Processing of Non-Metals
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Module - 1
Engineering Materials and Processing
Lecture - 2
Properties of Non-Metals

A warm welcome to all of you in this second lecture on the course processing of non metals; as we are discussing module one, which deals with the introduction to engineering materials and their manufacturing as well as the properties of non metal. Our focus in the first lecture was to study that what are the various types of engineering materials which an engineer can choose from for developing the products.

We have also seen that what are the various properties of the engineering materials, which are taken into account, while selecting a particular material for a specific application. We have further seen that, what are the various manufacturing processes which are available with the engineers and engineers can make use of the process capabilities of these processes to process different types of materials and to convert them into the final products. We have also seen the challenge of selection, if there are so many different types of materials available.

How the engineers can select the best particular material? For what criteria? What properties should be kept in mind, while selecting a material for a particular application? Similarly, we have seen the there are different types of manufacturing processes and these manufacturing process have to be selected for a particular application. There is a wide verity of processes which are there and out of this verity we have to select that which particular process can be use for a particular application.

We have also seen that, what are the challenges in the selection of a particular process; there are certain factors which we have taken in to account for selecting a process such as the shape of product, the size of the product, and the properties of the raw material. We have also seen that finally, in this particular course, our focus would be on processing of non metals. And, we have just out lined that what are the various modules which would be covered in this particular course.

In today's lecture, that is lecture number two in module number one our focus is on the properties of non metals. We would be focusing majorly on those properties which affect the processing of non metals. Our focus would not be much on the chemical properties but, our focus would more be on the mechanical or the physical properties which dictate the manufacturability or the process ability of the non metals. We would be comparing certain properties of the metals with the non metals and finally, we would be seeing that what we are going to cover in this course on processing of non metals. So with this introduction, we will just have a brief summary about we have covered in the previous class, and today we will see that what the various properties of non metals are which makes them suitable or which limits their use in certain applications.

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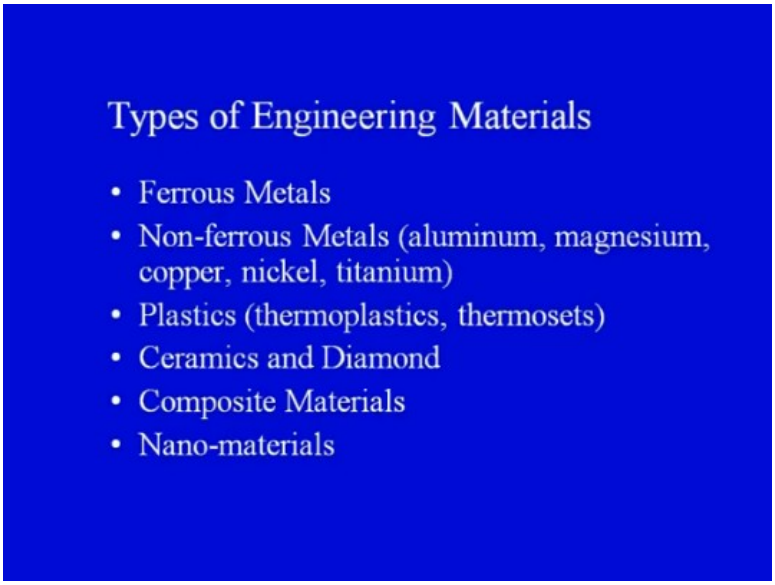

This is the slide which we in have covered the lecture number one that is the type of engineering materials available. On your screen you can seen, we have ferrous metals non ferrous metals such as aluminum, magnesium, copper, nickel. We have plastics such as thermo plastics and thermostats. We have other types of materials such as ceramics and diamond. We have composite materials, we have nano materials, so on your screen you have seen that there are large verity of engineering materials which are available. And, these are just the families of materials, with in these families we can even think of have a large verity of sub groups and those sub groups can further be dived in to large verity of materials or large types of materials further.

So this is just the family name, within the family there can be so many members. And these members may have sub members, so there is the wide verity of engineering materials available with the engineer and then there are large verities of manufacturing process are also which are available with the engineers. So we have seen that when we have to select appropriate material for a specific application, our focus primarily is on certain aspects of the materials. Now, what are those aspects? Those are the characteristics of material, the applications area of that material. We have to look for the advantages and limitations of those materials.

Finally, when we have a wide verity, we have to choose, we have to select the optimal material. We focus on the mechanical properties of the material, we focus on the physical and chemical properties of the materials, as well as we focus on the manufacturability accepts of the materials. So we have a wide verity of materials available, we have a factor or we have series factors which can we use to optimize or which could be use to optimally select a particular material for a particular application. And finally, we have a least of manufacturing processes which can be used for manufacturing of different types of material.

