Introduction to Materials Science and Engineering

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Lecture – 39
Thermoplasts and Thermosets

Two kinds of polymers are identified, Thermoplasts and Thermosets.

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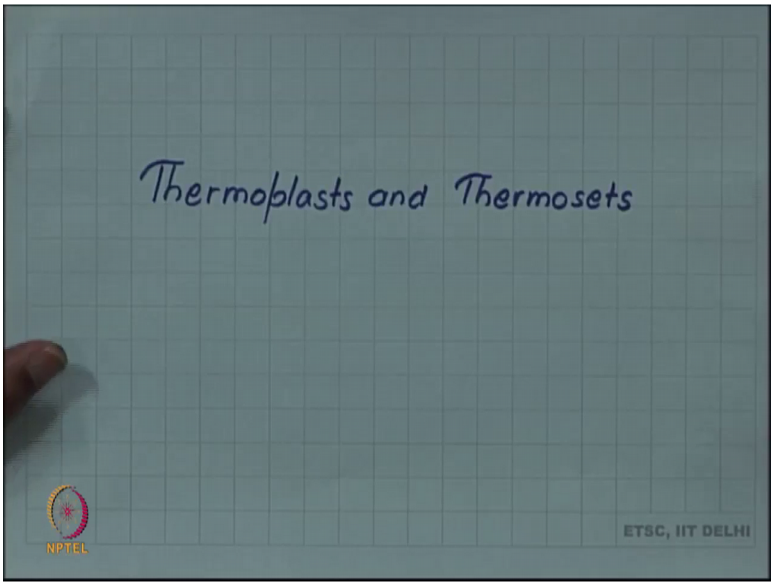

So, we will look at these 2 kinds.

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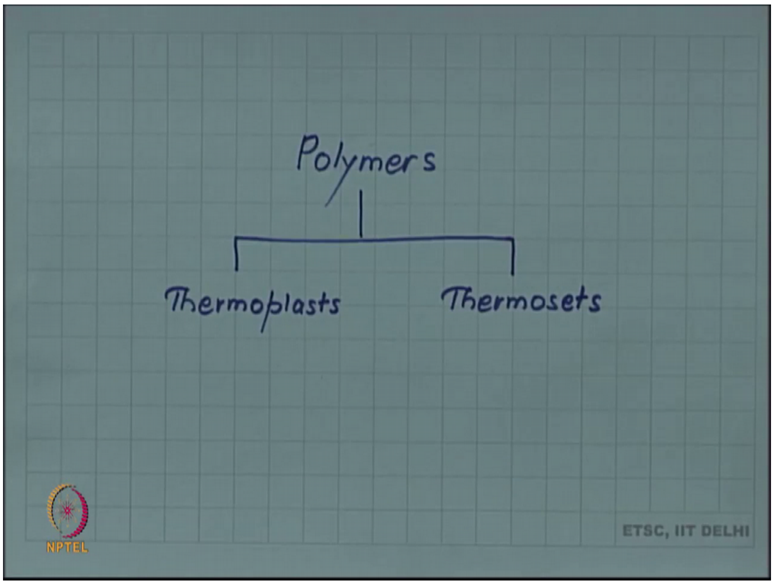

So, polymers classified as Thermoplasts and Thermosets.

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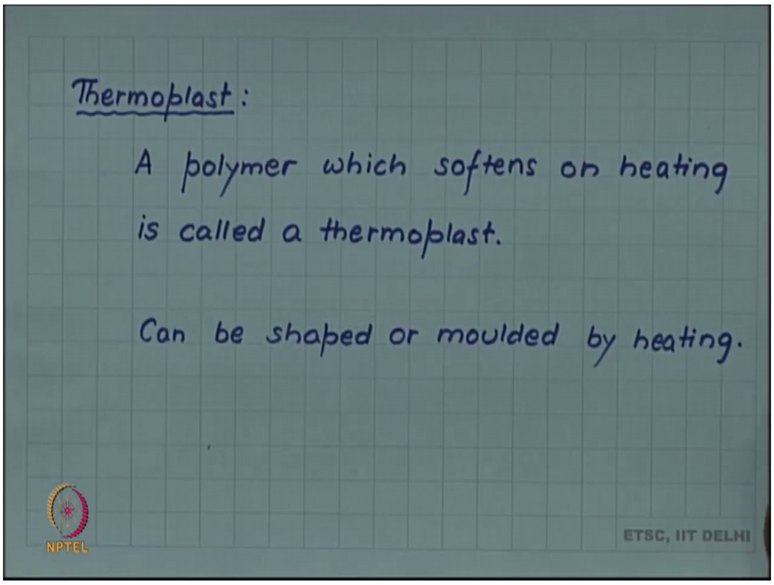

Thermoplast is a polymer, which softens on heating. In fact, the plast means plastic and plastic means mold ability that they can be molded or shaped by heating and that is why the term thermoplast is used for such polymers.

