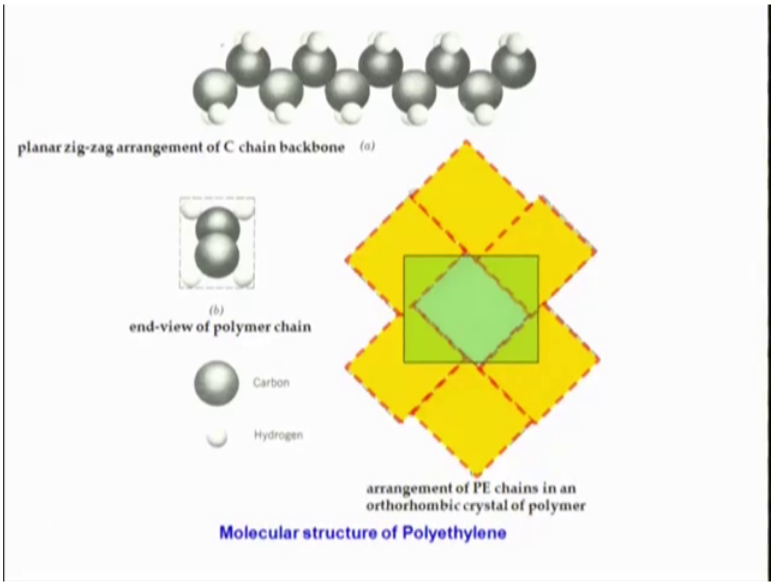

So, essentially it looks something like that you have they make a structure something like this, and you can make a unit cell which is this green colored unit cell which is the orthorhombic unit cell of polymeric chains. So, these are all chains ok, these are all chains, and they sort of arrange in a fashion, so that a crystalline form of polyethylene can make a orthorhombic unit cell. So, they tend to have a so highly crystalline form of polyethylene will make a orthorhombic unit cell.

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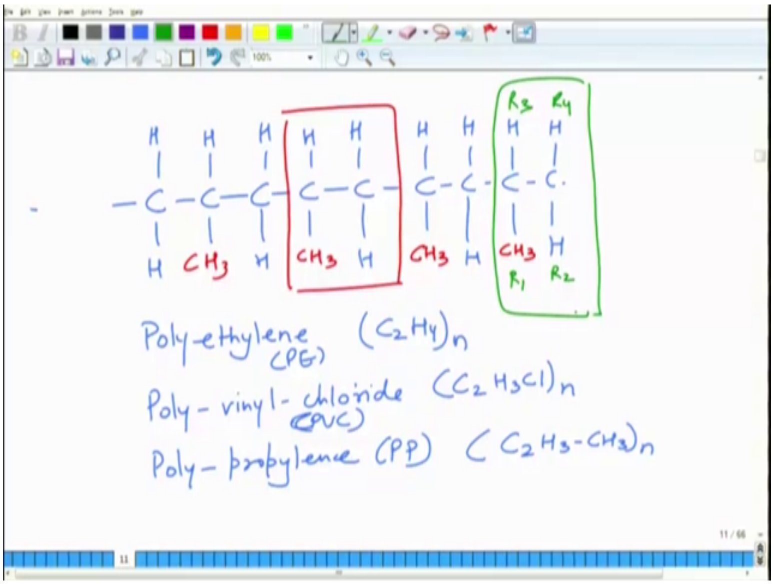

Now looking at these chains, the ability of polymers now you can see that it makes a chain like structure like this C, C, C, C and so on and so forth. You can one has the ability these chains are susceptible to modifications of the side groups which can lead to formation of various polymers.

For instance if you all put we have seen that if you put hydrogen's all across and then you will get polyethylene kind of structure; however, if I replace some of these hydrogen's with so this is polyethylene, poly ethylene which is nothing, but C 2 H 4 n. Now if I replace some of these hydrogen's with let us say in this case alternatively as chlorine, let us say here chlorine; chlorine then my basic unit is this.