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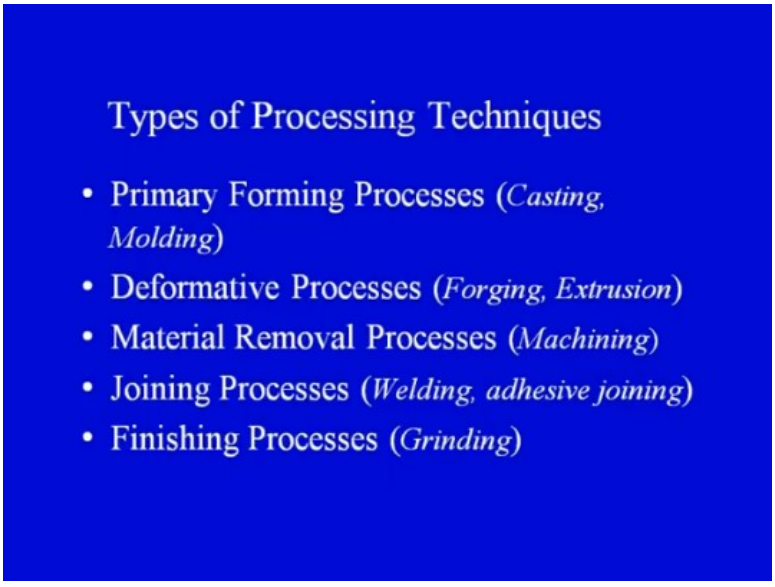

On your screen you can see very broad classification of the manufacturing processes, these processes also represent of family name only. Within each process there could be a wide verity or a wide classification of further processes with basic principal remaining

the same. But, the process variants give certain specific application area to the sub group of these processes. So, you can see on your screen the various types of processing techniques are the primary forming processes such as casting and molding.

Deformative processes such as forging and extrusion. Material removal processes such as machining, joining processes such as welding, adhesive joining, and finishing processes such as grinding. So, there are these are the family names which are used or these are processes which are use for converting the raw materials in to the final product. Now, what are the various types of raw materials that we have seen? The type of materials in the previous slide that we have a wide verity of engineering materials, these processes now we are convert raw materials in to the final products.

And now, these processes also represent a very big family of a process. For example, the primary forming processes, it is a big family, with in this family there would be so many members and further sub members. Similarly, in the deformative processes, just two examples are given on your screen, this is a deformitive processes. It is the very big family and within these processes there are large number of other processes which can we used to deform the shape of the material. So, basically our course, if you remember in the previous class in lecture number one, in module number one. We have seen that the product quality depends upon that product designs, it depends upon the materials and depends upon the processing technology.

So, our focus in this particular course of processing of non metals is on the material aspect as well as on the processing aspects. So, first of all we need to understand that what are the various types of engineering materials? And what are the various types of processes that can be used or the broad category of the processes which can we used to convert the raw materials in to the final products. More or less, when we will cover this particular course, we would be seen that these types or some variants of these processes are used for converting or giving shape to the non metals to get the final product.

To once again on your screen you can seen various types of processing techniques, primary forming processes, deformative processes, material removal processes, joining processes and finishing processes. So, when we will use or when we will use the non metals for a particular application, those have to be converted in to the usable form using

any of these processes. So, when we will cover our course, we will cover the module two, module three, module four, five, six and seven.

We would be using this broad category of processes to convert the materials; the materials in our case are the non metals. So, we would be converting the non metals different raw materials which fall under the category of non metal into the final product using these broad categories of processes which are mentioned on your screen. So, it is very important or it is imperative at the start of the course that we try to understand that, what are the various categories of processes which are used to convert the raw material in to the final product?

So, till now we have studied that, what are the various types of engineering materials available? And what are the various types of engineering processes which are available? Which can be used to convert the raw material in to the final product form? So now, we will see what exactly a non metal is? Try to define a non metal, then we will see what are properties of the metals which render them easily manufacturable or which render them easy to manufacturing. Then we will see what non metals are? What are the different types of non metals? What are the properties of the non metal? And finally, how these properties dictate the manufacturability or the process ability of the non metals?

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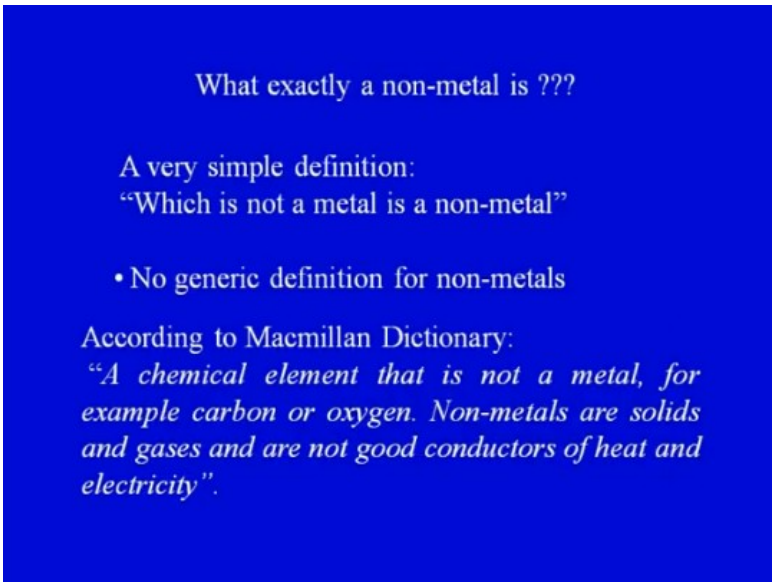

On your screen you can see what exactly a non metal is? A very simple definition can be non metal. From the word itself we can say which is not like a metal, it is a non metal.

So, on your screen, you can see which is not a metal is a non metal; so, which the material, which has properties which are not similar to those of the metals are called the non metals. So, there is no generic definition for non metals but, because of certain proprieties that the non-metal process they can be clearly identified from the metals. Even in the periodic table the differentiation is very, very clear and the metals and the non metals are clearly distinguished.