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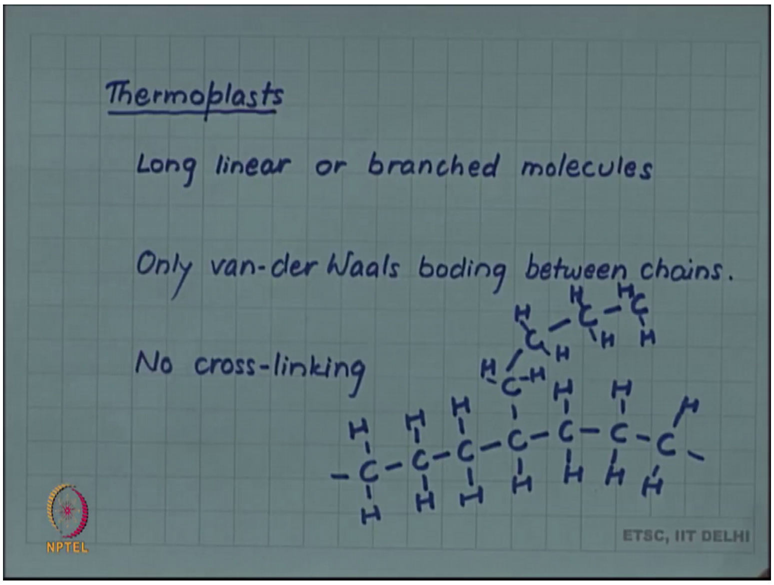

These thermoplasts usually will have long linear or branched molecules; we have seen the linear molecule let us talk about branching.

So, a linear molecule will have all carbon chains in 1 line, not necessarily straight line we have talked about conformation. So, about every bond there is a possibility of rotation. So, it can take different shape in space, but all carbon atoms are along 1 line let us say in polyethylene, but some and others are all hydrogen atoms, these are hydrogen atom, I am placing hydrogen atom at all of them except 1, if this hydro instead of a hydrogen atom here, suppose I place a carbon atom.

So, this carbon atom will then start another branch of the polymer and we will call this a branched chain or a branched polymer, others are still hydrogen. The other fact about these thermoplast, that there is only van-der Waal bonding between the chains. What this means?

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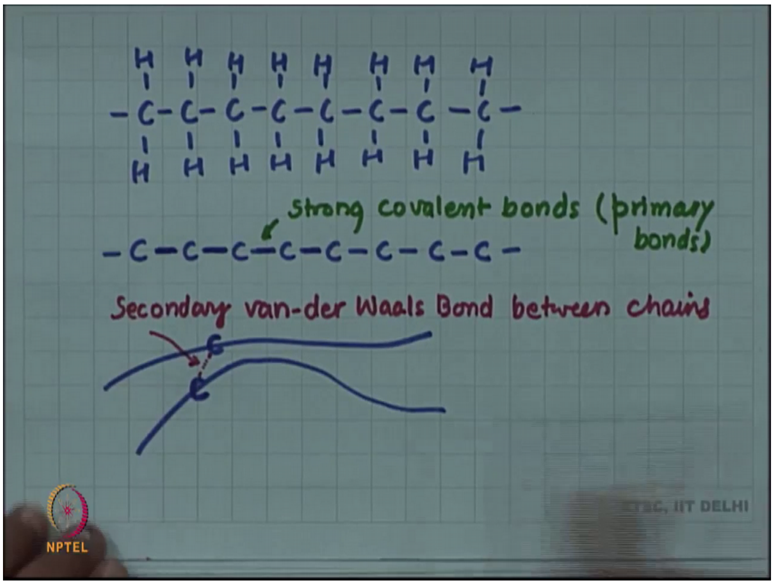

Let us explain, the van-der Waal bonding means, now I was drawing the carbon-carbon chain like this with hydrogen's attached to the carbon this is the structure of polyethylene which we have discussed.

