Processing of Non-Metals

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Module - 4
Plastics: Properties and processing
Lecture - 1
Thermoplastics and Thermo Sets

A warm welcome to all of you in this lecture on thermoplastics and thermosets. As we have been discussing in our series of lectures in the course processing of non metals, we have been discussing the series processing of various types of non metals. So, polymers are plastics also represent one category, which have properties which are far similar to the non metallic properties. So, in this particular module that we are going to cover now, that is processing of plastics or polymers, we would be having a series of seven lectures. Just to give you overview that in our course of processing of non metals, we have seven different modules, out of which this is module number 4.

We have already seen in module number 1, that what are the various types of engineering materials, what are the various types of manufacturing processes, which are used to process this materials? And we have seen that what is the basic differentiation between a metal and a non metal in lecture number 2 in module 1? Then we shifted our attention to the different classes of materials in module 2, we have covered glasses. We have seen that what are the various processing techniques of glasses, we have seen the melting of glass, what are the types of furnaces which are used? We have seen that how the shape is given to the glass when it is in the molten form? Different techniques with the help of the diagrams we have tried to understand.

Then in module 3, we have discussed the ceramics, and in module 4 now we are going to discuss the polymers or the plastics. Now, today's lecture is dedicated to the basic understanding about the polymers with differentiation between thermoplastics and the thermosets. Why? Because the processing would depend upon the properties of the type of polymer that we are going to process. Now, if we are processing thermoplastic the properties the processing would be dependent on the properties on thermoplastics. If we are processing thermosets, the processing techniques or the methodologies would dependent upon the properties of the thermosets.

So, basically we need to understand that what are thermoplastics? What are thermosets? How they are? What are the various advantages of each one of them or what are the advantageous properties of these materials, which we can take advantage of, when we want to convert them into any tangible product? So, there will be different types of product, which can be made by thermoplastics and thermosets, which we will be covering in today's lecture. That what are the various applications of the thermoplastics and the thermosets? In this particular module, we would be concentrating two lectures on the basic properties, the mechanical properties, the applications of the various types of polymers and the classification of various types of polymers.

Today is lecture number 1 in module 4, which is dedicated towards this particular discussion on the properties of the polymers. Lecture number 2 also we would be covering the same thing. Then the subsequent five lectures would be dictated or dedicated towards the processing of the polymers, in which we would be covering different types of processing techniques such as compression moulding, extrusion, injection moulding and some other processes, which are used for processing of plastics or processing of polymers. So, with this introduction to this particular module of processing of plastics, now we will start our basic definition of the plastics or the polymers.

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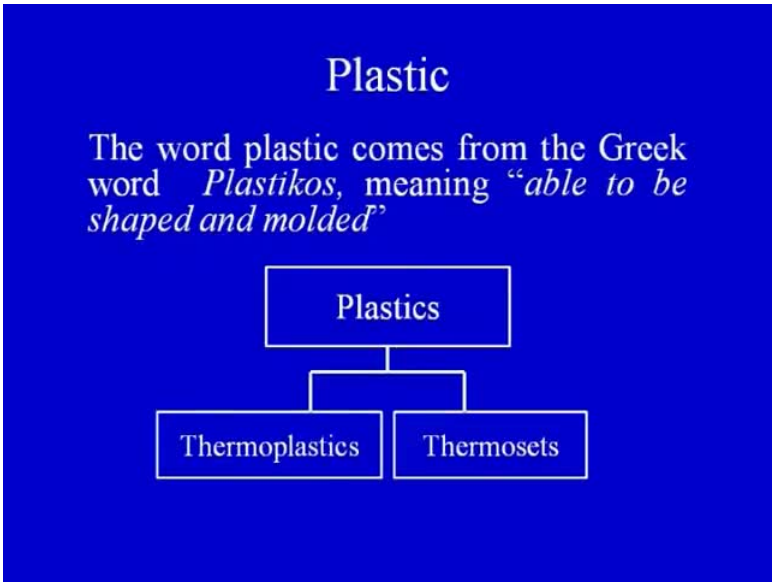

Now, what is a plastic? The word plastic comes from the Greek word plastikos, meaning able to be shaped and moulded. So, basically what is the basic criteria here, that this particular material, which we are calling as a plastic has the ability to be shaped and moulded, which means that we can give shape to a plastic material depending upon the requirement. Now, suppose I want to make a mouse that I am using with the laptop. So, this particular mouse has been moulded into the desired shape. The pen, the cap of the plastic pen, the cap is made up of a plastic material.

What does that signify? That any plastic which was in the raw form has been converted into the cap of the pen, which means it has been moulded or shaped into the desired forms. So, we will see that there would be a large applications of thermosets and thermoplastics that would be covered in today's lecture. But basically we should understand that what is a plastic? Plastic derives its name from the Greek word plastikos which means that it has the property to be shaped and moulded into the desired forms. Now, you can see on your screen, that the plastics or the polymers are broadly be classified into two categories.

That is thermoplastics and thermosets. This is the topic of our lecture today, to differentiate between the thermoplastics and thermosets and to address the various application areas of each one of these. So, as we have seen in the previous slide that the plastics or the polymers are broadly be categorized into two categories; that is the thermosets and the thermoplastics. So, we can see that definitely there has to be some distinction between these two types of polymers and therefore, they have been classified separately.

Another important point I would like to address here is, that why we are focusing on the properties of the thermosets and the thermoplastics in little bit detail, is because we have another module coming up in which we would be discussing the processing techniques for polymer matrix composites. So, basically a composite is made up of two broad constituents or two macro constituents, which are the polymer and the reinforcement or the matrix and the reinforcement.

So, a composite is made up of a matrix and a reinforcement and in case of polymer matrix, composite the matrix would be made up of a polymer. So, we need to understand that, which type of polymer we should use and which type of fibres can be incorporated

into that polymer, so that we get a very good property of a polymer matrix composite. So, from that point of view also or from basic understanding for module number 5 in which we would be discussing the processing techniques of polymer matrix composite. This discussion is also equally important.