So according to the macmillan dictionary a chemical element that is not a metal for example, carbon or oxygen, non metals are solids and gases and are not good conductors of heat and electricity. So, not good conductors of heat and electricity just to emphasize the point, so we can see there are two or three important properties which are mentioned in this definition which separate or distinguish the non metals from the metals. On your screen, again I am reading a chemical element that is not a metal.

So, first thing is as I already said non metal means it is not a metal. For example, carbon or oxygen two of examples are given, non metals are solids and gases. So, they can exist in both solid and gas form and are not has to be highlighted. They are not good conductors of heat and electricity which means on the opposite the metals are good conductors of heat and electricity. So, this gives us a very broad definition of the non metals that they can exist in different phases and they can be good not they are poor conductors of heat and electricity.

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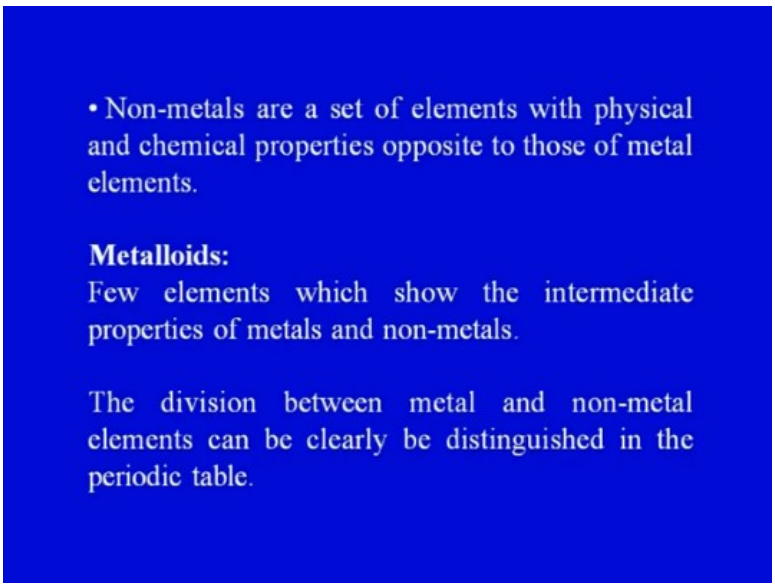

They are not good conductors of heat and electricity, again non metals are a set of elements with physical and chemical properties opposite to that of metallic elements or the metal elements. So, basically to distinguish between metals and non metals we have to focus on certain properties, so that the distinction is very, very clear or we are able to distinguish them very clearly.

So, our focus in today's lecture would be on these properties only, we will see that, what are the properties of the metals which make them easily manufacturable? And what are the properties of the non metals which have to be taken care of when we are rendering them to the manufacturing or the processing. So, that we get a good quality cost effective product which is the final aim of the all activity of manufacturing. So, we have seen what are metals? What are non metals? We will further try to understand the differentiation with the help of certain properties.

But, there is a distinction in between also between metals and non metals. We have metalloids, few elements which show the intermediate properties of metals and non metals. So, clearly there is a distinction between a metal and a non metal. But, there exists a common feature that is metalloids which are intermediate or which shows the properties which are intermediate properties of the metals and the non metals.

Once again I will read it for you, on your screen you can see the metalloids few elements which show the intermediate properties of metals and non metals are called the metalloids. The division between metal and non metal elements can be clearly distinguished in the periodic table which I have already emphasized that metals and non metals can be easily distinguished when we look at the periodic table.

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Now, before we go to the non metals, let us first see that what are the properties of the metals? So, our focus primarily would be on those properties which render them easily process able. So, metals, the physical properties are on your screen luster that is shininess. So, most metals are silver in color except copper and gold, all metals are shiny when freshly cut. So, this particular application, this particular property renders them easy for the machining process.

So, when we will machine or when we will remove the material as you can see freshly cut. Freshly cut means that they have been machined, so when we machine, we will have a very good surface finish in case of metals. Why because, they have the property of shininess and luster. Second property, they have high density, so metals will not find application where we are focusing on the light weight applications. So, for light weight applications metals are not suitable and where we have light weight applications we may certainly advocate the use of the non metals.

There are certain types of non metals which do not have the properties similar to those of metals and they have less density as compared to metals and therefore, they can be used for light weight applications. So metals have the luster the property of the luster, metals have high density and sometimes this high density is also suitable for rendering them easily manufacturable. Because there would be some manufacturing processes which

would be making use of the density of the metal to, sometimes to gravity feed the metal into the mould cavity.

So, this property of density would be used in certain processes for the advantageous conversion of the raw material or the metal into the final product. So, this density is also important point. Next is high melting and boiling points, so that is also important. High melting and boiling point sometimes we want that to work with a metal at the room temperature. So, at that room temperature the metal because they have high melting point they will not melt and in most cases whenever we have to cast them their melting point would be an advantageous.

We would, would be an advantageous property, because we will melt them and then we will pour them into the mould cavity. But very high melting point is also not desirable, because then we need to have the furnaces which have the properties to melt the metals. So, high melting point again is important from the machining aspect, suppose we are machining a metal and it has very low melting point. So, when the tool will be in contact with the work piece and the work piece is made up of a metal which has a very low melting point, as soon as because of the friction the heat will increase the metal may melt.

