Processing of Non-Metals

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Module - 6
Ceramics Matrix Composites: Processing
Lecture - 1
Ceramic Matrices Composites

A warm well come to all of you in this modules of ceramic matrix composites as you are well aware that we are in the process of discussing that subject on the processing of non metals. We have already covered 5 modules in which we have discussed different aspects of non metals. In our earlier modules or the initial model of this course that is module 1. We have seen that what is the important of materials engineering materials and how they are manufacture or what are the challenge is in manufacturing of engineering materials of varies classis and forms. Then, we have seen different types of materials we have seen in glasses, we have seen polymers and we have even seen polymer matrices composites.

We have also discussed module, which is a prerequisites for this particular module that is module on ceramics, in which we have taken different aspects of ceramics. We have seen what are the various types of ceramics material? What are the structure and properties of ceramic material and how the ceramic powders are made? What are the processes and which are used to converts these powders into ceramic products? What are the various applications of the ceramic product? So, that was one particular module which was module number 3 which have already been covered in particular course,

If you remember in module number 4, we have seen what are the different types of polymers, thermo sets and thermo plastic? And, what are the structures and properties of polymer or the plastic? We have seen in our previous module in our last module what are the various types of composite materials? And specifically modules 5 were focusing on the polymer matrix composition. We have seen different types of process, which are used for processing of polymer matrix composites. We have understood basic mechanism of various processes is that how polymeric matrix composites are made? And, how the raw material if you member there is the matrix and reinforcement. Today also, we will see the same diagram and the will try to understand that what is the basic philosophy of

ceramic matrix composites? And, what is the matrix in a ceramic matrix composite and what are the different types of reinforcement in the ceramic matrix composites?

So, just taking reference to what we have already discussed in polymer matrix composites. We have seen that how a polymeric matrix is blended with the reinforcement? What are the various types of reinforcement, which are used in polymer matrix composite? And, we have also seen different process which is used to blend these 2 constituents of composites materials together that is the matrix and the reinforcement.

So, all that we have covered in this particular course in till now have this focus on different types of material which have non metallic property. And, the processing roots for converting these materials into a tangible product or it into different types of tangible products. So, whenever we have discussed a particular process our focus has been on the conversion process that how the raw material can be converted using different forms of form of energy or a different types into the final products. So, our focused has been on the process, our focused has been on the process capability, our focused has been on the advantage of that particular process.

Also, we have highlighted what are the disadvantages of particular process? And, finally, we have 0 down and certain specific application of that particular process or that product which has been process by that particular process. So, we this background we are going to start today another module that is on ceramic matrix composite. So, this introduction is necessary because this relates to the broad course that we are covering that is the processing of non metals. So, basically total course is processing of none a metal and different material that has been the focused area in this particular course has been the glasses, the plastic and the ceramics. And, for plastics we have already taken 1 course or1 particular module on processing of polymer matrix composite.

And, this particular module that is module number 6 is focusing on the ceramic matrix composite. And, in our last module that is module number 7 our focus would be on the secondary processing of different types of non metallic materials; specifically focus on the materials which have non metallic property and the composites of these materials. We will be focusing on the secondary processing in terms of machining of and joining of polymer matrix composite and to some extend to the ceramic matrix composites. So, that is going to be our last module of this particular course.

So, with this introduction now I come to beginning or introduction of today's lecture that is on ceramic matrix composites. So, what are ceramic materials that we are just going to revise because this particular things or this particular topic has already been covered in our module on ceramic materials. And, we are going to revised today that what are the ceramics or there may be audience, which is only it is interested in this particular lecture.

So, for them, just to have an introduction that what are the ceramic materials; and what is the need when already we have a ceramic material. Already we have that technology to convert a ceramic basic constituent into a final product. So, we can use the ceramic raw material and we can convert into final products. Then, what is the need to reinforce this ceramic material into engineering into a new engineering material, which we are calling as the ceramic matrix composite.

So, already that technology is there the science of ceramic is understood the technology for converting the ceramic into tangible products is well known. Then, why we are using this particular material that we are calling as the ceramic matrix composites. So, there has to be some logic, there has to be some need, there has to be some requirement for the development of advance materials such as ceramic matrix composites. There has to be certain specific applications spectrum for which ceramics by themselves are not suitable.

