Processing of Non-Metals
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Module - 2
Glass: properties and processing
Lecture - 2
Glass Processing

Good morning to all of you, I welcome all to this second lecture of module number 2 that is glass processing 1. If you remember in module number 1 when we started this course on processing of non metals we seen, that what are the various types of engineering materials? What are the various types of manufacturing processes? How the properties of the materials affect their manufacturability? We have seen so many examples where we have seen that hardness melting point are some of the properties of the materials, which have to be taken into account when we are going to manufacture or process these materials.

In lecture number 2 of module 1, we have briefly differentiated between the physical and chemical properties of the metals and the non-metals. Since, our course is on processing of nonmetals our focus was on the various processing techniques which are used for various types of materials, which have the properties equal to or similar to the non-metals. In that direction our first module was on processing of glass or glass structures properties and processing.

In lecture number 1, we have focused on the structure and the properties of glass, where we have seen that what are the various types of glasses? Normally there can be broadly we can say there can be more than 500 types of glasses which are available today and which are used in various applications, depending upon the requirements. For example, for chemistry lab equipment, we require sometime a glass which can bear elevated temperature or high temperature. Sometimes we want to make a glass which is shatter proof, sometimes we want to make a glass which is opaque or sometimes which is transparent.

So, depending upon the requirement there can be different types of glasses which can be used in various engineering applications. So, in the lecture number 1 we have seen, that

what are the various types of raw material that can go into the manufacturing or processing of a glass. Moreover, we have seen that on the basis of the raw material how the properties are dictated? A glass which we have processed with a specific sei of inputs will have specific requirements or specific applications. If we modify the input we can make a different type of a glass. Basically we can control the constituents that will go in the making of the glass.

Finally, the final properties of the glass would be dependent upon the constituent, also the final properties depends upon the processing technique, that we have developed or that we are going to develop or that we are use. The shape size of the final glass that we are going to make, will depend upon the processing technique that we are going to follow for processing of glass. So, if you remember a brief summary of what we have discussed in lecture number 1, we have seen the properties and the structure of the glass and how these properties will affect the processing of the glass.

In today's lecture we will see that what are the various manufacturing techniques, so we in this particular module we are going to have three lectures. Lecture number 1 we have already discussed the properties and structure of glass. In the other two lecture that is lecture number 2 and lecture number 3 our focus primarily would be to the processing of glass. As the course is on processing of non-metals, so our major focus in all the modules would be on the processing aspects of materials, rather than the chemical and the physical aspects of the materials.

Although we would briefly be outlining the physical and the chemical properties of the materials because these are the properties, which would further dictate the processing of the materials. We will also focus on the mechanical properties as if you remember, as we have already seen in lecture number 1 of module 2 that, how is the stress strain behavior of glass? When the glass has been made, how it would behave in a particular application, when loaded under tensile condition or under the compressive conditions? So, our focus primarily is on the processing techniques and therefore, we would be seeing that how different forms of glasses or different types of glass can be made?

So, broadly the processes can be classified on the type of glass that we we manufacture. For example, we can have float process in which flat glass sheet will be made, we can have a process in which the glass wool can be made, we can have a process in which the

glass can be processed in the form of fibers, we can have a process in which the glass can be processed in the form of tubing, in another case we can have a tampered glass, we can have a laminated glass. So, there can be different types of forms of glass that can be processed using a number of techniques.

So, in today's lecture our focus primary would be to highlight the basic aspects of some of these forms, which we have already discussed. So, briefly summarizing what we have already covered in lecture number 1, we have covered the structure and properties of the glass. Today I have summarized that these are the properties these are the structures of the basic glass which would dictate. So, basically the structure and the properties of the glass would finally, define the processing techniques, which can be employed for the processing of glass.

So, we can very easily now correlate that we have to in each and every module first focus on the properties of the material and these properties would be the guidelines or would dictate the processing of those materials into the final shapes or final forms or the final products. So, we have already discussed in lecture number 1 the basics of the glass and today we will focus our attention on the processing techniques. So, with this introduction to today's lecture, let us start now the processing techniques for the glass. On your screen you can see that glass manufacturing stages or glass processing stages can broadly be classified or can broadly be summarized as on your screen.

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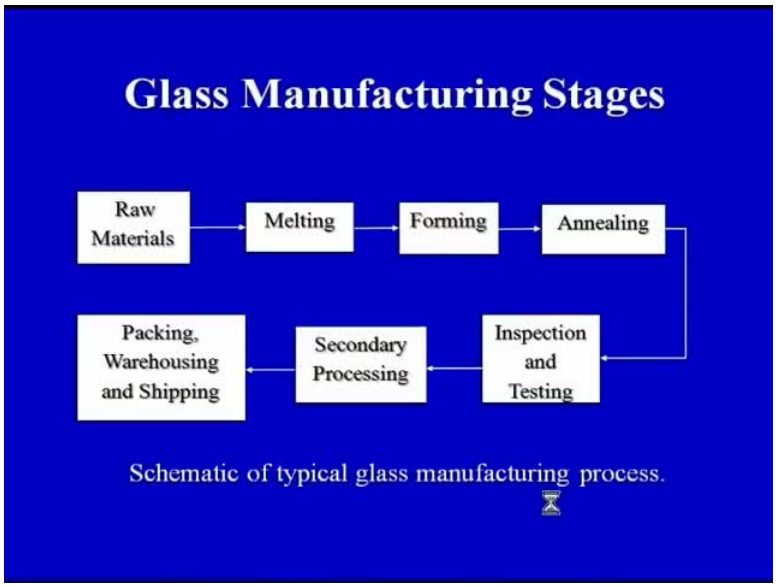

So the very first stage is the raw material stage, in which you have to manipulate, we have to control the proportion of the various constituents that go into the manufacturing of the glass. So, we have to see that what are the various types of raw materials that will go into the processing of glass and there are some raw materials which are completely essential to make the glass. So, we have seen in lecture number 1 that what are the various types of glasses on the basis of the raw materials that are used to process these glasses.

So, by the name we can see that there are different types of glasses, which we have already covered and I will not repeat in today's lecture, because today we are going to focus in the processing techniques. But we have seen in the previous lecture that what are the various types of glasses, on the basis of the raw materials that go into the glass. So, first important point is the raw material because we have to first manipulate or to first decide on the proportions of the raw materials that will go into the processing of the glass.