So, there also high melting point can be advantageous, because it will be able to sustain a lot of temperature before actually melting. So, all these properties have with one or the other connection with the manufacturability. So, we have seen metals have luster, metals have high density which can be used in certain manufacturing processes. They have high melting point which also renders them useful in for certain manufacturing processes, then ductility which is one of the most important properties which render them deformable.

If the materials are not ductile then it is very difficult to deform them, suppose it is a brittle material we will not be able to deformate as per the requirements of the final product. But, if the material is ductile and on your screen you can see the metals are ductile in nature. Therefore, they can be drawn into long wires so you can all the wires that we see electrical wires, copper, aluminum wires, all the wires are made up of metals.

So, these metals have the property of ductility and this ductility renders them easily deformable and when these are easily deformable we can deform them according to the

requirement. So, wire drawing is one of the operations which is done on metals to deform them into long wires. So, ductility is very important, most metals can be drawn into thin wires which are already presented on your screen. They have the property of malleability, malleability means most metals can be hammered into thin sheets.

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So they malleable, the property of malleability also renders them manufacturable. If we want to make a thin sheet, we can very easily make out using a metal. So, you can see on the screen just as a revision exercise that what are the physical properties of the metal, which render them easily manufacturable. They have the luster so that we can get a very good surface finish they have the property of shininess. They have high density, high melting and boiling points, they have the property of ductility that means they can be drawn into thin wires.

They have the property of malleability most metals can be hammered into thin sheets. So, these are the properties which render them manufacturable and the properties or the manufacturing processes which has been designed or which have been developed for processing of metals are well advanced and fully automated processes are already in place. So, the meaning is that metals have certain physical properties which make them easily manufacturable.

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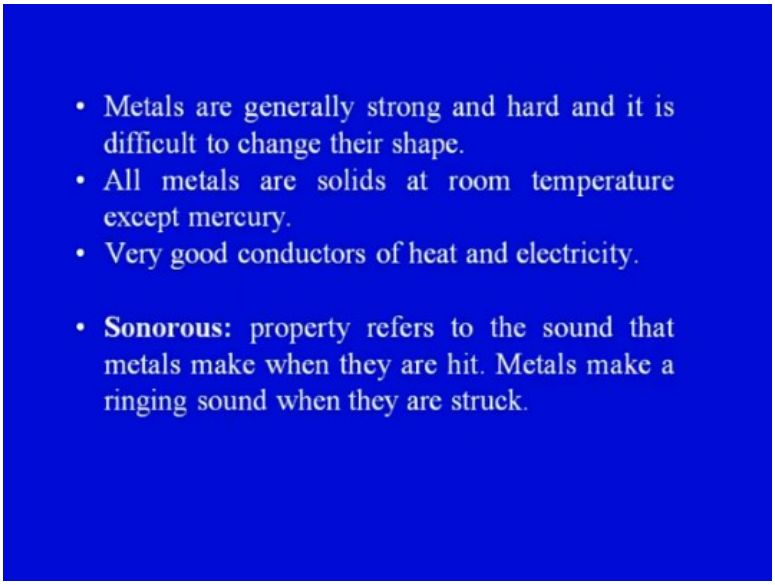

Other properties of metals are, metals are generally strong and hard and it is difficult to change their shape. So, on one hand they have the property of ductility, they have the property of malleability. And on the other hand they some of the metals are very hard and it is difficult to change their shape. So, when the metals are hard that is also advantageous in certain situations.

And, when they are non-deformable that is also advantageous in certain situations where we do not want that the metal should deform under the application of load, there we want it should be hard and it should be difficult to change its shape. We want dimensional stability; the shape of the metal should not change on the application of very minimum amount of load. So, these are also the properties which are also certain times advantageous.

All metals are solids at room temperature except mercury, so metals are existing in the solid state. They are very good conductors of heat and electricity which is also a property which can be used to deform their shape or to remove the material from the metals. If you remember or if you are aware of that there are certain non conventional processes which can only be done on the metals which are conducting in nature or that can only be done on materials which are conducting in nature.

So metals are good conductors of heat and electricity therefore, all those processes to name one of them electric discharge machining that is e d m process. e d m can be

applied to the work pieces which are conducting in nature, so most metals are very good conductors of heat and electricity. Therefore, the metals can be easily machined with the electric discharge machining set up so good conductors of heat and electricity is also, sometimes important.

Heat also good conductor of heat also important, why? Because sometimes when you are machining the temperature rises at the tool and the work piece interface. So when at the tool work piece interface the temperature is higher though there are chances that the tool may get deformed. Because of this high temperature, although the tool material should have a property of hot hardness but, sometimes if the heat is not dissipated properly or a proper cooling agent is or a cooling medium is not employed.

There are chances that there may be the surface finish may be spoiled, the tool may break and there may be certain impressions on the work piece which we do not want. So, good conductor of heat means that if a metal has a good conductivity, heat conductivity it will conduct the heat very fast and the temperature at the tool and the work piece interface can be maintained.

So, the property of good conductor of heat as well as good conductor of electricity is beneficial for the metals, because then they can be easily processed using one or the other processing techniques. They have the property of sonorous; the property refers to the sound that metals make when they are hit. Metals make a ringing sound when they are struck, so this is another physical property which is there with the metals. So metals are sonorous in nature which somehow is not directly related to the manufacturability of the metals.