They have to be reinforced by cretin reinforcement. So, that they are able to meet the needs and the requirements that particular application. So, what are the limitations of the ceramic that all so we are going to cover in today's lecture. Then, we will see that what are processing challenges is for ceramic matrix composites, because this particular modules is focusing on various processing techniques that are used for processing of ceramic matrix composites. So, with this introduction today's lecture let us now focused on the primary or the basic fundamentals of the ceramics.

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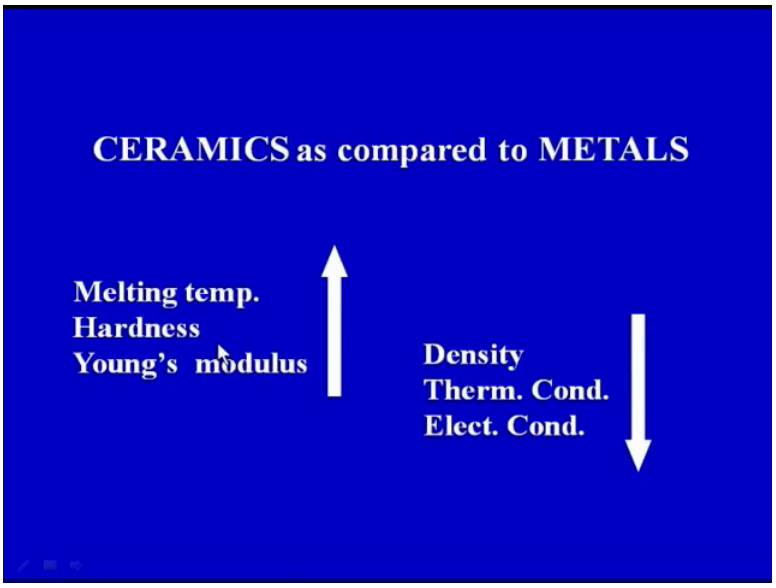

Now, first important thing is that the comparison of the ceramics and the metals. So, on your screen you can see that there are few properties which are better in case of ceramic as compared to metals. So, you can have a feel the melting temperature of ceramics is higher than the metals. The hardness is also higher as well as the young's modulus. So, most of the ceramic will have high melting temperature they will have high hardness and they will have higher young's modulus.

So, when we have a material at hand which has high melting temperature, which has high hardness and higher young's modulus? For those materials we need to have specific manufacturing processes or specific processing roots. Why because if we go to the primary manufacturing process or the forming primary forming process, which are the basic process which are used for forming may be one of the process may be costing because if the shape to the products.

So, when the melting temperature is very high it is difficult to melt the material. So, ceramic have high melting temperature therefore it is difficult to melt them. When it is difficult to melt the particular material, it is difficult to be the processed by the simple casting process. So, therefore casting or molding which we are using very frequently or widely for metals as well as in molding in case of plastic.

So, casting in case of metal and molding in case of plastics is the relevant because both the materials have relatively lower melting point; but in case of ceramic we have a very

high melting process. So, when melting points higher than the metals it is difficult to make them by casting process. Similarly, the hardness is very high. So, if you remember in the basic case in the basic classes of manufacturing it is start that if you have a machine are material. The hardness of the tool should be higher or greater than the hardness of the work piece. So, if we want to machine ceramic materials the hardness of our cutting tools higher than the hardness of the ceramic.

So, we have a material in our hand which has very high melting temperature, which has considerable high hardness, which has higher young modules as compare to the metal. Therefore, the processing technology or the processing techniques required for processing of ceramic would be different than those for metals, because of these properties. Why I am focusing only on the processing, because our focus area is processing. We are discussing course on processing of non metals. And, these particular applications or these particular properties would certainly advocate some important applications for these materials like these material can be used for high temperature applications. So, we will see that what are the various specific application areas of the ceramic material

So, this is just a revision of the module which has already covered, but it is in important because it is going to lay of foundation for the discussions related to the manufacturing or processing of ceramic matrix composite. So, if there are few properties which are higher or better than metal we should not say better, because in cases these properties may also prove to be a challenge in case of ceramics or prove to be a limitation in case of ceramic. So, the melting temperature hardness and young's modules in case of ceramics is higher as compared to metals whereas the density, thermal conductivity, electrical conductivity, in case of ceramic is lower as compare to metal.