Second is the melting of the raw material, there are different types of furnace which are used to melt the raw materials. We will see that if the time permits in these three lectures our focus would be at least briefly outline that what are the various types of furnaces, which are used for melting the raw materials? So, the first stage is manipulation or the

combination of the constituent depending upon the final properties of the product that we are going to make out of glass?

So, depending upon the final requirement for example, we have to make a bullet proof glass, so for bullet proof glass we have to decide on the constituents in the first stage only were we deciding what are the raw materials? Suppose we want to make a self-leaning type of glass, there also we have to decide going to be the raw materials that will go into the glass? So, once the raw materials we have decided, sometimes after making the glass also depending upon the final requirement it may be quoted. So, there also that material of the quoting has to be decided that this particular glass would be quoted with which type of material and it should form a proper bonding, so that it is able to satisfy the desired requirements of particular application.

So, first two points are that we have to decide on the raw materials that will go into the glass processing of glass. Secondly we have to, second stage is the melting of those raw materials and once the material have been melted, it has to be formed. If you remember in lecture number 1 we have seen that, deformative process are processes are one of the important processes for processing of materials. So, here also once the we have the raw materials we have melted the raw materials, we have to give them the required shape.

As I have already told in the introduction to today's lecture that, we may be requiring the glass in the form of tubing, we may require glass as a flat sheet, we may require glass in the form of glass wool, we may require glass in the form of fibers, so depending upon the final shape or the final form of the glass that we want to manufacture at third stage, we will give that shape and that would be given by the stage of forming. So, the first three stages are; we have the raw materials, we melt them and using one or the other technique we give them the desired shape.

And finally, due to the processing and high temperatures involved in the glass processing, there are bound to be thermal stresses that may bound to be developed or there would be certain induced stresses in the final glass that we have manufactured. Therefore, this particular glass has to be annealed. So, the process of annealing would be done which we have already seen that heat treatment processes are done in the case of metals in order to relieve these stresses and for grain refinement in certain cases. So, here also in terms of glass processing we will do annealing in order to reduce the induced

stresses, which have been there in the final glass because of the processing. So, the fourth stage is the annealing stage.

So, basically these are the four stages in glass manufacturing processes. Once again we can revise that what are these four stages? The four stages are, the raw materials are combined together. This mixture or these we can say the combination of the various constituents of the raw which fall under the category of raw materials are combined together, they are put in a furnace or a melter where they are melted and after melting this particular glass or this particular constituents, various constituents that form the glass go into a deformation depending upon the final shape that we want. We have different deformational forming processes where different shapes will be given to the molten glass, which has already melted in the melter.

So, that shapes that we are going to make or that we are going to discuss in today's lecture are we can make a flat glass, we can make glass wool, we can make glass fiber, we can make glass tubing, we can make laminated glass, we can make tampered glass, so all these shapes would be given in the forming stage. Once the glass has been formed into the desired shape, the final glass that we have got would be annealed and the annealing is done in order to remove the internal stresses or the induced stresses due to the processing stages various processing stages.

So, once the stresses have been relieved we will go for the inspection and the testing of the glass. Why inspection and testing is required? Because the glass has to perform the desired operation or function, depending upon the application for which is it has been processed or has been manufactured. So, once we have a particular application in mind, the testing and inspection would be done whether the glass which has been processed with the initial four stages on your screen would be able to meet the stringent designed requirements for which it has been made or whether it would be able to satisfy the application for which it has been processed?

So, various inspection and testing techniques would be used to check the suitability of the glass for a particular application. The next step is the secondary processing. Sometimes in the secondary processing we may be requiring to make holes, so that this particular glass sheet can be processed or can be made or assembled with another part, which may mat be wood metal or any other material. So, secondary processing can be

certain finishing operations those can be certain machining operation, those can be certain types of coating that can be given on the glass for specific applications.

So, depending upon the final usage or final application many a times secondary processing would be imperative or necessary, so that the glass that we have made is finally, put to its desired application. Some of the secondary processing techniques, I have secondary processing methods I have already told or the secondary processing requirement we have already discussed, which are already important. Finally, the packing, warehousing and shipping, that is the packing warehousing and shipping would be done depending upon the requirements.

Now, we know that glass is brittle and there are chances that it may shut, so we have to pack it properly and we have to store it properly. We might have seen many a times it is written on the cardboard, handle with care, which means that when we are warehousing and shipping the glass in the various containers these containers should be marked properly, so that the glass inside the containers or inside the boxes should nor break. So, this particular slide gives us the summary of the basic manufacturing processes or the basic manufacturing stages we should say or the basic processing stages, which go into converting the raw material of a glass into the final shape that is usable.

So, basically we can revise once again because this is important, because this what we are going to discuss in the subsequent slide, where the basic processing would be given. So, in basic processing our focus would be on the two stages only that is the, that are the stage number two stage number three on your screen. In which we will consider that we have already got molten glass or the melting glass from the melter or the furnace. So, we have already got a molten glass.

Now, how a particular shape would be given how a glass would be formed into a particular shape that would be our focus. So, we would focus annealing in next lecture, but today our focus would be on the first two, first three stages, but primarily we are not going to discuss the raw materials which will go into the processing, why? Because in lecture number 1 we have seen that depending on the raw material, what are the various types of glasses that we can make? Today our focus is what are the various shapes and how those shapes can be made out of the raw materials?

So, our focus primarily will be in the stage number two and the stage number three of processing. But just to have a brief overview of what are the processing stages for glass, we can see that we have the constituents, we have the raw material, which is melted. Once it is melted it can be formed into any given shape, which can be done in the forming stage. Once the glass shape has been got we have got a glass in the form of a plate or a sheet or in the form of a fiber.

It may have certain induced stresses which have to be relieved, which can be relieved by the annealing process. Once annealing has been done, we do the inspection and the testing of the glass so that to we have to check the suitability of that particular glass, for a particular application. Then the secondary processing is done which may even require making of holes. Finally, the packing warehousing and shipping of the glass is done. So, one by one we will see the various processes that will be used for processing of glass into various shapes.