Now, what are the chemical properties of the metals? Although our focus is on non metals, but before going to the non metals we want to understand that what are the properties of the metals and how the non metals compared to the metals. So, chemical properties, I will read it for you usually have one to three electrons in their outer shell. Lose their valence electrons easily forms oxide that are basic in nature are good reducing agents, have lower electro negativities and they corrode easily.

So, in our case if we focus on the processing aspects most of the factors are physical in nature, although the chemical properties are equally important when we are talking about the materials aspect which are related to the manufacturability. So, on your screen there

are certain chemical properties which the metals posses and these properties have to be taken care of while we are processing the metals. And, another important point to note is they can, they can corrode easily.

It means that the in case of machining for example, when we are using a chemical as a cooling medium or when we are mixing any oil with water and making a cooling agent and that cooling agent or cooling water is being used to take away the heat from the tool. And, the work piece interface, there are chances that oil may react with the metal and the corrosion may take place. So, we have to very judiciously select the cooling agents when we are using them for the machining purposes. So, there are certain chemical properties also which have to be taken into account.

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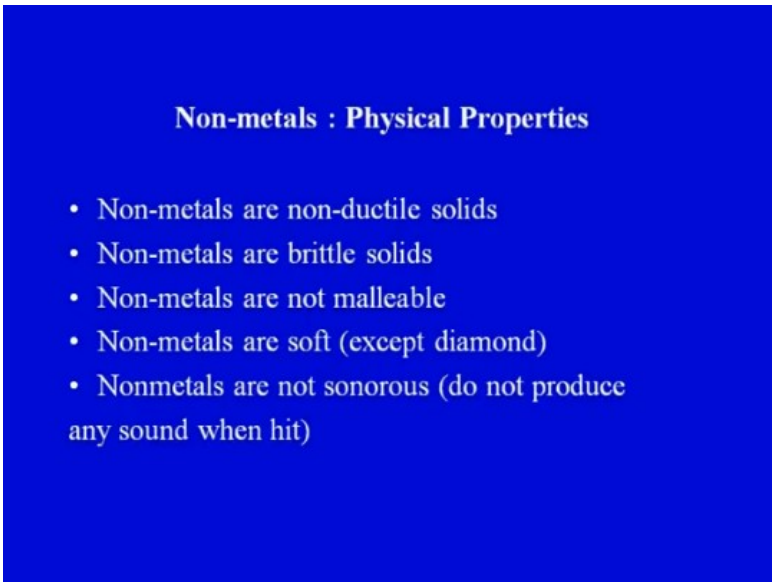

Coming on to our topic that is non metals; so there are certain physical properties of the non metals, which distinguish them from the metals. So, non metals are non ductile solids, so first property is non ductility, that they are not ductile. So which means that the most of the non metals cannot be drawn into thin wires? So, that is one important property but certainly there has to be certain modifications in which we have to process them in such a way that we can overcome this problem of non ductility. We have to think of certain processes, then the people have already developed processes where the properties of the non metals are used to convert them into the final product.

So this is they are non brittle in non ductile in nature. Non metals are brittle solids so they are brittle in nature for example, ceramics; they have the property of brittleness. Non metals are not malleable, so they cannot be drawn into thin sheets. So non metals are non ductile solids, they are brittle in nature then they are non malleable, they cannot be made into thin sheets. Non metals are usually soft except diamond, so this is one important property which we will always keep in mind when we have to process them with different processing techniques that non metals are not very hard, they are soft.

Soft means we can easily deform them; we can try to give them a shape. Because they have the property that is very useful, that is soft metals on the contrary we have seen that some of the metals are extremely hard and it is very difficult to machine them. Non metals are not sonorous do not produce any sound when hit. So all the polymers or the plastics if we hit them they do not make a sonorous noise. So plastics basically fall under the non metals category, the polymers fall under the non metals category. So, we have ceramics and the polymers which fall under the non metals category.

So, there are two important points that we need to do look at this particular slide. First important point is that the non metals do not have ductility; non metals do not have malleability. They are brittle in nature which means the processing techniques which focus on the ductility malleability and the brittleness or the non brittleness of the materials cannot be applied for non metals. Again I want to emphasize the same point that the processes or the processing techniques or the manufacturing techniques which focus on the ductility, malleability of the materials cannot be directly applied to the non metals.

Because the non metals are non ductile in nature, non metals are non malleable in nature. But, certainly they are soft in nature and if they are soft there are every chances that they can be easily converted into the final product. So we have to focus on this property of softness of the non metals. Non metals are not lustrous and usually have a dull appearance, so they are not shiny, they do not have a luster or a shining luster on the surface. So they usually have a dull appearance, non metals are poor conductors of heat and electricity.

So the properties or the processes which focus on the conductivity it can be heat conductivity or it can be electrical conductivity. So the processes which are focusing on

the electrical and heat conductivity of the materials and using that property that deforming the raw material into the final product, those processes are not suitable for non metals. Because non metals are poor conductors of heat and electricity so therefore, we have seen that in case of metals they are good conductors of heat and electricity therefore, electro discharge machining can be done on the metals.