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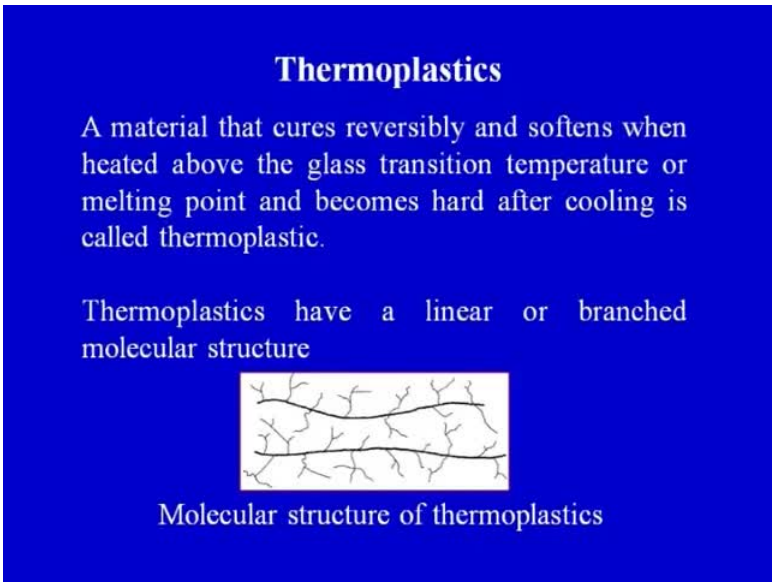

So, we should now try to understand that what are thermoplastics basically? So, a material that cures reversibly and softens when heated above the glass transition temperature or the melting point and becomes hard after cooling is called thermoplastic. This is a very very simple definition of a thermoplastic. Although, a more elaborate and more technical definitions can be given, but to make the understanding very very clear there are only two, three important words in this definition. I have tried to simplify the definition so that everybody can understand, that what is a thermoplastic? Basically, it is a plastic material, but it cures reversibly.

Now, important point to note here is cure. Now, what do we mean by cure? Cure basically means that it can be achieved by two different methods. It means that if the raw material that is the plastic is available in the raw form that it is suppose it is available in pellets from. Now, in this pellets we want to convert them into a solid form, so the curing process has to take place. So, curing basically can be done at a temperature or by combining or by a chemical reaction or combining two or three different constituents together. For example, in thermosets that we are going to cover in the today's lecture, we

will see that in thermosets suppose we have epoxy which is one type of a thermoset, this epoxy is combined with the hardener.

Because, of the reaction between the epoxy and the hardener that we have combined together, the curing process takes place. So, cures irreversibly means that from the raw stage to the final stage in which we want to use this particular plastic, it cures reversibly. Means once we can cure we can convert those pellets into the final product and again the final product we can heat it above the melting point of that particular plastic and again we can get the raw material. May be again it will soften and come backs to its original shape. So, basically a material that cures reversibly means that it can be brought back to its original shape or original type with the help of temperature.

So, a material that cures reversibly and softens when heated above the glass transition temperature or melting point and becomes hard after cooling is called thermoplastic. So, once we are suppose we have heated it while we are processing, it will become soft. Once we are remove the heat or remove the temperature it will become hard. So, basically we need to understand that thermoplastics cure reversibly. If I ask the question, that what can be the opposite of cures reversibly? The opposite would be cures irreversibly. So, in case of thermosets the curing process is irreversible. Once we have converted the raw material into its final shape or final product it cannot be brought back to its original shape or original type or original form.

So, that is a, that basic difference between the thermoplastics and the thermosets. We will that what are the various types of thermoplastics? What are the various types of thermosets? Why the difference between the two, when they are subjected to the curing process? Because, one is curing reversibly another one is curing irreversibly. So, there has to be some difference at a particular level, which makes this process to happen. So, thermoplastics have a linear or a branched molecular structure. Molecular structure of thermoplastics is given on the screen, we can see that these are the branches. It has the linear. Linear means this is linear, thermoplastics have a linear or branched molecular structure. There are different branches which are coming, this is a molecular structure of the thermoplastics.

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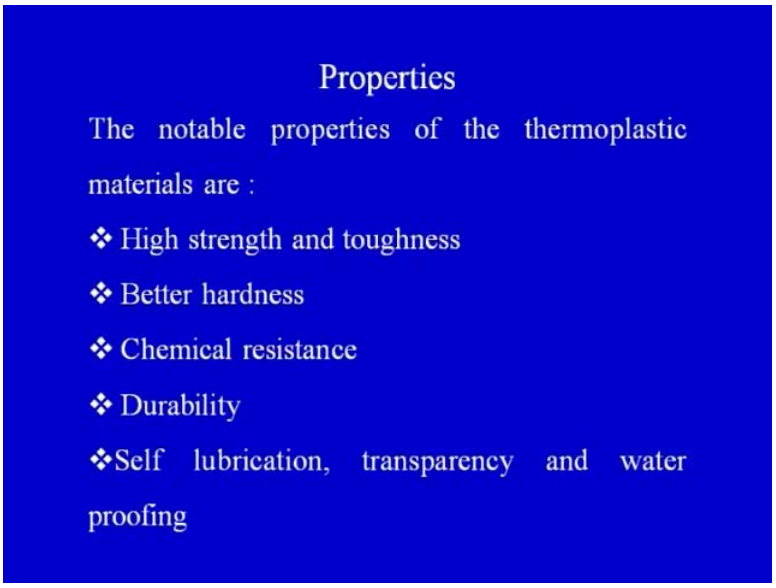

Now, what are the properties of the thermoplastics? The notable properties of the thermoplastic materials are they have a high strength and toughness, they have better hardness, chemical resistance, durability, self lubrication, transparency and water proofing. So, these are some of the properties and these properties would be useful when we are going to convert the thermoplastic into the final product. Now, we will see that what are the different types of products that can be made out of thermoplastic material? But these are the properties which would dictate their application into the market that for making a particular type of a product these properties would be useful.

So, once gain we can revise that one what are the various properties that the thermoplastic possess, that they have high strength and toughness, hardness is good, chemical resistance is good, durability thermoplastic components can be durable and they can have self lubrication properties and they can be made transparent also. And sometimes if if a particular product has to made for water proofing thermoplastic can be used for water proofing applications also. So, we have seen till now that thermoplastics are the materials, which cure reversibly. Once we have made a product again we can heat and bring back to its original form the plastic, once it has been converted to the final product we can heat it and again bring it back to its original form.