So, they are we can say poor conductors of thermal conductivity, electrical conductivity, and they have lower density as compare to metal. So, these particular properties of ceramics also advocate certain specific applications for ceramics. For example, ceramic can be used where light weight is the important design criteria. Wherever we have to design material, wherever we have to advocate the use of material for light weight application yes, we can certainly choose ceramic so our metal because they have lower density as compare to metals.

Moreover, where thermal insulation is required? Where we want less thermal conductivity? There also, we can locate the use of ceramic, also the electric conductivity. Therefore, we see huge application spectrum of ceramics in electrical insulation industry, or in electrical insulation application. So, summarize what is being presented in this particular slide we are trying to compare the ceramic metals. And, we have seen that the melting temperature the hardness and the young modules ceramic are higher than the metals. And, density thermal conductivity and electrical conductivity of ceramic is lower than that for metal. So, these are some of the property which should always keeping mind when we are doing any discussion related to the ceramics.

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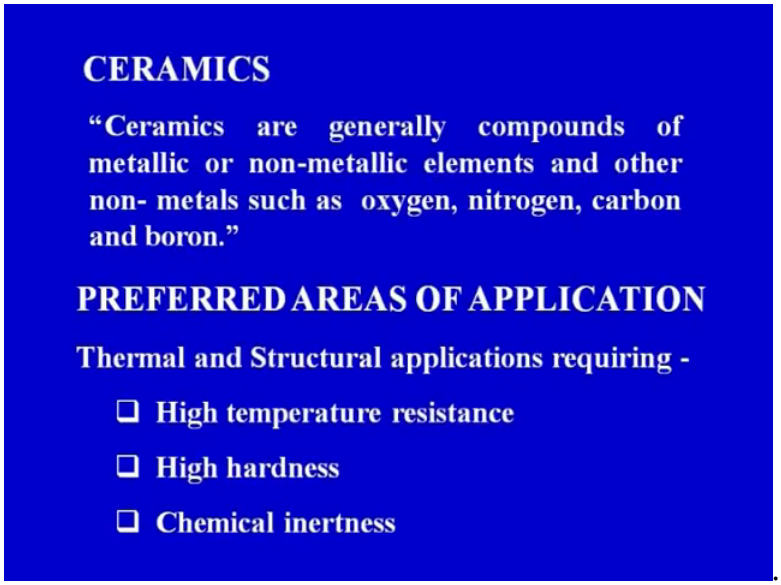

Now, just to revise the basic definition of the ceramics, ceramics are generally compounds of metallic or non-metallic elements and other non-metals such as oxygen, nitrogen, carom and boron. So, basically why this particular section is being discussed, why this particular module is being discussed in our course? So, here the word non-metal is coming 2 times. So, ceramics are generally compounds of metallic or non-metallic element and other non metals such as oxygen, nitrogen, carbon, and boron. So, basically the ceramics are made are these compounds which are made up for cretin elements which have non-metallic characteristics.

And, what is the difference between metal and non metal that we have already covered in our previous modules. So, we are not going to discuss those things in detail, but this

particular definition that we the summary of what are the basic we can say constituents of the ceramic. Also, we have seen the different types of the ceramics and their application in our previous module. So, what are the preferred areas of application, where the ceramic are used? So, we have certain thermal and structural applications where the important design guidelines are there the material that is used for those applications. The applications can be thermal applications or structure applications. So, those applications advocate high temperature resistance. So, where high temperature resistance is required because we have already seen in the previous slide there the thermal conductivity of ceramics is a lower as compared to that for metals.

So, were high temperature resistance is required there we can advocate the use of ceramics high hardness is required. For example, we are going to take please high hardness may mitigate the fact of were. So, there also we can say there ceramics can be used also were chemical inertness is required. In the subsequent slides we will see that what are the specific advantages of using the ceramic material? And, there we will see that 1 of the important advantage of ceramics is that they have chemical inertness. So, they do not react with many chemicals they can be used where chemical inertness seasons important design criteria.