Whereas if you take example of polymers or polymer matrix composites which are poor conductors or which are non metals and poor conductors of heat and electricity. In those cases we cannot do electrical discharge machining, because it requires the raw material to have a good conductivity of electricity or it should be a good conductor of electricity. So on your screen you can see that non metals are poor conductors of heat and electricity. Non metals may exist as solid, liquids or gases at room temperature, so they can exist in different phases. Non metal have lower melting and boiling than metals.

This is also advantageous for example, we have a polymer it is very easy to melt a polymer and change the shape of the polymer. There are so many different processes which are used to convert the raw polymer into the final product or a raw plastic into the final plastic product. To name one of the process we have injection molding, so in one of the module that is processing of plastics, our focus would be on various techniques or processes which are used for processing of polymers or plastics.

So this lower melting and boiling points also, sometimes render them manufacturable by the process of molding. There can be different molding techniques that can be used, so the basic principle is because they have low melting points we can easily melt them. And when we, when we can melt them easily we can get a polymer melt and then we can put it into a desired mould cavity and get the final product. So, non metals also have got some certain important points that if taken care of can be helpful in converting the non metals into the final products.

Now again to emphasize there are two, three important points which have to be taken care of that non metals are poor conductors of heat and electricity. Therefore, the processes that we choose should focus on this property that it should not focus on that. They should be good conductors of heat and electricity, because we already know that non metals are poor conductors of heat and electricity. So the processes should be such where these particular properties are taken care of.

Similarly, non metals have low melting points, so we can say that it is easy to melt them. And, we can develop some processes which have already been developed which are available in the textbook literature. The processes which are used for processing of non metals focusing on one important property that is they have lower melting points. So, lower melting point basically means that we can melt the polymer and deform the polymer or mould the polymer into the desired shape. So just to summarize the physical properties of the metals and the non metals we can just say that metals have the property of ductility, malleability.

They have they are good conductors of heat and electricity and therefore, there are certain set of processes which can be used to convert the metals into the final product. On the contrary the non metals are poor conductors of heat and electricity they are non ductile, they are non malleable. But they have certain advantages in terms of that they have lower melting points and they are soft in nature. Therefore, the processes that will be used to convert the metals into the final product and the non metals into the final product would be different, because they have different physical properties.

Similarly there are few chemical properties also of the non metals which are non metals have higher electro negativities. Non metals readily gain or share valence electrons, they are electron acceptors. Non metals form oxides that are acidic in nature; non metals are good oxidizing agents. So, there are few chemical properties of non metals which can be useful in some of the processing techniques when the non metals are being converted from the raw material into the final product. So, we have now covered the physical and the chemical properties of the metals. We have seen the physical and the chemical properties of the non metals and we have seen that how these properties influence their manufacturability or the process ability.

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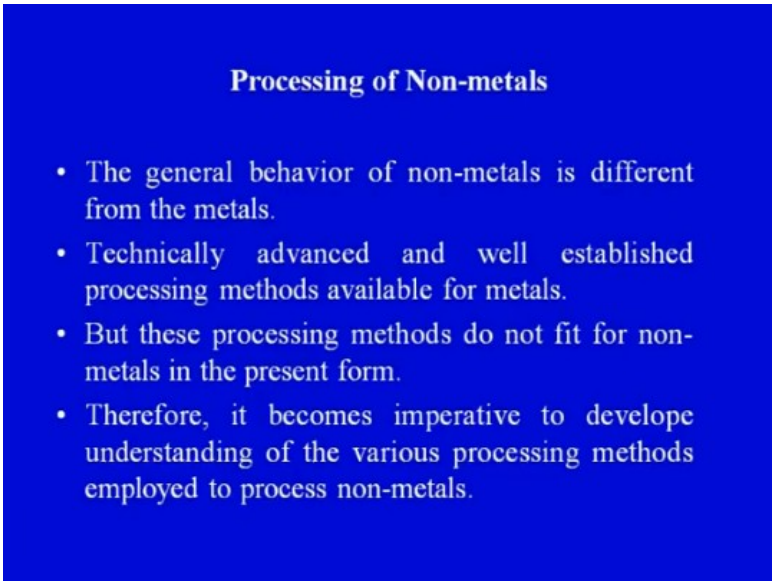

Now coming on to our course that this processing of non metals, so we have seen metals and non metals, the physical and chemical properties of the metals and physical and chemical properties of the non metals. We have tried to understand with the help of certain examples that which property can be utilized for which particular process.

Similarly, for non metals also we have seen that as they are soft, as they have low melting points then there are few processes which can make use of these properties of the non metals and can convert them readily into the final product. So, the general behavior of non metals is different from the metals, so we can conclude that the physical and the chemical properties of the metals and the non metals are different. Therefore, the general behavior of non metal is expected to be different from that of metals, technically advanced and well established processing techniques are available for metals.

So, when we pick up any textbook of manufacturing most of the chapters you will find would be dedicated towards the manufacturing or the processing of metals. All the manufacturing processes that have been developed or we can just refer to the second slide that we have seen today, in which we have seen the types of manufacturing processes. The first manufacturing process is primary forming, then deformative processes, material removal processes, joining processes and finally, the last one, that is the finishing processes.

All these processes are well developed for the metals; you take any metal you will find one or the other process which can be used to convert it into the final product also. I have told that whatever processes we have seen those are just the family names within the family, there are so many members and sub members. There are different generations of processes which are available within one family which can be very easily used to convert the metal into the final product. But, in case of non metals we will not find very subsequent or very substantial literature in which we will get an idea that how to convert this particular non metal into the final form.