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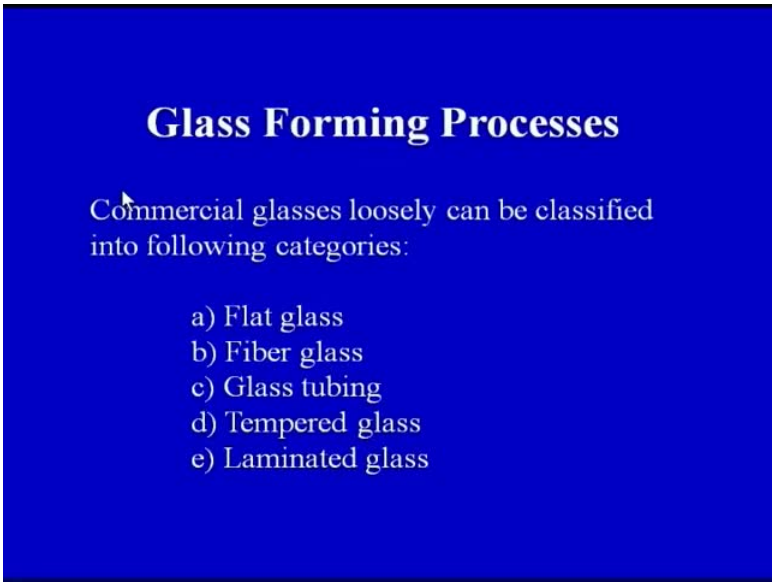

Now, this glass forming processes basically are we can see commercial glasses loosely can be classified into following categories. Now, we would definitely like to make the glass in any of these forms because these are the primary or general forms of glass, which are used in our everyday applications or everyday products. So, we can see we can have a flat glass, we can have a flat glass we can have fiber glass, we can have glass tubing, we can have tempered glass, we can have laminated glass.

Now, depending upon the requirement, we will have different types of glasses. The processing techniques of all these types of glasses would be different. Basic stages would be same as we have seen in the previous slide, that we will have the raw materials, we will melt the raw materials, we will form the raw materials into the desired shape. Finally, when we have got these shapes for example, we have got a glass tubing, if there are some internal stresses that are present it would be annealed, in order to relieve those stresses. Finally, the inspection would be done and the later stages of product development cycle, but primarily these are the various forms or various shapes of glasses which are used in our everyday applications.

Now, the processes that are used for processing of glass would also depend upon these shapes. For example, for a flat glass we will you have a different processes for glass tubing, we will have a different process. Similarly, for a laminated glass we will have different process. Now, we will see one by one that what are the various processes that are used for processing the glass into these types of commercially available glasses.

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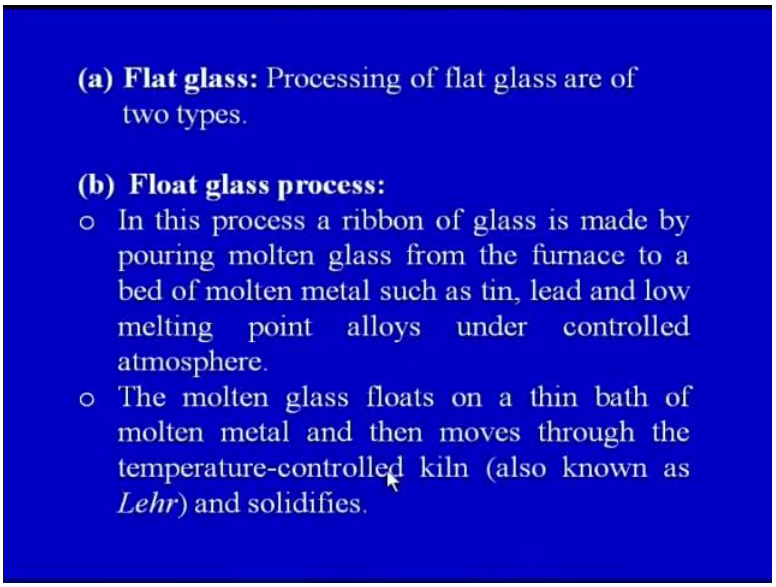

Flat glass that is the first type of glass. Processing of flat glass are of two types, now two types of processes can be used for flat glass. First one is there on your screen, we will try to understand with the help of a figure also, but but in order to have an idea of float glass process works, let us see in a float glass process a ribbon of glass is made. In this a

ribbon of glass is made by pouring the molten metal or the molten glass sorry, not the metal these are the processing techniques glasses. So, our focus is on glasses.

So, in this float glass process, a ribbon of glass is made by pouring molten glass from the furnace I have already told that furnaces are used to melt the raw materials, which will further be used or formed into the given shape. This particular process is focusing on the flat glass and the name of the process is float glass process. So, in this process a ribbon of glass is made by pouring molten glass from the furnace to a bed of molten metal. Such as tin lead and low melting point alloys under controlled atmosphere. It is not only tin and lead can be used, other low melting point alloys can also be used.

So, the bed would be made up of the molten metal such as tin, lead and low melting point alloys. And the temperature and the other important atmospheric conditions would be controlled. So, in this process we have a ribbon of glass is made by pouring molten glass from the furnace to a bed of molten metal. So, in this particular case the raw materials are melted, since we want to get a flat shape. Therefore, a ribbon, ribbon means flat geometry. So, a ribbon of molten glass is poured over the molten metal. So, we have a bed of the molten metal and the molten metal is of any low melting point alloy. So, examples are given on the screen we can have tin, lead or any other low melting point alloy.

So, we have a bed and on top of this bed we are pouring the molten glass and the glass is in the form of a ribbon. So, the molten glass glass floats on a thin bath of molten metal and then moves through the temperature controlled kiln, which is also known as the layer and finally, the glass solidifies. So, first of all we have the raw materials, we have melted them in a furnace and the ribbon of the molten glass is poured over the molten alloy of any low melting point alloy. Finally, the molten glass floats on the thin bath of molten metal and then moves thru the temperature controlled kiln, which is also known as the layer and finally, the glass solidifies.

So, I have revised or I have said whatever is written on the slide two times, so that we are able to understand that how and what are the various, we can say steps involved. So, we will try to understand this with the help of a diagram, but the important variables that have to be controlled in order to process a flat glass by this process with these. The

variables are the temperature of the glass is maintained at one 1000 degree centigrade for a long period of time, to separate the irregularities and to get the desired flat surface.