We have seen what is the, it has the linear and the branched structure and we have seen that what are the important properties of the thermoplastics? Now, we will see types of

thermoplastic materials, because it is a very big family. When we will see the various processes or various processing techniques, which are used to process this thermoplastics into the final products or different types of product with these would be the raw material that would we would be using to convert them into the final product. So, what are the various types of thermoplastics materials?

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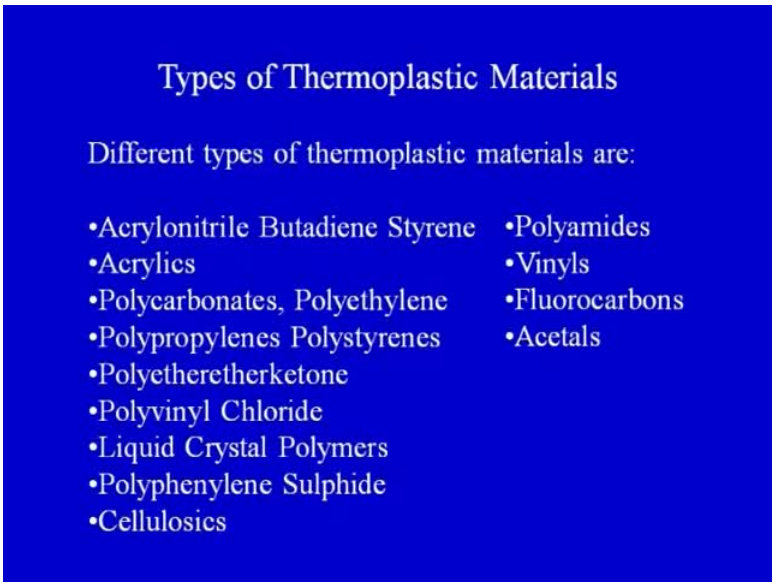

On your screen, you can see types of thermoplastic materials. Different types of thermoplastic materials are acrylonitrile butadiene styrene, which is most commonly called as ABS. Acrylics, polycarbonates, polypropylenes, polyvinyl chloride, liquid crystal polymers, cellulosics, polyamides, vinyls, fluorocarbons and acetals. So, there are different categories of thermoplastics materials and which can further be blended and there can be a huge family of thermoplastic material, which can be used to convert various types of tangible products. So, we will see that what are the various types of products that can be made out of thermoplastic materials.

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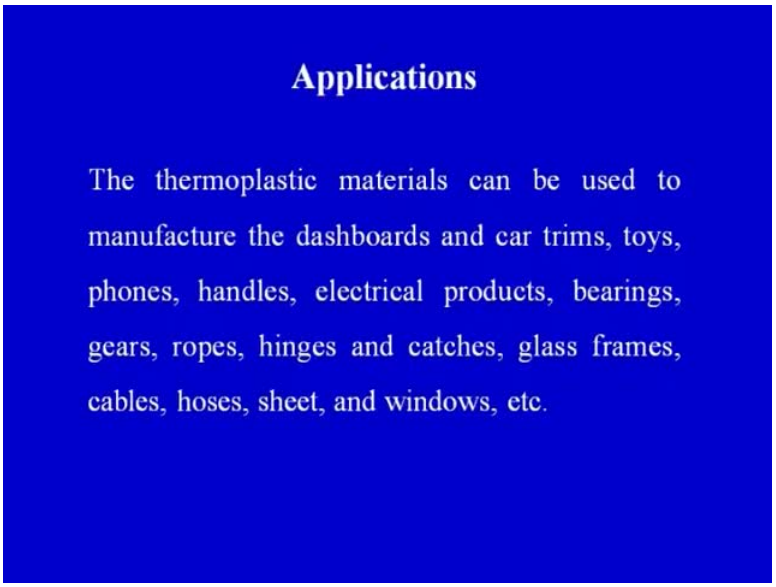

So, coming onto the applications that what are the various applications of the thermoplastics? The thermoplastic materials can be used to manufacture, now these are the applications. In our module our focus is to understand the processing technique that can be used to process this thermoplastic into these products. Now, the products are there on your screen already. We can convert this thermoplastic materials into dashboards, we can make car trims, different types of toys can be made out if these thermoplastic materials, phones, handles, electrical products, bearings, gears, ropes, hinges and catches, glass frames, cables, hoses, sheets and windows can be made.

So, different types of products can be made. Now, just see the products that are listed on the screen. Just take a while and have an idea, that what are the various types products which are listed on the screen. We can see that these products vary in the application spectrum. Some particular products have got some specific require On your screen ments, some particular products have to be used under some specific requirements or some specific conditions.

Each product will have a different shape. It will have a shape complexity. Each product will have a size there would be some big product, there would be some small products. So, we can see that there are two three important things that come to our mind when we see the applications spectrum of thermoplastics, which is there on your screen. There are so many different types of products can be made of thermoplastics. We can have an idea,

now that the processes that would be used to convert these thermoplastics into the final product should also be very versatile.

So, that they can process the thermoplastics into various shapes into various complexities and into various specific designs. So, that the products which are made out of thermoplastics should be able to meet the design requirements of a particular product or of a particular specification. So, applications are there, materials are there, we have taken some examples of thermoplastics, we will see some examples of thermosets also. But how to convert these thermoplastics into the final products? How to convert the thermosets into the final product?

That would be our main objective of discussion in module number 4. As the title of the course goes processing of non metals, our focus is more on processing and less on basic physics or chemistry of the materials. But before going to the process we should understand, that what are the various materials that we are going to process? So, we have seen till now thermoplastics. In thermoplastics these are the materials, which cure reversibly.

Once we have converted them into final product they can be brought back into their original form. How? By the process of heating, above a particular temperature and when you heat it above a particular temperature they will again come back to its original forms. That means they cure reversibly. We have seen some examples of the types of thermoplastics, which are used in industry. Now, on your screen you can see the various applications of the thermoplastics which are there in our day to day life.