So, technically advanced and well established processing methods are available for metals which are not available for the non metals. But, these processing methods do not fit for the non metals in the present form. So, these are the general processes which are used for the metals but, certain modifications in these processes, certain variants of these processes can certainly be used for the non metals. So, we have to see that what exactly the non metals are different categories of non metals and which are the processes, which are the modifications or sometimes completely new processes which have been developed and dedicated for processing of non metals.

Therefore, it becomes imperative to develop understanding of the various processing methods employed to process non metals. So, this gives the justification of the course of processing of non metals that most of the knowledge that has been developed till date has focused on the processing of metals, because all around us if we see the various types of materials which we have seen, we will see most of the products are made of one or the other type of a metal. But with the passage of time and in the last few years we have seen there are large category of materials which are being made up of polymers or plastics or polymer matrix composites or certain sophisticated applications of ceramic matrix composites.

So there are certain non metals which are now getting into the consumer market. So, it is very important to understand that what are the manufacturing techniques for these non metallic type of materials which do not have those properties which the metals posses and which makes them easily process able. So, we have to focus we have to design, we have to understand that which are the processes which are being used and what are the specific requirements which will help us to design the processes which are dedicated for non metals.

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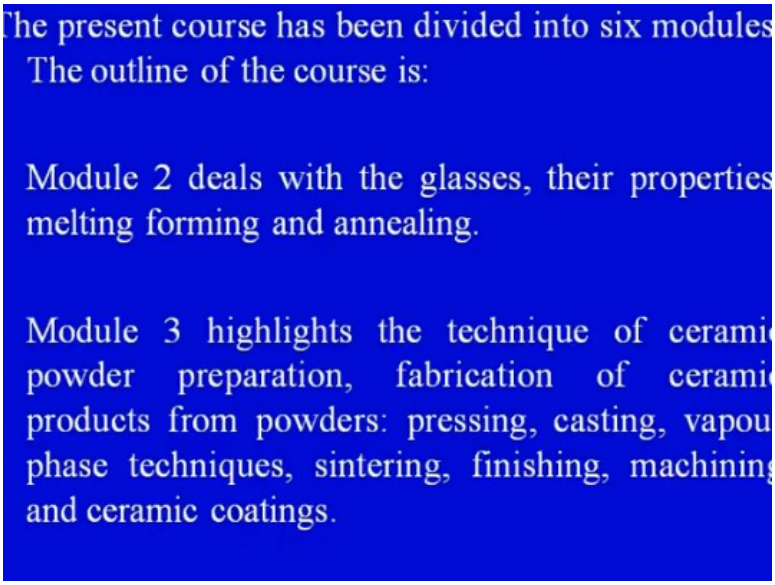

So, the present course has been divided into six modules the outline of the course is module two, as we are already at the end of module one. In module one, we have seen that what are the types of engineering materials available? We have seen that what are the different types of manufacturing processes available? So, we have broadly tried to understand the classification of the engineering materials. The classification of the manufacturing processes and within the discussion we have seen that how the materials affect the manufacturing.

We have seen so many examples for again to emphasize, hardness and melting point are two important material properties which dictate the manufacturability of the materials. So, we have tried to understand the properties, we have tried to understand the manufacturing, we have tried to classify the different types of manufacturing processes. And we have seen that if we have to select a particular process. What are the factors that should be taken into account and similarly we have seen that if we have a wide variety of engineering materials available. What are the factors that should be taken into account to select the most optimal engineering material?

So, with this we, we finished our lecture one of module one and today in lecture two of module one. We have tried to correlate the physical and the chemical properties of the metals and non metals with their processing that which are the properties of the metals

which render them easily process able. And, which are the properties of non metals on which we can focus so that it is easy to process them into the final products.

So, the total course has been divided into seven module and with today's lecture we come to the end of module number one in which we have taken two lectures. The subsequent lectures would be focusing on. On your screen you can see module two will deal with the glasses their properties, melting, forming and annealing. So we will see different processing techniques for glasses. Module three highlights the technique of ceramic powder preparation; we will see ceramics fabrication of ceramic products from the raw materials.

Some of the techniques of ceramic processing such as casting, vapour phase techniques, sintering, finishing, machining and ceramic coating. So, we will see how the ceramic products can be made and what are these processes? For example, pressing, casting, vapour phase techniques, sintering, finishing, machining and ceramic coating. The focus would be on ceramics and the processing techniques for the ceramic products.