So, what are the important three applications spectrums for ceramic material? They can be use for high temperature resistance, they can be used for high hardness is the design criteria as well as were the application requires chemical inertness. So, we have certain preferred areas of those applications for ceramic materials. So, certainly where ceramics are used their ceramic matrix composites can also be advocated or can also be applied or use. Therefore, we before going to the ceramic matrix composites we can just target on cretin specific areas were these materials that we are going to study there are going to be applied. So, these are some of the specific application areas for ceramic as well as their composites.

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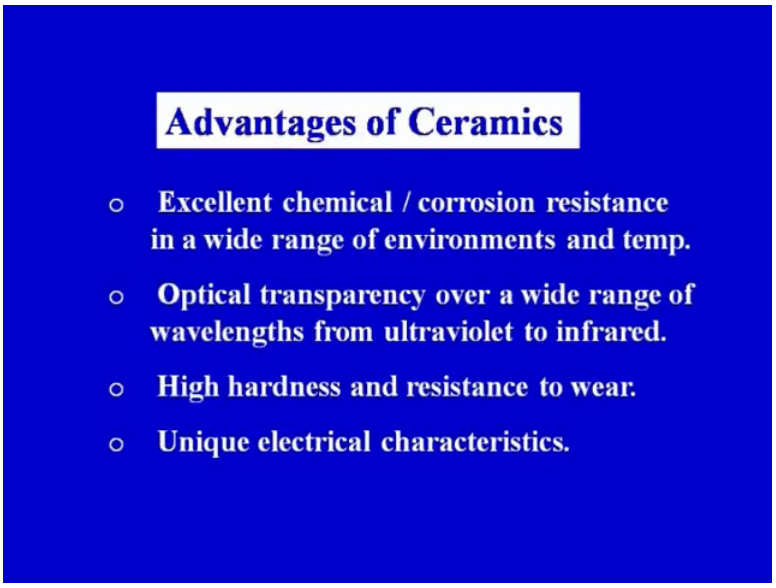

As I have already told now we are going to just see that what are the advantages is of ceramics? Now, from the previous discussion, which we have undertaken in today's lecture many things are very, very cleared. Because we have seen that what are the various applications was ceramic matrix composites are till toady may be till now we can say ceramics can be used. So, those applications are advocated, because they have cretin property. Now, we just outline that what are the advantages of ceramics?

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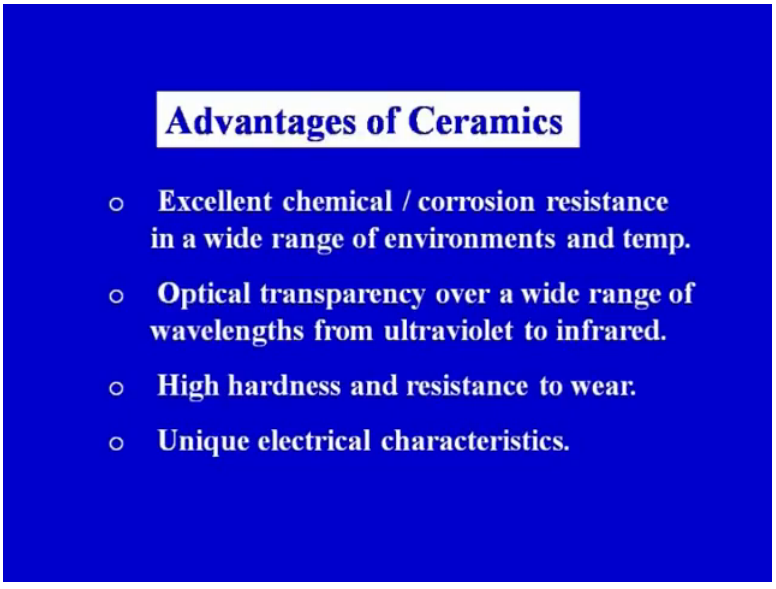

So, one of the important advantage of is that they have excellent chemical corrosion resistance in a wide range of environments and temperatures. So, what was the last point in the previous slide that the ceramics can be used in those applications where chemical inertness is required? So, same point is being emphasized again now that is one of the important advantages of ceramics. So, the important advantage is that they have excellent chemical and corrosion resistance and that also under wide range of environment. So, widely are most of the environments are not going to effect the ceramic material and therefore they are used for applications which require chemical inertness also the temperature does not affect the structural or the property of the ceramics. So, therefore they are use for high temperature application also.