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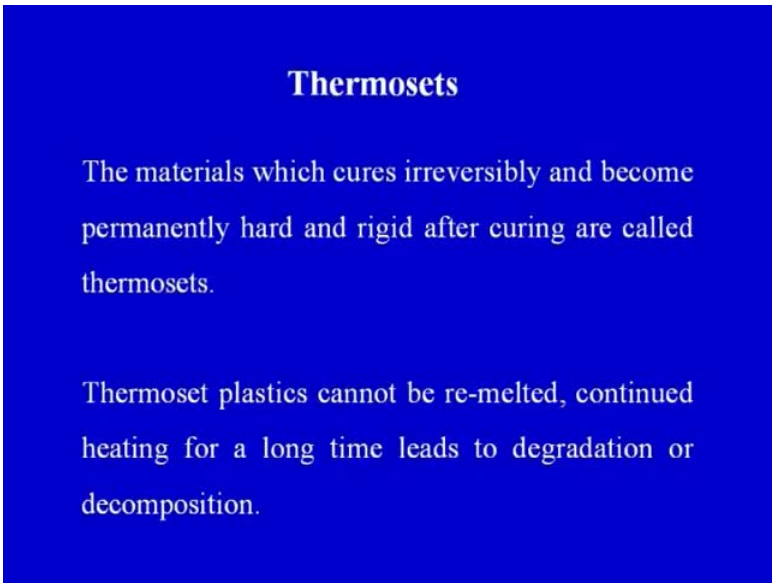

Now, coming on to the thermosets, that the second category of materials that is up for discussion in today's lecture the materials which cures irreversibly, the basic difference cures reversibly, cures irreversibly. So, cure irreversibly means that once we have converted the raw material that the thermoset material into the final product. How it can be converted? Either by heating or by a chemical reaction. As in the very beginning of today's lecture I have given one example that epoxy is one type of a thermoset and it can be converted from it is, suppose epoxy is available in a viscous liquid form.

It is we can say, it is available in a liquid form. Now, we can mix a hardener which is also a liquid. So, epoxy is available in a liquid form sticky form and we have the hardener also available, which is also in the liquid form. We combine these two stir them together and the curing process takes place. Now, in this particular curing process from a liquid raw material we get a solid final product. So, for conversion of the liquid into the solid can be very vaguely called as a curing process.

Otherwise there are chemical reactions that takes place in this process, but just to understand that we have a raw material. The raw material is in the liquid form or we can say sticky liquid form or a gel form. We mix another material that is we call as a hardener, so we have a epoxy, we have a hardener, we mix the epoxy and the hardener in a predetermined proportions. It can be by weight or volume and then you mix them

together and allow them to cure or allow them to solidify. So, from liquid raw material we are getting a solid final product.

So, that is called the process of curing, but what we try to understand here is, this process in case of thermosets is irreversible. As on your screen you can see the materials which cures irreversibly, once we have converted this gel with the hardener by the heat or the reaction of the heat, heat of the reaction sorry, it converts into a solid form and we get a product. Now, suppose this is the product I get from the liquid I have got the solid. Now, suppose if I heat it at a critical temperature or higher temperature, this I will not be able to get my constituents back.

What I have added? I have added epoxy and hardener in predetermined proportions. Now, these two things have combined together, one was available in a gel form, another one was available in a liquid form. These two were combined together, they were mixed and then were put into a mould, which was having this particular shape and the mould when the curing process took place, it took a solid form, this is the final product I have got.

Now, this if I heat again at elevated temperature or at a critical temperature for this particular type of a thermoset, I will not be able to get the constituents that is a gel and the liquid again. Why? Because, the answer is very clear on your screen, the materials which cures irreversibly. So, the process of curing conversion from that liquid into the solid is irreversible process. That means that I will not be able to get the raw materials in the same form in which I have used before producing this particular product. So, the materials, which cures irreversibly and become permanently hard and rigid after curing are called thermosets.

Whereas, in case of thermoplastics if I combine the two raw materials together and make a final product and if I heat I may be able to get or if it is one material only, one raw material and it is heated, because I have told that curing process can be a complete in two different ways. Either we can heat it and do the curing process another is by the reaction of two different constituents together we can start the curing process or we can perform the curing process. So, basically if we have only heated the raw material and converted it into a final product, again if we heat we may get back the raw material in its original form, in case of thermoplastics, but in case of thermosets this is not possible.

So, again I am reading the definition of thermosets on your screen. The materials which cure irreversibly and become permanently hard and rigid after curing are called thermosets. Thermosets plastics cannot be re melted which I have already highlighted. So, they cannot be re melted, continued heating for a long time leads to degradation or decomposition.

So, the final product which I have made out of the thermosets, it will degrade, it can decompose, it can burn, it may not be usable after the heating process again, because it will decompose or degrade the properties may not be the same, as we have made earlier. So, basically in case of thermosets we are not able to get back our raw materials, once it has taken its final form. So, thermo sets have this specific property to be converted into hard and rigid solids after the curing process and it is the curing is reversible in nature, whereas in thermo plastic curing is irreversible.

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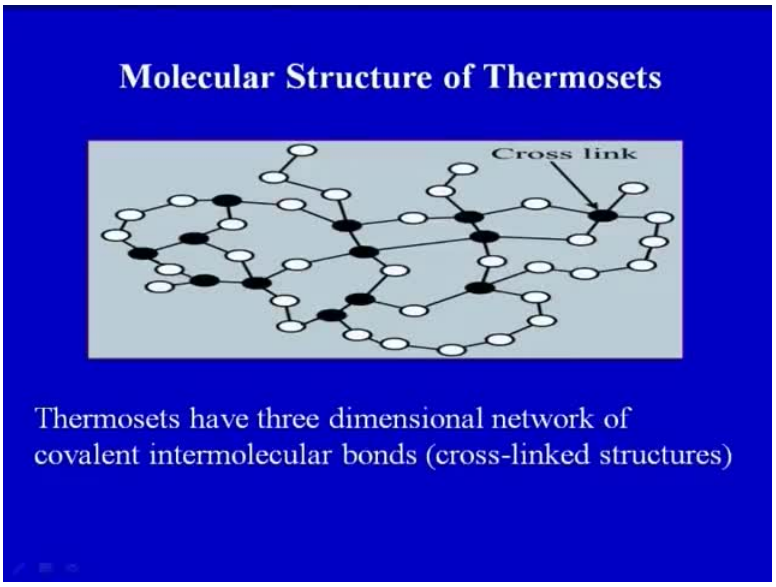

Now, this is the molecular structure of thermo sets, we can see on your screen. There is a cross link, this black portion, there is a cross link structure 3 dimensional, cross link network of covalent intermolecular bonds, cross linked structures are there. So, this are the 3 Dimensional network of covalent intermolecular bonds, which prevents prevent the reversible curing. In case of thermo plastics, this 3 Dimensional network is not formed, and therefore, the curing process is reversible in nature.