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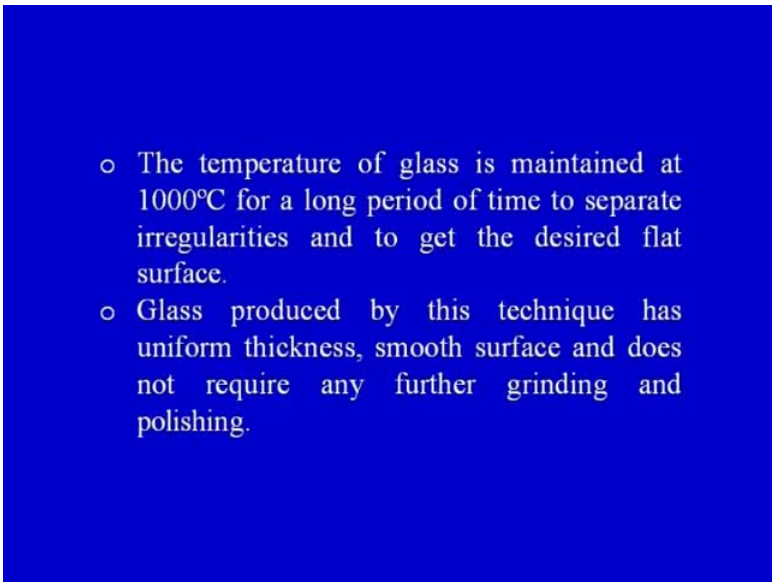

So, basically our objective in this particular case is to make a flat glass and for that we have to maintain a temperature of 1000 degree centigrade for a fairly long period of time. Sometimes we want to remove the irregularities of the impurities from the glass. Therefore, for a long period of time elevated temperature is maintained glass produced by this technique has uniform thickness. Now, these are the advantages of this process the glass which is made of flat glass, which is made by this process has uniform thickness smooth surface.

It does not require any other grinding and polishing, so the surface finish that we get is very good in this flat glass manufacturing or flat glass processing technique. So, the quality that we are getting is very good and the thickness we are getting is uniform. Therefore, and therefore, this process is widely used in the processing of flat glass. So, primarily what we have seen in this process we would try to understand with the help of a diagram.

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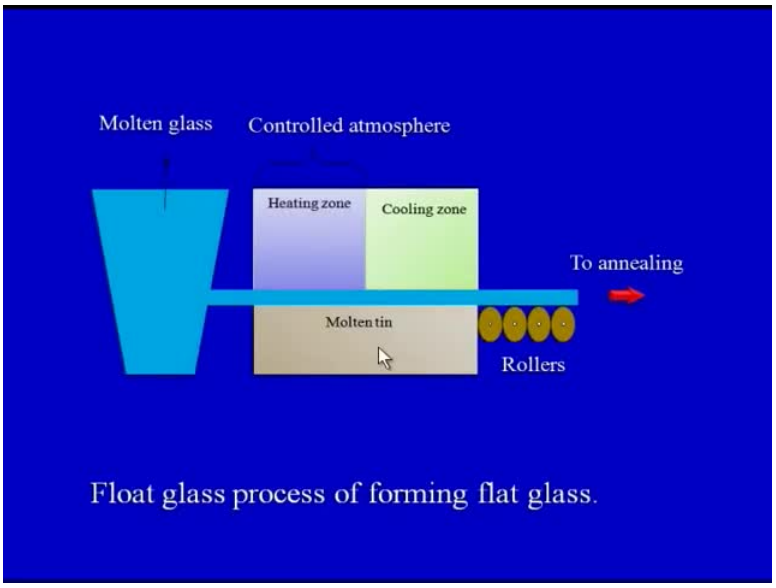

On your screen there is a fairly simple diagram; this is the molten glass, this particular chamber, this is containing the molten glass and this particular section is under the controlled atmosphere, this particular section on your screen you can see this section is under the controlled atmosphere and this is the molten glass. So, once the raw material is available we have already melted the glass,. the glass flows through this controlled atmosphere. This is the heating zone, this is the cooling zone.

So, initially this particular glass or the molten glass would be heated and finally, cooled. So, that we get a solid cooled flat glass and this is the molten tin, we have seen that molten metal can be of any low melting point alloy this is the molten tin. So, in this molten bar the glass would be processed into the flat glass and these are the rollers, which would be continuously be rotating. The finished glass would be rolling out and once it has rolled out there may be because of a very high temperature which is maintained during the process as we have already seen 1000 degree centigrade.

So, there are chances there may be some induced stresses in the final flat glass that we have produced, which have to be removed and how this can be removed? This can be removed by the annealing process. So, what we have discussed as till now is, one of the processes for making the flat glass which is the float glat glass process of forming the flat glass. So, as we have seen we can try to correlate this particular process with what we have discussed earlier, where we have seen that what are the processing stages of the

glass? So, we have a set of raw materials which are melted in the furnace and finally, formed into the desired shape.

So, here we have we can see that we have a molten glass, which is being processed now into a desired shape. Now, what is the shape that we are getting? The shape we are getting is a flat glass on top we have the heating zone and the cooling zone. So, initially the molten glass is at an elevated temperature and finally, it is cooled to give it the desired shape. This all process is taking place over the molten bed and the molten bath is provided by any low melting point alloy. In this particular diagram we have used tin as the low melting point alloy.

In this particular case we will get a glass a flat glass sheet or a flat glass, which will have uniform thickness and a very good smooth surface finish. So, finally no grinding or the finishing of the glass would be required. So, here that thing is being carried out under the controlled atmosphere. So, this is the process number one for forming the flat glass using the float glass process.