Now, for simplicity let me just draw the carbon backbone, when we have to simplify drawing these molecules, if we just draw the carbon-carbon backbone and assume hydrogen to be attached, wherever they are required. It is still a simpler way is to just draw a line and assume that this is the carbon-carbon backbone with hydrogen's attached to it. So, this is 1 polymer chain and they there can be another polymer chain in the same sample, so this is chain 1 this is chain 2.

Now, within the chain we are seeing that carbon-carbon bonds are all covalent bonds, these are strong covalent bonds, these are called primary bonds. However, this is within a chain, across the chain between 1 chain to another chain. So, suppose there is a carbon atom here, so all it is bond is satisfied and another carbon atom is here all it is bond are also satisfied. So, there is no primary bonding between this carbon and this carbon.

So, they attract each other only through a secondary bond called the van-der Waals bond, the secondary van-der Waals bond between chains. So, if only secondary bonds like this is there, 1 chain is more or less free with respect to the other chain and can slide easily. So, the deformation of such polymers is easier, that is why when it is heated at higher temperature the our molecular vibrations are sufficient to overcome these van-der Waal bonds and 1 chain can slide with respect to the other chain and deformation or moldings is possible.

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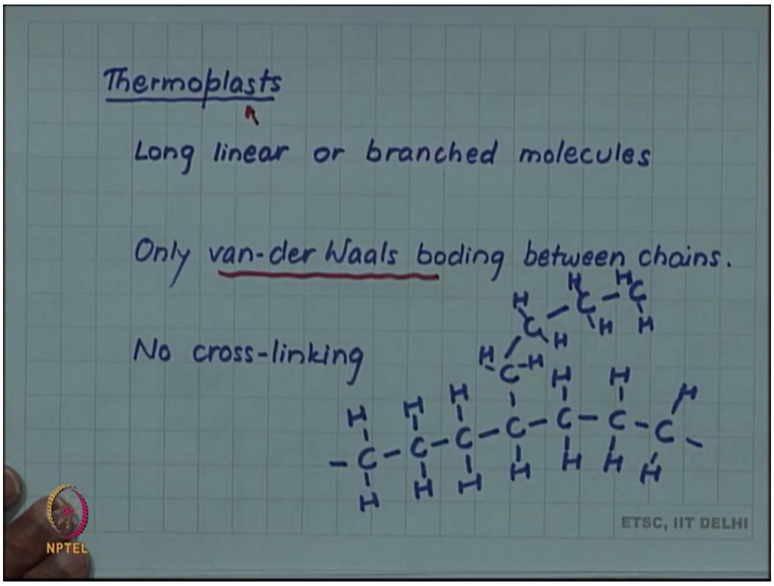

So, that is why these thermoplasts have only van-der Waal bonds, which actually gives them the plasticity, also there is no cross linking between the chains. So, if we think about the cross linking, let us talk about the cross linking.

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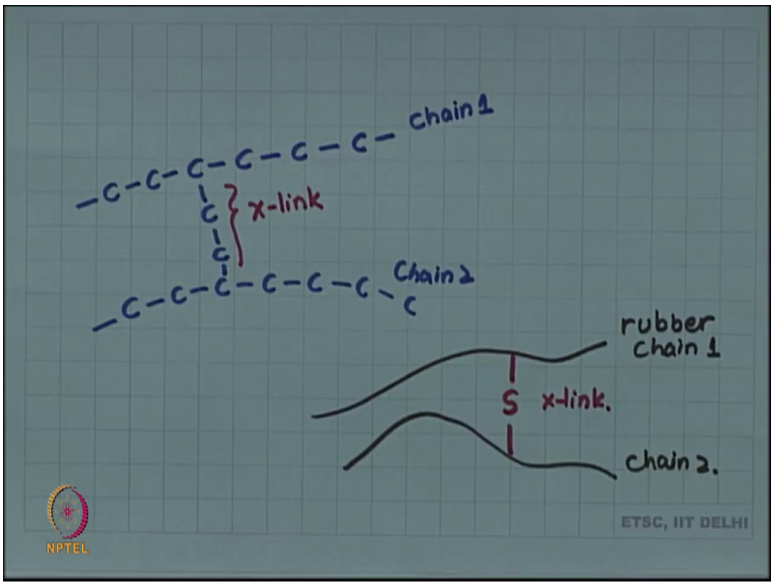

So, just like we saw that a carbon-carbon chain can be there with hydrogen attached to satisfy all the 4 bonds, but if there is another carbon-carbon chain and suppose there is a carbon-carbon bridge between these 2 chains now, instead of 1 of the hydrogen was replaced by a carbon here and that bridge continues and connects with the other chain.