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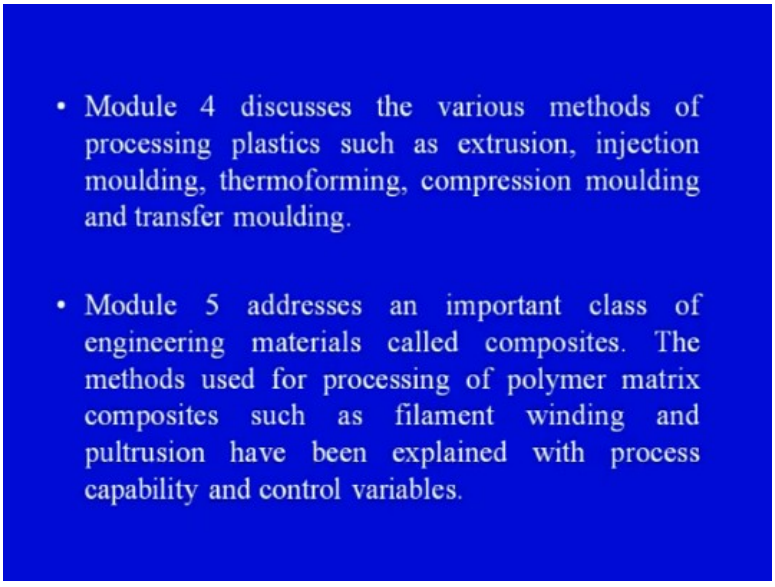

Module four will discuss the various methods of processing plastics such as extrusion, injection molding, thermoforming, compression molding and transfer molding. So, the focus would be on plastics, so in the previous two modules we can see in module number two the focus is on glasses. Module number three the focus is on ceramics and module number four the focus is on plastics. And module number five would focus on the

important class of engineering material that are composites. And we are in module number five the focus would be on polymer matrix composites in which the matrix would be a polymer.

So, again the polymer we have, already we have seen the processing of plastics in module number four. And module number five would see advanced plastics with the incorporation of reinforcements which are called the polymer matrix composites. So module five addresses an important class of engineering materials called composites. The methods used for processing of polymer matrix composites such as filament winding and pultrusion have been explains with the process capability and the control variables. We would focus on the process details as well as we would focus on the advantages, limitations and the application of various processes which are used for processing of polymer matrix composites.

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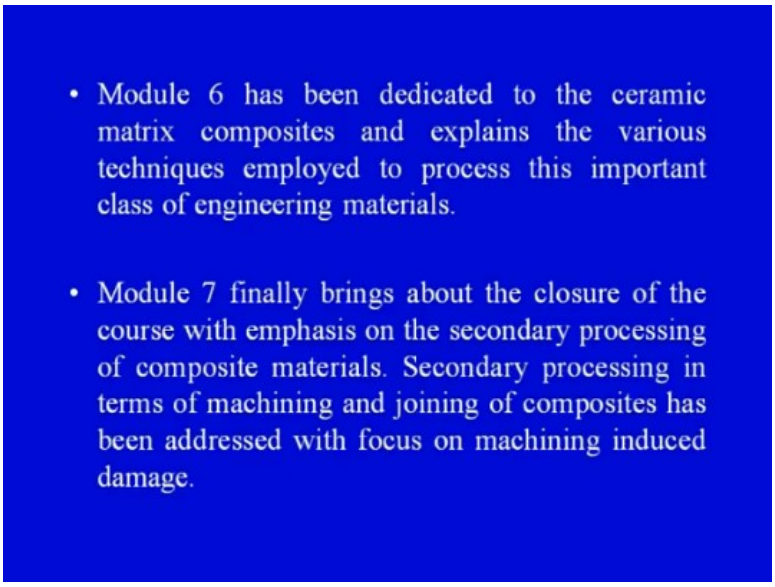

The module six which has been dedicated to the ceramic matrix composites, in module five we have covered the polymer matrix composites, in module six we would be focusing on the ceramic matrix composites. Basics of the ceramics have already been covered in one of the previous modules, so this will explain the various techniques employed to process this important class of engineering materials.

So, our focus would be primarily on ceramics and ceramic matrix composites and polymer then polymer matrix composites as well as on the glasses. And finally, we

would come to the module seven which brings about the closure of the course with emphasis on the secondary processing of composite materials. Secondary processing in terms of machining and joining of composites has been addressed with which will focus on the machining induced damage.

So, to emphasize on this particular point why secondary processing is required? Basically, when when we are processing the non metals, we will be making a near net shape. A near net shape means so suppose I have to make this mouse I will have a mould and mouse can easily be made depending upon the requirement of the shape. So mould is there I have a raw material in the form of the plastic, the plastic can be melted. It can be injected into the mould cavity and because it is the polymer melt, it will take the shape of the mould cavity. And I will get a mouse. So finally, in one shout I have been able to get the mouse.

But, sometimes we have to machine it, get to trim a particular section; we have to cut it in order to have a scroller inside. So there are so many requirements which are later on added, once we get the near net shape. So, once we get the near net shape of the mouse, we require that is called the primary processing. That is in the single shot process or the near net process where we are getting the exact shape but, this shapes sometimes maybe have to be assembled to some other component.

So, for assembly operations or for cutting of holes or for sometimes drilling, requiring the bolts and rivets for the assembly operations. So certain requirements are there, suppose we have to make a huge structure, the total structure cannot be made by the prime. We can make the individual members individual structural members but, these structural members have to be assembled together to get the complete structure. And, for that we require somewhere holes and in some cases we need to join the structural members using one or the other techniques which can be permanent or temporary in nature.

So the secondary process that is the module number seven would focus on the joining and the machining aspects of non metals and which we will focus on the damage that takes place. And our focus primarily would be on the composites which are advanced forms of the conventional ceramics and the polymers. So, last module would be towards the secondary processing otherwise also first the product is made and the machining and

joining is done towards the end. Therefore, the secondary processing that is module number seven would be the ending part of the total course of the processing of non metals. So, in the subsequent lectures we will start module number two in which our focus would be on the glasses.

Thank you.