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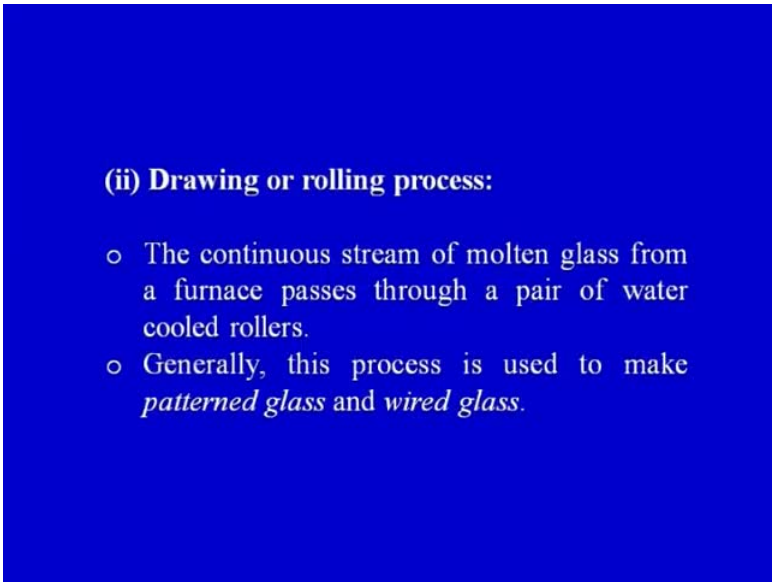

Second is the drawing or the rolling process. In this particular process the continuous stream of molten glass from a furnace again the furnace is used. So, the second stage is still there, the processing of glass there is various stages raw material stage, melting stage, forming stage and annealing stage and finally, the other stage is like inspection and testing. Again the same route is being followed, how the continuous stream of

molten metal? It means a specific set of raw materials or the constituents of the glass have been melted that stream of molten metal from the furnace passes through a pair of water cooled rollers.

So, there are two rollers which are water cooled and the continuous stream of molten glass is passing through these rollers. Generally this process is used to make patterned glass and wired glass. Sometimes we may have a wired glass for specific applications or fire retardancy, there we have to have specific applications. So, we can have patterned glass which have specific pattern on the glass or the wired glass and the process that is used for making the patterned glass and the wired glass is the drawing or the ruling process. So, continuous stream of molten glass from a furnace passes through two pair of or pair of water cooled rollers. On your screen you can see the diagram.

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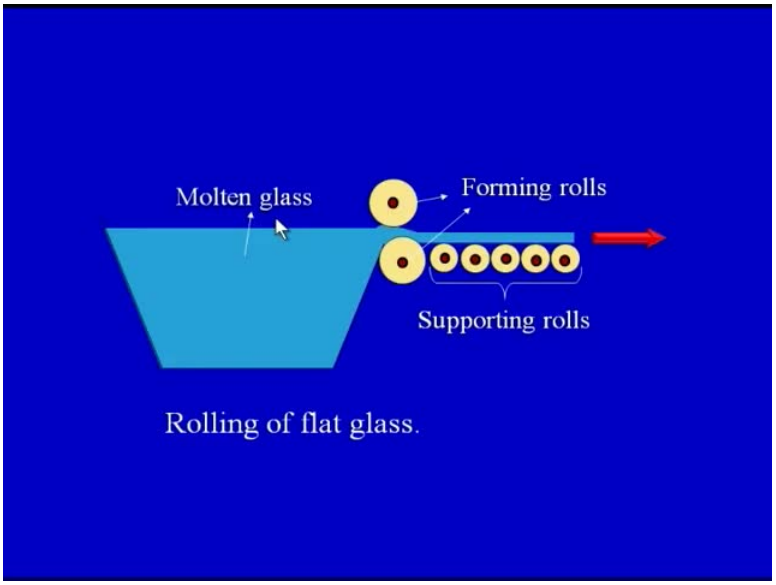

We have a molten glass again here, this is a molten glass which has come from a furnace or the it may be a furnace. Only from the furnace the molten glass goes, these are the two rollers. These are the form forming rollers which will give shape to the glass and these are the supporting rollers, which will roll out the glass. Finally, it will go to the annealing stage. So, this is rolling of flat glass, so we have seen that flat glass can be made by two processes. One of the process we have already seen and this is the second process on your screen.

Once again we can see the process is fairly simple, but control variables are very important. We have to maintain the viscosity of the molten glass, we have to select the rolling speed of the rollers, we have to see that how the rollers have to be cooled? How much cooling has to be provided? So, the process variables have to be controlled, but certainly flat glass can be made by using this drawing or the rolling process. So, on your screen again you can see that we have a molten glass, which is rolled out by the forming rollers which are water cooled. The rollers basically give shape to the glass and this is the final glass or the flat glass that we are getting out of this rolling process.

So, we have seen that two processes can be used to make the flat glass. That is process number one and that is float glass method and second is the rolling of the flat glass. So, we can make the flat sheets or flat glass using two methods. So, primarily what we have discussed till now is that, there are few basic primary stages or basic or the primary processing stages for glass, which are common to all types of processing techniques. So, we have seen that when we have to make the flat glass, we can use two types of processes. Now, we will see that if there is a change in the shape, what type of processes can be used?

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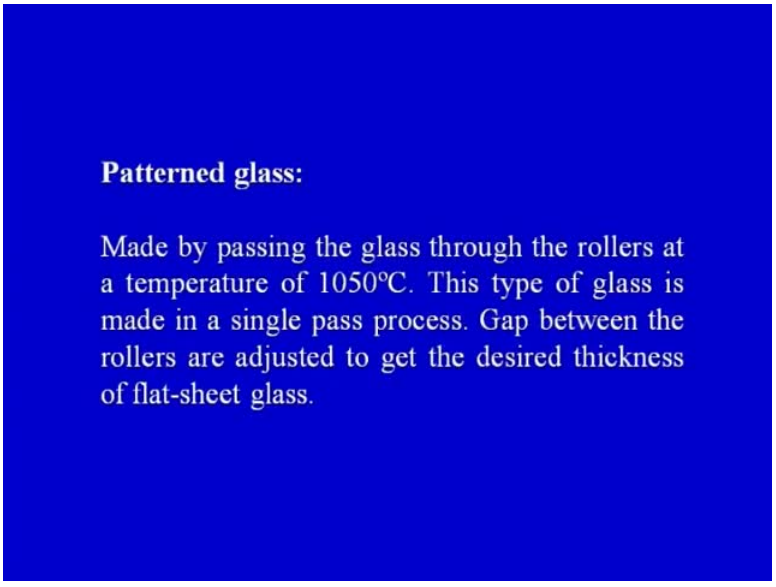

Suppose, we want to make a patterned glass. This is made by passing the glass thru the rollers at a temperature of at a temperature of 1050 degree centigrade. This type of glass is made in a single pass process, gap between the rollers are adjusted to get the desired

thickness of flat sheet glass. So, we have already seen that patterned glass can also be made by the help of the rollers and whatever pattern we want to make, that can be made in a single pass process. The temperature that is required as you can see on your screen is 1050 degree centigrade.