So, this is let us say chain 1, this is chain 2 and this will be what will be called a cross link. You can see, any such cross link will prevent the easy sliding of the 2 molecules because if 1 molecule wants to slide, the other molecule will hold it through the cross link, so it is much more difficult to deform such cross linked polymers. What I have shown here is an internal cross link made up of same polymer chain as the original polymer, but you can have and we will see 1 example later in rubber, where if there is 1 macro molecule of rubber and another macro molecule of rubber. So, this rubber chain 1, this is the chain 2, then a process of vulcanization happens were using an external chemical element in this case sulfur, you can have a cross link.

So, here is a cross link by an external element or a different element, we will talk about this a little bit more detail later. So, there is no cross linking.

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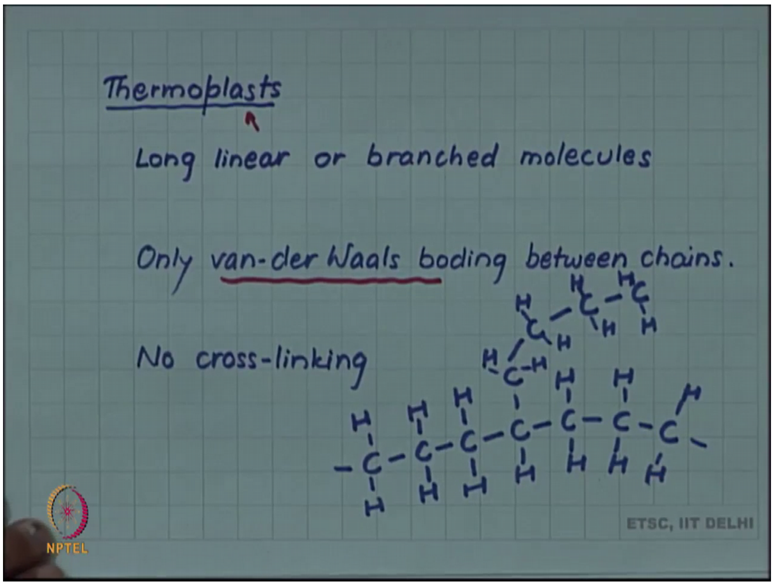

In thermoplastics, there is no such cross linking. We will see that in thermoset such cross linking are there.

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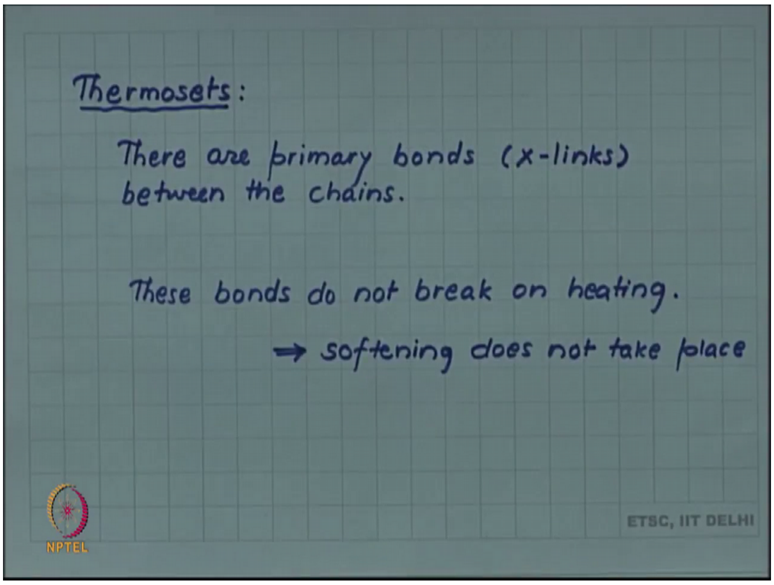

In thermo sets, there are primary bonds or cross links between the chains. So, these cross links are also primary bonds. So, these bonds do not break on heating. So, softening does not take place. So, they cannot be molded by heating, once their shape is set after making the polymer and setting it for the first time their shape is set. So, that is why they are called thermo set by heating these primary bonds do not break and cannot be overcome and so the deformation or molding is not easy, so these are called thermo sets. Let us look at some example of thermoplast.