Whereas, in case of thermo plastic this 3 Dimensional network is formed, which avoids the process of reversibility or which makes the curing process of thermo sets irreversible. So, in case of thermo plastic no 3 Dimensional networks is formed, therefore the thermo plastic the curing process is reversible. In case of thermo sets you can see on your screen, thermo sets have three dimensional networks of covalent intermolecular bonds or cross cross linked structure, which makes the curing process irreversible in case of thermo sets.

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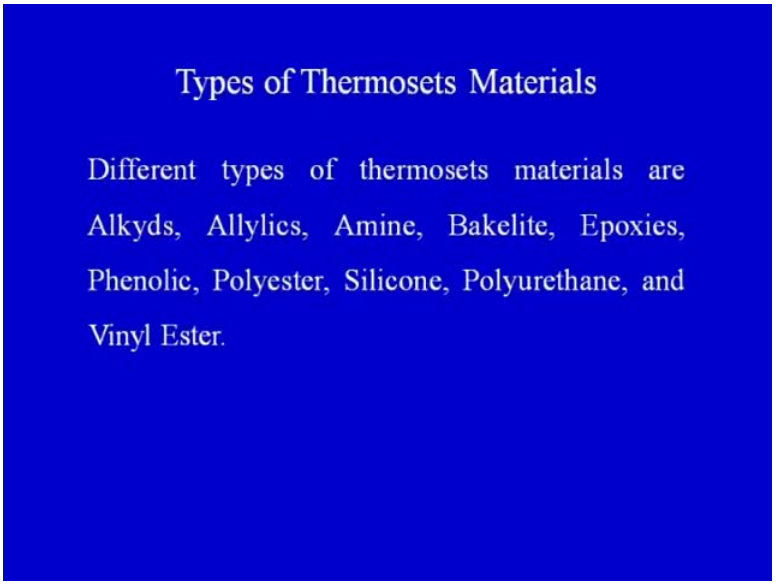

Now, we can see the different types of thermo sets materials. Different types of thermo sets materials are alkyds, allylies, amine, Bakelite, epoxies I have already given you an example of epoxies. We can have phenolic, polyester, silicone, we can have polyurethane and vinyl ester these are some of the thermo setting material, there can be other also. We have seen they are different types of thermo plastic material, they are different types of thermo sets materials. These materials have given different shapes and depending upon the requirement. They have different application spectrum, we will try to see that, what are the applications of the thermosets?

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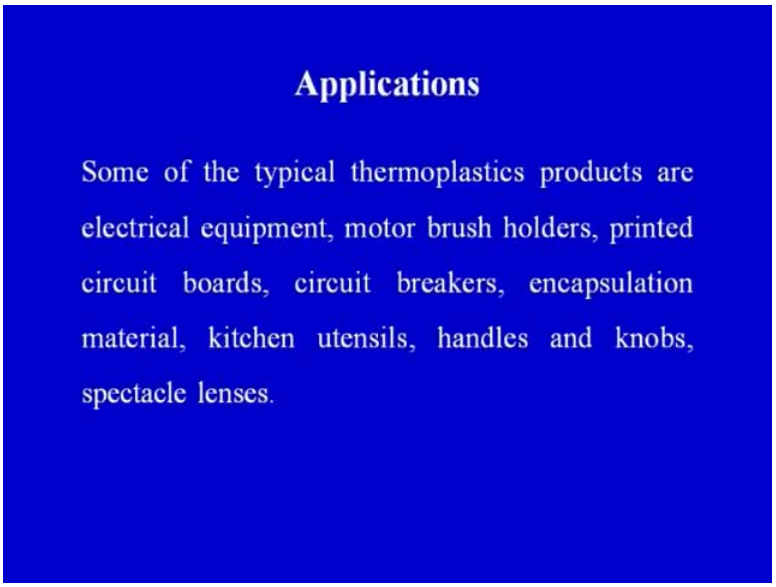

Now, on your screen you can now see the application of some of the typical thermo sets products. By so mistake it is thermo plastics, but some typical thermo sets those are the example of thermo sets. Some of the typical thermo sets products are electrical equipment, motor brush holders, printed circuit broads, circuit breakers, encapsulation material, kitchen utensils handles and knobs and spectacle lenses. So, they can be different types of application for thermo sets also.

We have seen that what are the application for thermo plastics, what are the application for thermo sets, and these are only some of the application, which we are able to list, in this particular presentation. But there are large number of application areas are also, where the thermo plastic and thermo sets are been used. So, we can see again here the different types of products are made out of these materials. One particular material we can see is curing reversibly, another one is curing irreversibly, but still we have a large variety of the materials available.

We have seen a list of thermoplastics which is available with the engineers, we have seen a list of thermo sets which is available with the engineers and all this materials can be converted into different shapes and form and into different products, which are been used word wide. So, basically need to understand, that what are the process which can be used to convert these basic raw materials. These raw materials may be as I have given u an example has epoxies, an epoxies are available in gel or a liquid form.

The other raw materials are also available in pallets form or powder form some time liquid or gel form. So, different types of raw materials, so different types of thermo sets and thermo plastics are available in different forms and these particular forms have to be converted into tangible products and different types of product that can be made out of thermo sets and thermo plastics have already been listed in this particular presentation.

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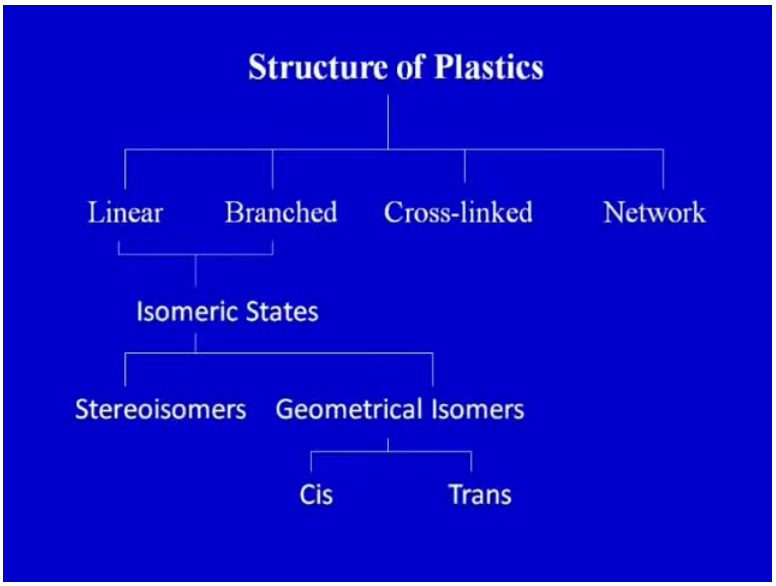

Now, we will try to understand the structure of the plastic. So, how basically a plastic or a polymer structure look like? So, different types of plastic and polymer can be there. So, we can have linear structure, branched structure, cross linked structure, network structure. So, different type of structure may be there, we will try to see the structure with the help of the diagram and which particular structure look like, because the final property of the polymer would depend or final product plastic will depend upon the type of structure, which is present in the polymer.