Depending upon the final thickness of the flat glass that we want to produce, the centre to centre distance between the rollers would be adjusted, so that we get the desired thickness. Again there is no need to go for finishing because we will get a very good finish depending upon the requirement. As this particular glass is a patterned glass, so their finally, the secondary processing may not be required in most of the cases. So, we have seen that when we want to make a flat glass there are different techniques and two of them we have discussed till now. So, depending upon the final shape, we can have other processes which ha which are well developed for processing of glass.

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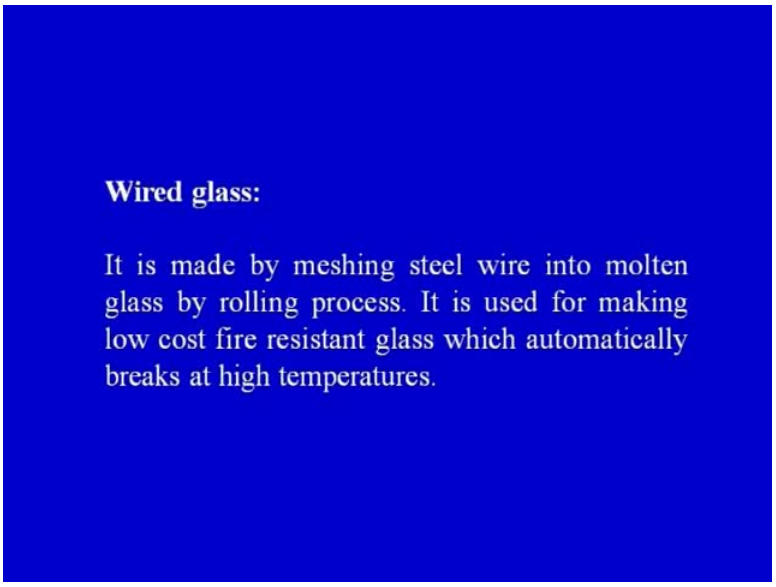

Then another one is the wired glass. It is made by the meshing steel wires into the molten glass by the rolling process. It is used for making low cost fire resistant glass which automatically breaks at high temperatures. So, wired glass is made for very very specific applications and how this is made? It is made by machine steel wire into the molten glass by the rolling process. So, we will have a definite, we can say cross section of this particular type of glass and we will have steel wires, which would be present or inside the glass.

So, in this particular case meshing of steel wire into the molten metal molten glass gives us a particular type of a glass, which is called as a wired glass and which has got specific applications. What are these specific applications? That is fire resistant glass, which automatically breaks. When the temperature will be higher this particular glass would automatically break. So, these type of glass or these type of specific applications can be met by the processing techniques that we are discussing. So, we can make a flat glass, we can make a patterned glass, we can make a wired glass with the processing techniques that we have discussed.

Now, coming on to the other type of the manufacturing of glass. In particular now we want to make the fibers. In the previous process we have seen flat glass can be made . In within flat we have seen different categories of flat glass, but now our focus is primarily on the glass fibers. We will see how glass fibers are made? In one of our modules which we will discuss later, we will see the application of these glass fibers. Glass fibers would be used to reinforce the polymers. We would also be discussing what are polymers? What are different types of polymers?

We would be discussing polymer matrix composites and in this polymer matrix composites the glass fibers will have a very huge role to play, because they would be acting as the reinforcing materials for the polymer matrix. The composite that we will get with the reinforcement of the glass fibers would have properties, which would be significantly better than the polymer itself or the glass fibers taken together. So, the composite will have a properties, which would be the combination of the glass fiber and the polymer matrix.

So, today in this particular lecture we will see that, how glass fibers are made? So, when we will discuss polymer composite matrix and we will see the use of glass fibers in the various forms. For example, we can have continuous glass fibers, we can have short form of glass fibers, we can have glass fibers in the form of sometimes glass wool. So, depending upon the type of glass fiber we are using to reinforce the polymer matrix, we will have a different type of composite. So, at that particular moment we may not be able to address that hoe the glass fiber or the glass wool is made?

But this particular lecture is focusing on these aspects only that how a flat glass can be made? How a glass fiber can be made? How glass wool can be made? So, these are the

processes that we are going to discuss today, but this particular glass that we are manufacturing is very very useful in advanced materials such as composite. So, it is really important to understand that how a glass is made into the fibers form or into the glass wool form? So, this particular discussion is important because this is going to help us in our subsequent modules. So, this is important to understand that how glass is processed into various shapes? So, glass fibers basically if we want to process them into a continuous glass fiber form, the process is fairly simple. So, what are the various steps in the process that we would try to understand.

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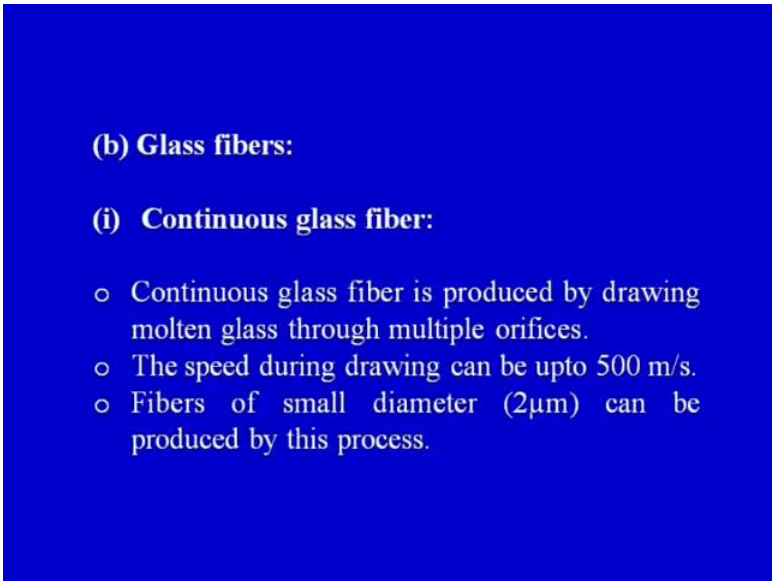

The continuous glass fiber is produced by drawing molten glass through multiple orifices. So, we have a multiple orifices large number of holes we can say through which the molten glass would come out in the form of the fibers. So, once again I will read what is there on the screen. Continuous glass fiber is produced by drawing molten glass. Again the raw material is melted using any type of a furnace. So, the molten glass is coming out of the orifices, there can be large number of orifices we will try to see or understand with the help of a diagram, but before we go to the diagram we should be able to understand that what are the terminology which would be present in the diagram or depicted in the diagram?