This makes what we call as poly vinyl chlorides; basically it is C 2 H 3 C l n, now if I make another change here. So, this is PVC, let us say instead of C l, I put let us say C H 3. Then it makes what we call as poly propylene, which is commonly known as PP, this is known as PE this is known as PVC; PVC pipes are so common right. So, this is nothing, but C 2 H 3 C H 3 n, basically it is 3 x x right. So, this is how you can tweak the structure of polymer.

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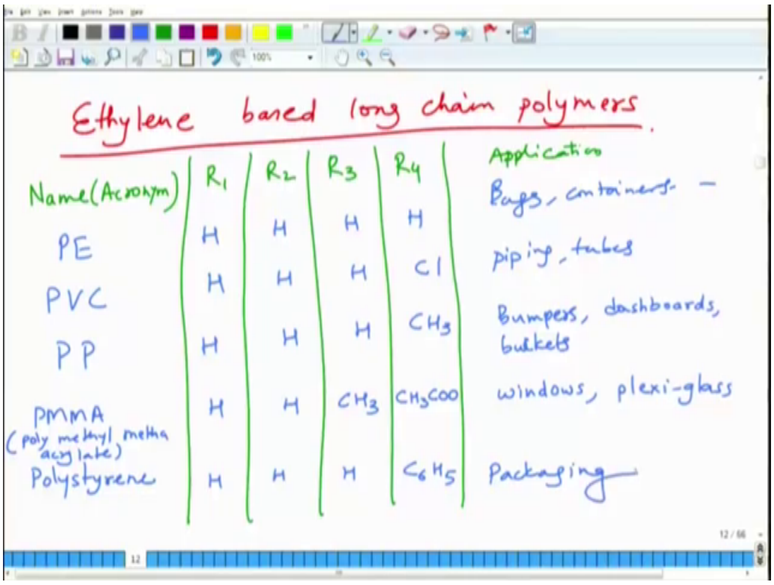

And this has profound impact on the type of polymers that we have. So, the you can have let us say if you have 4 of these groups, ethylene based basically if I make a classification between ethylene based, based long chain polymers alright. Then I have so let us say first let us define the name the acronym ok, and then let us choose the group R 1, R 2, R 3 and R 4.

So, here what I mean basically is you have so this is let us say R 1, this is R 2, this is R 3, and this is R 4 in one unit ok. So, R 1, R 2, R 3, R 4, and then let us say applications ok. So, the first one that we have seen is PE in which all the groups are hydrogen, and this is used for a variety of applications such as bags, containers, and so on and so forth. Polyethylene is a very useful material right, bags, containers, and so on and so forth, Vessels..

Second thing that we made was PVC in this case 3 hydrogen's remain the same, fourth one is chlorine, and PVC is a little harder because chlorine is a bigger molecule right. So, it adds to the strength of the polymer which is for making pipe for example, tubes third one is polypropylene which is PP, in this case we saw you have three groups as H and the fourth one becomes CH 3.

Polypropylene is again a nice material which is used for things like making you know dashboards in the car, bumpers. So, bumpers in cars bumpers a little harder than polyethylene dashboards are also harder materials, buckets are typically made up of, vessels are made up of any wherever you require hardness more harder than polyethylene you make it of propylene and it does not contain chlorine ok.

So, PP is another form then you have PMMA, poly methyl methacrylate in this case you have 2 hydrogen's, one goes as CH 3 and another one is replaced by CH 3 C double o, this is used for variety of applications much more harder, it choose for example, glasses as a window glass.

So, windows it is also used as plexiglass, that we use in our lab to make variety of things out of this plexiglass as we call it a plexiglass plexiglass has more like a trade name right, so this is PMMA poly methyl methacrylate.