So, we will try to see the linear which have the polymer or plastic, which have linear structure, which have linear cross linked structure, which have branched structure? And further this linear and branched are and can further be categorized into isomeric state. The isomeric state and these are isomeric state can be stereo isomers or geometrical isomers. So, what are isomers that also we can understand in the subsequence slides. And finally, the geometrical isomers can be further be classified into cyst and trans type of

isomers. So, basically the main objective of today's lecture is to have a brief idea about basic theory of thermo sets and thermo plastic or in general the plastics as a whole.

We should know, how or what the basics characteristics of thermo plastic materials? What are the various characteristics of plastic material? What are the basic structure of a thermo plastic material? What are the monomers? And how these monomers get converted into the polymers? And how these polymers further made into desired products? So, our focus primarily is to have a review of the plastics or the basics science of plastics.

So, in this particular slide you can see the different types of structures are available. So, we can have linear structure, branched structure, cross linked structure, network structure and then the different isomeric stage are there for linear and branch structure. So, further stereo isomer and geometric isomers, and within geometric isomer we have cyst and trans type of isomer, now one by one we will try to see.

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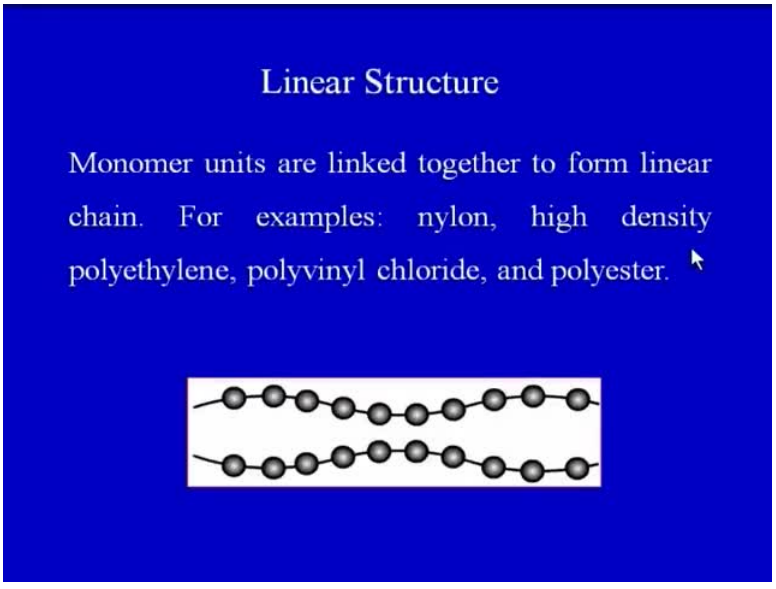

The linear structure is a very simple type of structure, you can see on the screen this is a linear chain. Monomers units are linked together to form linear chain. For examples nylon, high density polyethylene, polyvinyl chloride and polyester. So, all this types of polymers which are mentioned there that is nylon, high density polyethylene, polyvinyl chloride and polyesters all this have a linear structure. So, you can see the monomer units are link together to form a linear chain, so this is a simple type of linear structure. Now,

why we are discussing the particular terminology here that, some of the polymer may have a linear structure, some of the other polymer may have a branched structure, some of the other polymer have a cross linked structure.

Why? Because this particular structure would finally, dictate the properties of the material and these properties we need to understand and when we have to process them into the desired products. So, once we know that, this is having a linear structure very easy have an idea of what type of behaviour this particular polymer will show, when we try to process into a desired form? So, basic knowledge of the structure is important. So, one of the primary type of molecule, we can say structure of polymer is linear structure, in which the monomer links are formed together to form a linear chain. So, few examples are also given on your screen.

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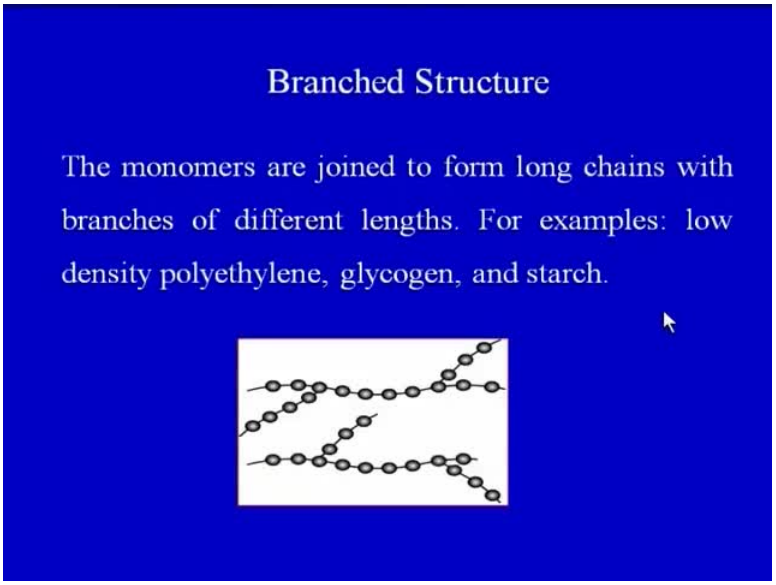

Then we have a branch structure in which the linear structure have branches also. You can see the monomers are joined to form long chain with branch of different lengths, we can see this is a branch, this is a another branch, this is a another branch. So, the length of the branch may be different, so the monomers are joined to form long chains, with branches of different length. So, what are the examples of branched structures? Low density, poly ethylene, glycogen and starch.