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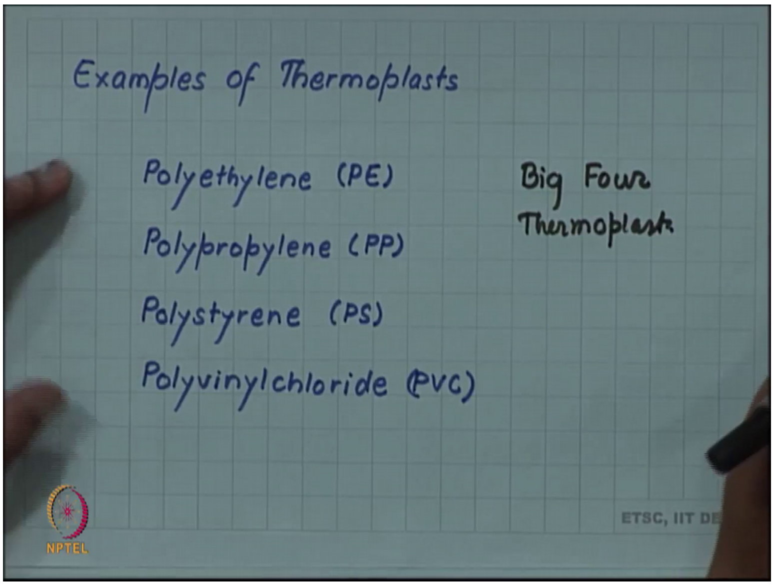

So, all the vinyl polymers which we were talking about, all of them are actually thermoplast and 4 of the most important, the so called big 4, these are big 4 thermoplasts polyethylene, polypropylene, polystyrene and polyvinyl chloride. They actually constitute about 85 percent of the thermoplastic market.

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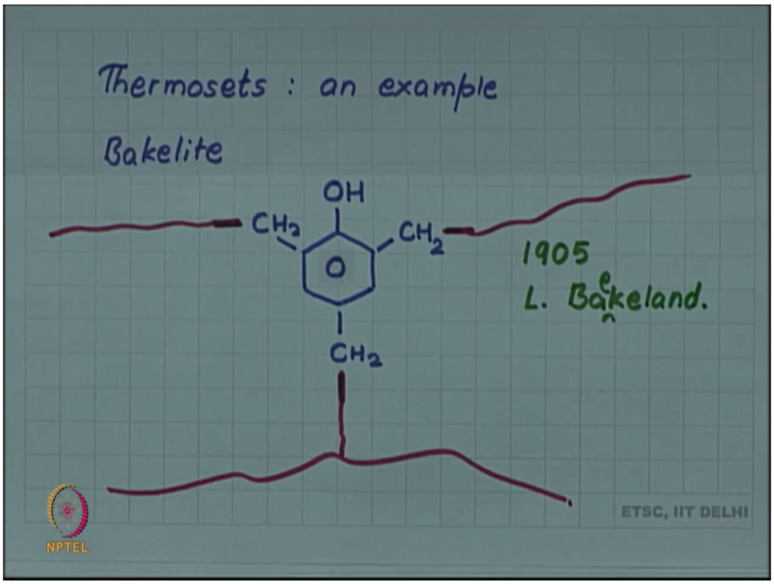

A really interesting example of a thermoset is a Bakelite, you can see in the Bakelite monomer which is shown here this is the aromatic or benzene ring, 3 of the hydrogen's are substituted by CH 2 group and 1 hydrogen is substituted by the OH group and these CH 2 groups then have 1 free bond to connect when other monomers, but since each monomer unlike polyethylene, where each monomer had only 2 free bonds.

So, it grew in a linear way, here each monomer has 3 free bonds. So, you can see that it will grow in a network structure and which will naturally be cross linked, the chains will not be free, but will have, if suppose this with the addition of monomer this chain is growing this way, but this will then be cross linking to some other chain in the structure. So, these get a network or cross linked structure, this was in fact, Bakelite, Bakelite was 1 of the first polymers developed around 1905 by an inventor called Leo Baekeland. This was 1 of those first synthetic polymers developed by mankind.