Then we have polystyrene, so this is poly methyl methacrylate, this is polystyrene polystyrene you have H H H and C 6 H 5, this is for basically polystyrene is a very well known packaging material ok.

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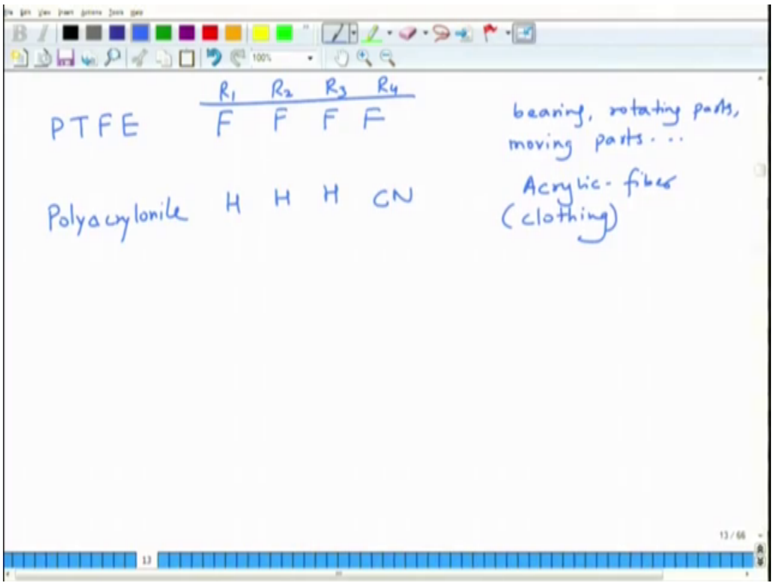

And then we have some other examples two more examples. Let us say few more examples PTFE poly tetra fluoro ethylene in that case R 1, R 2, R 3 are all replaced by fluorines F, F, F, F. So R 1, R 2, R 3, R 4, F F F F and PTFE is something which is a very well known engineering material it is used for making bearings, it is used for making sliders, it is used for making various other components, and devices ah. So, this is for making bearings for example, rotating parts, moving parts and then we have polly.

So, this is polly tetrafluoroethylene ok, and then we have polyacrylonile here 3 fluorine hydrogen's remain. One is replaced by cyanide group, and this has basically a acrylic fiber; where is it used for the sweaters that we are clothing. So, wool is substituted by this fiber which provides you a cheap, cheaper yet durable sweaters. So, these are some examples of polymers that we poly poly ethylene based polymers that we see.

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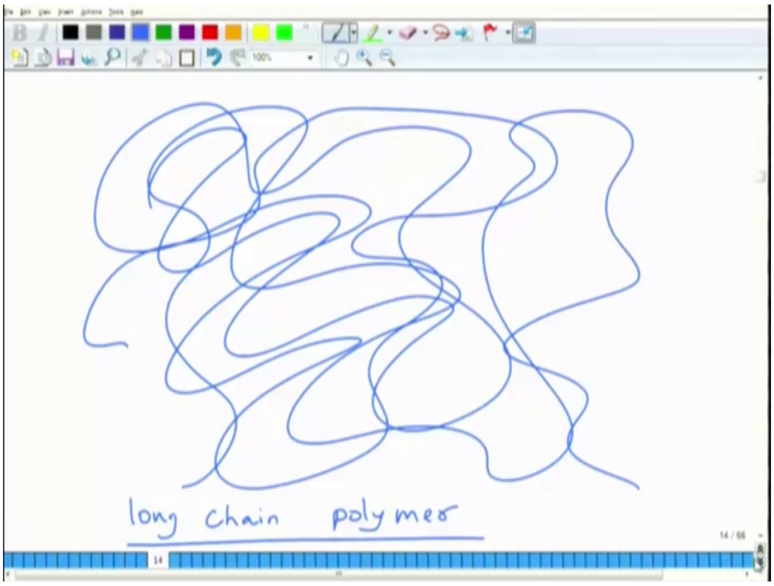

So, essentially so a long chain polymer basically would look like you have this long chain going. And then you have another long chain going like this and along the chain you will have molecules sitting next to each other. So, this is basically a long chain polymer.