So, these are the three examples where they have a branch structure. So, we have seen that some of the polymer have linear structure, some of the polymer have branched

structure, and also some of the polymers have cross linked structured. Now, in crosslink structure, the monomer units are cross linked chain, so that it form a cross link chain.

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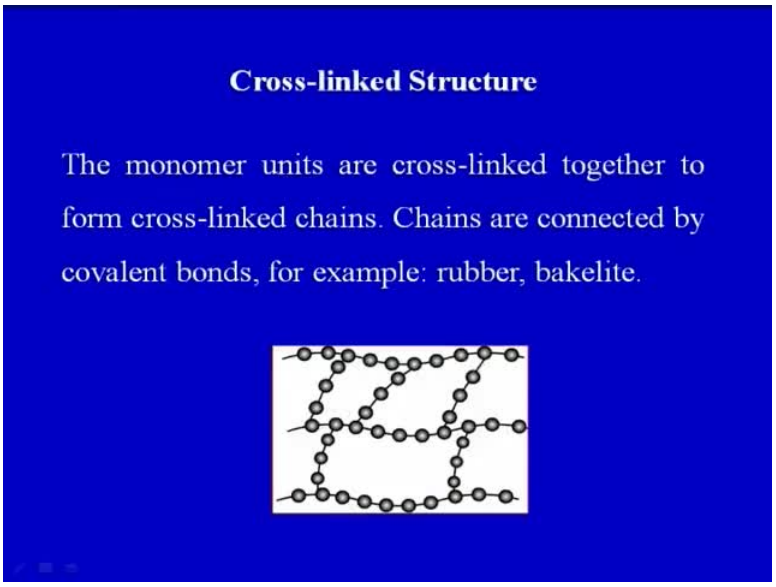

So, on your screen you can see the monomer units are cross linked, so there are cross links here. This is a cross link, this is a cross links, these are the linear chains, this is a linear chain. The monomer units are cross linked together to form cross linked chains. Chains are connected by covalent bonds. For example, rubber and bakelite. So, we can see that few examples of cross linked structure also. We can see the different types of structures are there, we have seen the linear structure, we have seen the branched structure in, which the branches of monomers chains are there and we have seen the cross linked structure.

So, this structures definitely we can see they are having special characteristics. Why? Because here you see the example is rubber and bakelite. Now, these two types of example are different in their properties in relation with other polymers, which are having a linear structure or which are having a branched structure. If you remember the linear structure have got certain examples, the branches structure also have got certain examples. So, those examples if you just have a overlook, that what was the materials, which were there linear structure or branches structure.

The properties of those materials would be different all are different from the properties of rubber and bakelite, which clearly indicates that the structure is definitely having

effect on the properties of the material. So, that is why we need to understand the different types of structures which are available, because when we discuss the process for processing of polymer or plastic, we would be seen, we would be telling this particular material suppose a epoxy has this type of structure.

Therefore, this type of process is been user for processing of a epoxy based products or they can be some other type of polymer. Because, of its structure a process would be used for process or processing, a particular technique would be used for processing that particular polymer. Therefore, we need to understand that they are different types of structure are there and each structure has got its own characteristics.

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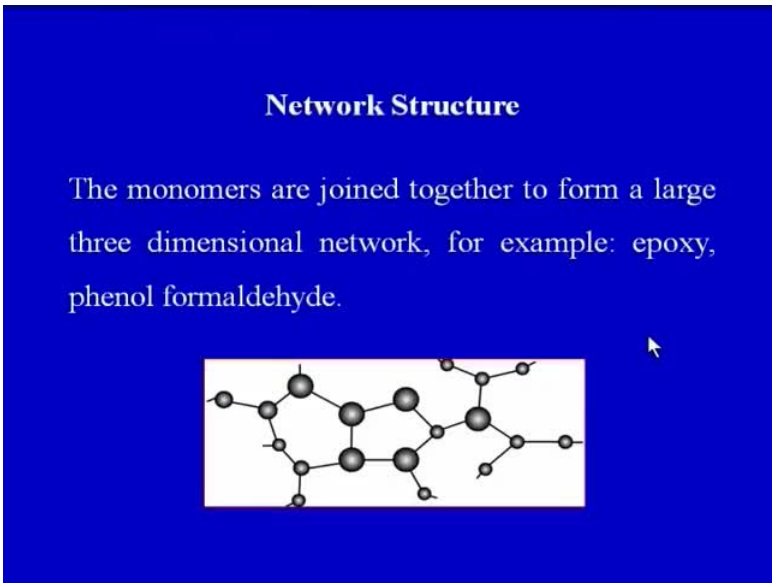

Finally, we have the network structure. The monomers are joined to form a large 3 Dimensional network. For example, epoxy or phenol formaldehyde. So, here also we can see, a epoxy has got a large 3 Dimensional network. And therefore, one important point that has been emphasized today in the lecture itself, that when we combine an epoxy with a hardener and make it cure it into the final product, the final product cures irreversibly.

That we cannot get a epoxy back, why? Because, of this structure. The monomers are joined together to form a large 3 Dimensional network, which is a rigid network and once this type of a network 3 Dimensional structure is formed, we are not able to do the curing irreversibly sorry, we are not able to do the curing reversibly. So, epoxy has got a

3 Dimensional network. So, we have seen different types of network are there, we have seen the linear network, there can be a branch network or a cross linked network or this is a network structure.

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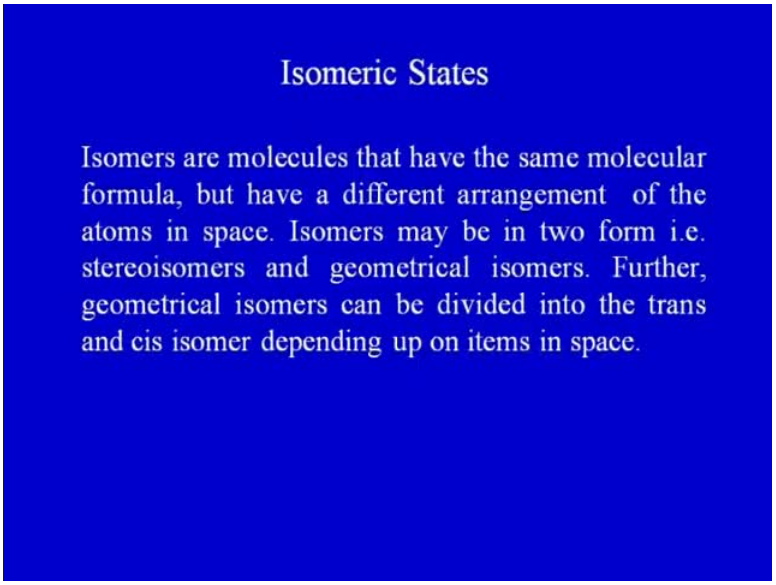

Coming on to the isomeric states, now what are isomers? Let us first read on the slide. Isomers are molecules that have same molecular formula, so that the molecular formula is same for isomer, then why there different? But have different arrangement of the atoms in space, so that the chemical formula of the molecular formula is the same, but they have different arrangement of the atoms in space. Isomers may be in two form, that is stereo isomers and geometrical isomers.