So, we have a molten glass, we have orifices thru which the molten glass would come out. The speed during drawing can be 500 meters per second. So, it is coming out at a

fairly high speed. Fibers of small diameter that is even 2 micro meter can be produced by this process. So, very fine fibers can be made up to a diameter of 2 microns. So, the process is simple, we have a molten glass we have orifices and the fiber, the molten glass is coming out of the orifices or it is being pulled or drawn out of the orifices at a fairly high speed. Very fine fibers to the tune of 2 micron the diameter equal to 2 micron can be made by this process.

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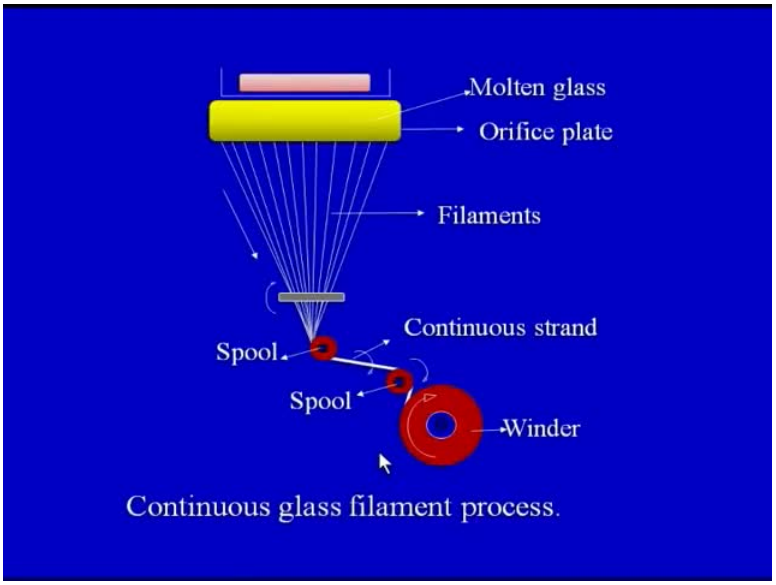

So, on your screen you can see a very simple diagram. We have the molten glass and the orifice plate. The molten glass passes thru the orifice plate in which there are large number of very fine very small diameter holes. These are the filaments and fibers which are coming out on your screen you can see. There are number of filaments, which are coming out. So, two stages are already passed, primary stage is the melting of the glass, then the second stage is the passing of this molten glass thru the orifice plate. And because there are very fine holes there, we get the fibers or the filaments.

So, these are the filaments or glass, which are coming out of the orifice plate. So, these are the filament, now these filament this spool is making these filaments into a kind of a fiber. Here you can see this is a continuous strand of the filaments or you can see continuous strand of filaments are coming from here. This is the strand we can see, the diameter here of the strand is more than the individual filament. So, number of filaments

which are coming down from the orifice plate have been combined together at this spool into the form of a continuous strand.

We can see that the individual filament can be to the diameter to the diameter of 2 micron to the ranging from 2 micron to the 10 micron to the 15 micron. So, it is very difficult to handle these filaments. Therefore, the glass is processed into the form of continuous strands. So, different filaments would be clubbed together or bound together in the form of a strand. The strands are finally, used as the glass fibers. So, we have a continuous strand, this strand travels and there is a winder. In this winder the strands would be wound.

So, this is the continuous glass filament process, we have a molten glass, we have a orifice plate, very fine filaments are coming out of the orifice plates, spool converts them into a continuous strand and the continuous strand finally, gets wound over the winder. So, this the continuous glass filament process, in which a continuous filament of glass would be made. Now, suppose we want to make short glass fibers or glass. This is also called glass wool process. We have seen in the previous slide that how the continuous glass filament fibers can be made? Now, we want to see that how a glass wool or short fiber can be made? So, we can see, what is the process called or how the process is done if we want to make short fibers or the glass wool?

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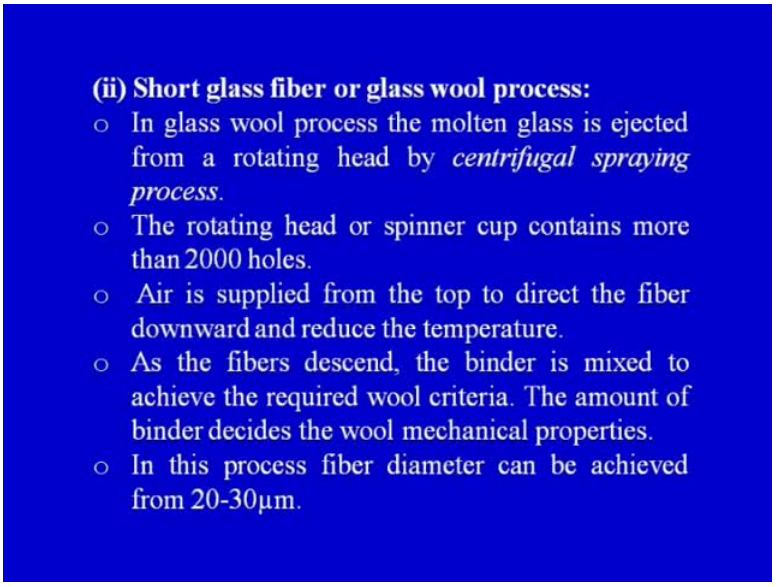

In glass wool process, the molten glass is ejected from the rotating head by centrifugal spraying process. So, we have a centrifugal spraying process, and there molten glass is present and the molten glass is sprayed using this centrifugal spraying process. The rotating head or spinner cup contains more than 2000 holes. So, this particular cup or the spraying head contains or the rotating head contains 2000 holes. Air is supplied from the top to direct the fibers downward and reduce the temperature.