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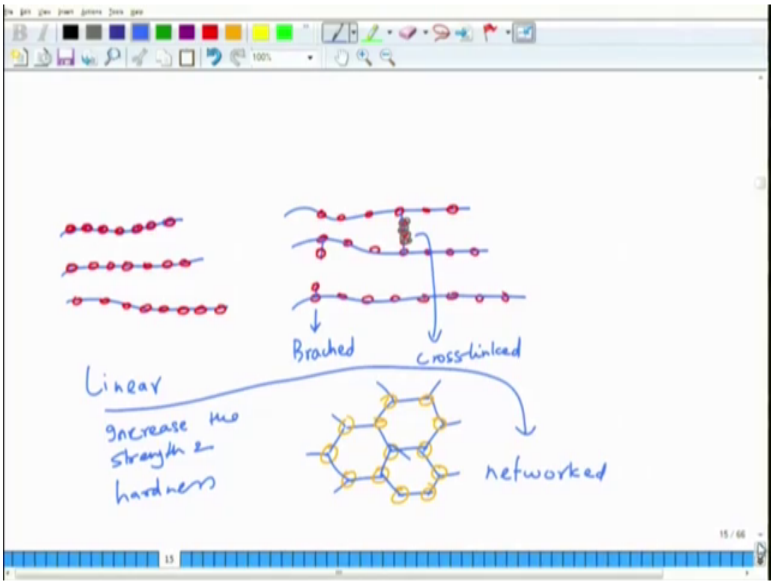

And if you want to see the chain configuration a linear is like this. So, you have these molecules sitting across like this if I use different color, these are linear molecules and so these are linear ok. And the ones which are cross linked are so you have these as other polymers, you have these molecules mer units, and if these are arranged if these are connected with each other using linkers.

So, you can have these branches here. So, you can have some molecules linking them, similarly you can have this linker this could be complete linkages, they could be broken linkages. So, for example, if its if it is broken here let us say it is incomplete ok, it is it could be like this or it could be like that ok. So, this is basically this would be branched, and this would be cross linked ok.

Student: Cross link will be also a mer unit.

Of course cross linking also you know you can have mer units, you can have some other units. Cross linkers are bit typically different cross linkers. So, cross linkers for example, when you do vulcanized sulfur sulfur replaces the makes the cross linkers. So, cross linker molecules can be different, so these are cross linked so.

Student: (Refer Time: 26:52).

I do not need.

Student: (Refer Time: 26:53) secondary bondings.

Yeah secondary bond does not really cross link for cross linking you need to provide some molecule which links the two chain. So, this is basically a cross linked structure, this is a branch structure where they do not talk to each other. They are close to each other, but they do not talk to they are not connected to each other.

So, this is branch this is and then you have network structure network structure could be something like that, like this. Let us common, but it is possible. So, you have molecules sitting here, here, here, so this is a networked structure just like you saw in glass quads ok, so this is a network structure.

And this basically as you go from here to here to here to here you increase the the strength and hardness. As the site groups become more and more bulkier or heavier as strength increases that is what you see in polymers linear chain polymers, as you go from hydrogen to chlorine you know CH 3 group or C 6 H 5 group typically they lead to increase in the strength and hardness.

And if you have more cross linking it is going to lead to even more branching or cross linking it is going to make it even more stronger and harder. Because chains will not be able to move against each other very freely and if you network it it is going to be becoming even more rigid. So, this is typically the classification of different types of polymers.

So, what we will do in the next class is we look at some more classifications of the polymers and some examples of elastomers and other kind of materials. Before we completely close the chapter on structure of materials moving on to the structure characterization, and defects in materials before we complete the course ok.

Thank you.