Further, geometrical isomers can be divided into the trans and cis isomer, depending up on items in space. So, further the geometrical isomers can be divided into the trans and cis types of isomer. So, in many cases we will see that the polymers may exist in isomeric states also, so isomers because this terminology we may be using some of our subsequent lecture. Therefore, this point has been clarified here, that what is basically are isomers?

So, isomers are molecules that have same molecular structure or some molecular formula, sorry, have different arrangement of atoms in space. So, isomers may be formed stereo isomers and geometrical isomers. Further geometrical isomer can be divided into two categories that is cis and trans type of isomers. So, this is just to have a brief over

view of isomeric state, which may exist in some polymers. Now, this are the plastic monomer which are further made into polymers, so this is an idea how a monomer may exist.

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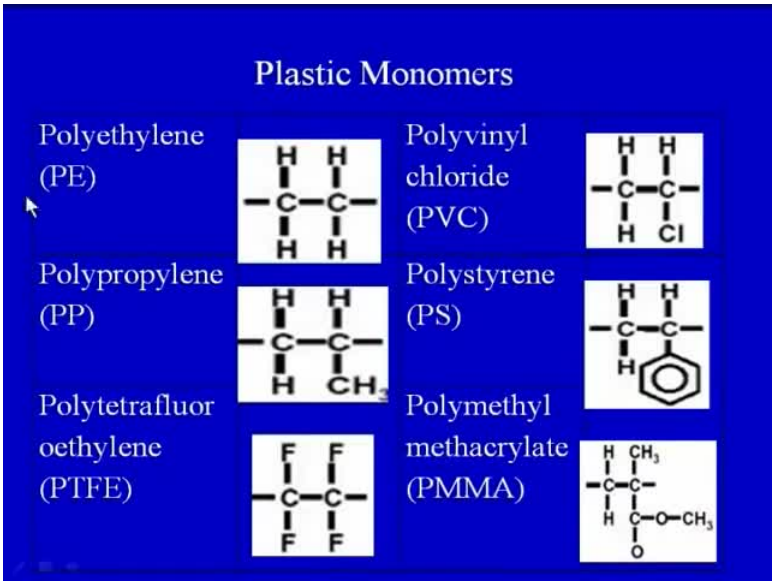

So, on your screen you can see this is a polyethylene monomer, the formula is given. Polypropylene this is PTFE, it is given here. Polyvinyl chloride we can see, polystyrene, PMMA polymethyl mrthacrylate. This is just to give an idea plastics are made up of different monomers and this monomers combine together to form a polymeric structure or polymer. As we have seen different types of structures, now what are the different types of structure which we have revise today? We have seen a linear structure, we have seen a branched structure, we have seen a cross linked structure and we have seen a network structure.

So, different types of structure we have seen. Now, this structure would have made up of monomers only. So, each monomers are then will combine with another monomer, then another monomer and polymerization will take place and we will get a polymer. Once we get a polymer that polymer will have its own distinct characteristics, it will have a different mechanical property, it will have a different physical properties, different properties of the polymer made out of this monomers would be different. So, here you can see the basic constituents are different, when different monomers will combine to form a polymer.

May be in this particular case if you say polyethylene monomer is given. So, the properties of polyethylene would be different from the properties of PMMA. Similarly, the properties of polypropylene would be different from the polystyrene. So, when this will have different properties, there processing techniques would be also different. So, our discussion would also focus on some of the properties of this type of plastics, which we are covering today.

So, our today's lecture is focusing on primarily on the revision of what are thermo sets and thermo plastics? What are monomers? What are the various type of structure which are present in the polymer? But subsequent lecture will focus on properties, because now we have seen that there are monomers combine together to form a polymer. How the polymer melt would behave? At what temperature what is going to happen? If we load a polymer into particular loading environment, how it is going to behave?

How the stress would been, stress strain behaviour would be there for a particular polymer? How the stress behaviour of the polymer would be different from metals or the brittle materials? So, all these things discussing in our subsequent lecture that is lecture number 2, so with this we come to the end of lecture number 1 in module number 4. So, I will just revise what we have covered today in lecture number 1 of module number 4. We started our discussion with a brief introduction of module 4, that we are going to cover in module number 4.

In module 4, our focus will be on covering on processing of plastics. So, major emphasis is processing on plastics, but before we go and start converting a raw material that is a plastic into a final product, we need to understand that what a plastic basically is? For that we have seen that plastic has desired his name from a Greek word which means that it can be easily molded and shaped, that is the shape can be given to the plastic easily. We can see that plastic can broadly classified into two categories, that is thermo sets and thermo plastics.

And in thermo plastics the curing process is reversible and in thermo sets the curing process is irreversible. We have try to understand that what is a curing process? In which have seen curing can be done either at a elevated temperature or by the reaction of the constituents. So, we have seen that, what are thermo plastics and what are thermo sets? What are the structure of thermo plastic and what are the structure of thermo sets? What

are the application of thermo plastic, what are the application of thermo sets? Moreover, we have seen that what are the various types of structures are there?

In which we have seen the linear structure, the branch structure, crosslink structure and finally, the network structure. Further we have tried to understand what we mean by isomeric states and that may exist in certain polymer. And finally, on this particular slide we have seen what are the various monomers, which are there present there in different types of polymers? And these are the polymers which we are going to discuss in a subsequent lecture or over subsequent series of lectures, when we would be making product out of polymers or these plastics. With this, we come to the end of lecture number 1 in module 4.

Thank you.