So, air has two important roles to play. First one is it has to direct because once we are spraying, the small fibers or the glass wool may have the tendency to fly randomly. So, this has to be directed, so that it goes and settle down at the place where we want to collect the glass wool or the short fibers. So, the air will direct the glass wool or the small fibers to the destination. So, air has first important role to direct the short fibers to their respective location. The second one is because the glass is at high temperature in the molten stage, it has to be cooled also.

The second part, the second role the air has to play is in the cooling of the glass short glass fibers. So, there are two stages that we have seen, that in glass wool process the molten glass is ejected from a rotating from a rotating head by centrifugal spraying process. So, the rotating head is rotating at a high speed and the centrifugally we are spraying the small fibers. The rotating head or the spinner contains a large number of holes, out of which the glass would come out in the form of short fibers or the glass wool. Air is supplied from the top to direct the fibers downward and temperature.

As the fibers descend or they come down, the binder is mixed to achieve the required wool criteria. Now, glass wool has to be different fibers have to be binded together. So, the binder is added when the fibers are coming down. The amount of binder decides the wool mechanical properties. So, when we are making the glass wool, the final properties would be dependent upon the amount of binder, which we have injected when the glass was being formed or it was being descending under the application of air or under the pressure of the air.

Binder is added and in this process fiber diameter can be achieved about 20 to 30 microns. If we compare with the first process or in which the filaments were being made or the glass fibers were being made, the diameter was 2 micron, but here we are getting a higher diameter. So, here we are getting the diameter which is equivalent to 20 or 30

micron. So, in this particular process we can see, that there is a rotating head, there is a air pressure, and there is a binder which is injected, so that we can get a very good quality glass wool. So, very simple or a fairly simple diagram is given on your screen.

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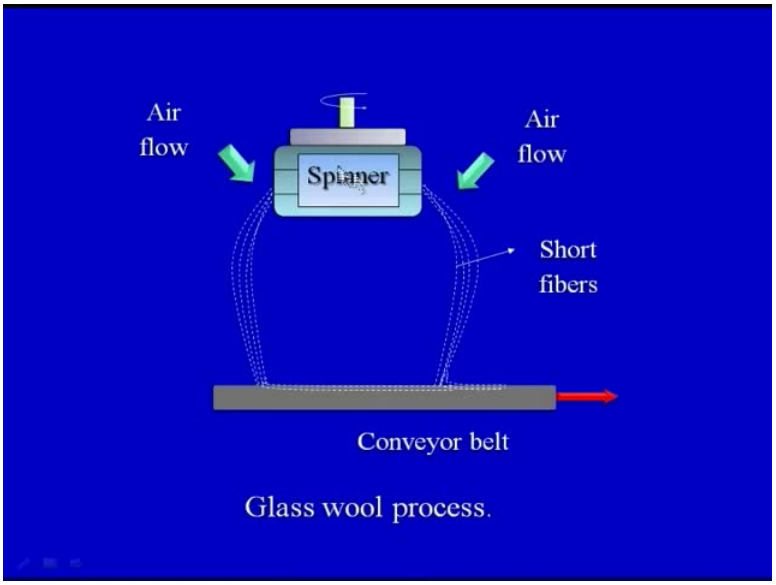

This is the rotating head or the spinner. The molten metal is present inside and when this is rotating at this is the rotation which is shown. So, when the spinner is rotating at a very high speed it has large number of holes present and the molten metal, molten glass is inside I think I have earlier mentioned molten metal. It is not molten metal, it is molten glass because we are processing of glass. So, the molten glass is present inside the rotating head. There are large number of holes in this rotating head the molten glass would be spread out because of the centrifugal spraying action, as this rotating head is rotating.

So, because of the centrifugal spraying action the glass in the form of small, small fibers of the diameter of 20 to 30 micron would be sprayed out. We have a air pressure which would guide the small fibers on to the conveyer belt and the conveyer belt is continuously moving. We have the small fibers short fibers, which are being sprayed on top of the conveyer belt and they are coming down under the application of air pressure. Binder is also we can say manipulated here or binder is also we can say mixed with the short fibers if we want to make the glass wool.

The amount of binder would dictate the final mechanical properties that we can achieve out of the glass wool which has been made by this process. So, the binder also we can say mixed during the process. Finally, we will get the glass wool which is sprayed on top of this conveyer belt. So, this is a glass wool process. So, if you remember what we have covered in today's lecture, we have briefly viewed what we have covered in lecture number 1 and lecture number 2 of module 1, in which we have focused on the engineering materials, their manufacturability.

The broad differentiation between the metals and the non metals. In lecture number 1 of module 2, we have seen the history of the glass that when the glass was started to be used for various applications? Then we have seen that what are the various properties of the glass? What are the various applications of the glass? And we have also outlined the basic structure of the glass. We have seen on the basis of the raw materials that go into the processing of glass, how the glass can be classified into various categories? In lecture number 2 today our focus was to primarily understand, that how glass can be processed into various shapes and into various products? We have seen that what are the primary processing steps or primary manufacturing stages in case of processing of glass?

We have seen that we have specific constituents or specific raw materials which are melted and once melted they are deformed or formed into the requisite shapes. Once the shapes are got there may be some stresses, which are there which have to be relieved by the process of annealing. Once the annealing is being carried out, we do the inspection and testing of the formed glass. After that the certain secondary processing operations are performed on the formed glass and finally, it is shipped and warehoused. So, these are the primary processing steps for converting the raw material into the final product, where the raw material is a glass. Then we have seen that how a flat glass can be processed?

There were two processes that we have seen for processing of flat glass. And finally, we have seen that how a glass fiber or filament can be made? As well as we have seen with the process that is still there in your screen, in which we have seen the glass wool process or how the glass wool can be made? So, today we come to the end of our lecture number 2 of module 2, with the, with the title as glass processing 1.

In our last lecture of this module, our focus would be on other techniques which are used for making glass and we will also focus on annealing as an important topic to relieve the stresses. So, with this we come to the end of lecture number 2 of module 2 and we will meet again we would discuss the title glass processing 2 in which we will see other processing techniques and the annealing.

Thank you.