So, one of the important advantage of ceramics is the chemical inertness; second advantage is the optical transparency over a wide range of wavelengths from ultraviolet to infrared. So, that also advocates the use of ceramic in various applications that is the optical transparency and that over also over a wide range of wavelength of ranging from ultraviolet to infrared.

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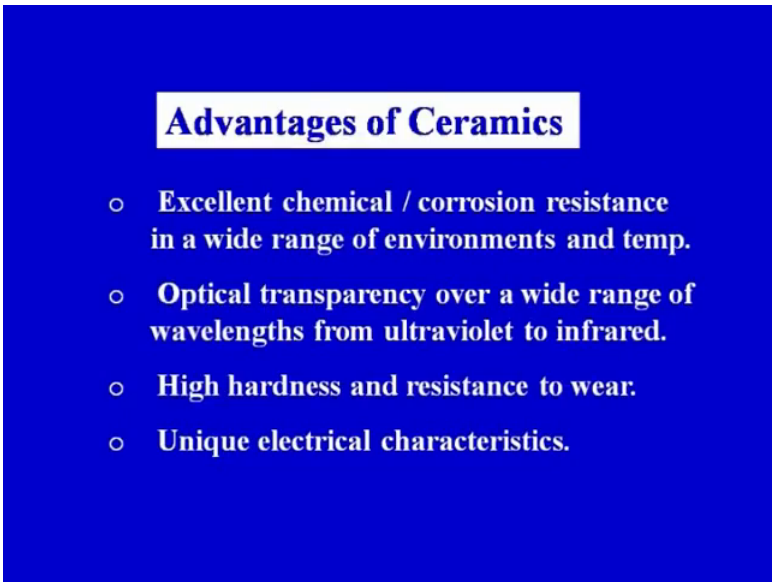

So, again reading the point for you optical transparency over a wide range of wavelength from ultra violet to infrared. So, to the applications spectrum is huge ranging from the ultraviolet to infrared the ceramics of offer optics transparency. So, there also because of this property ceramics have got certain specific applications also high hardness and

resistance to we at which I have already told that wherever we are is going to be a problem we are going to use a ceramics components there because of its high hardness.

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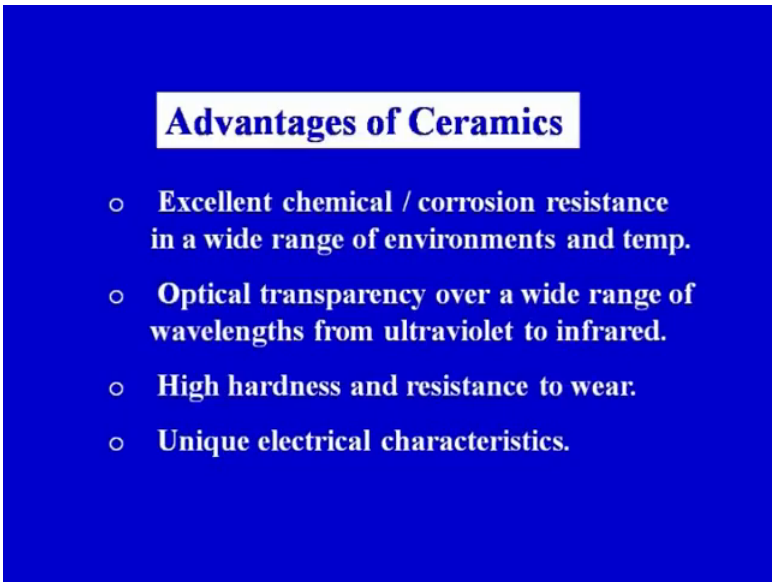

When the hardness is the higher the where should be lower under ideal conditions because this thing can be refuted or it can be challenging certain other applications. But wherever the hardness is increased we can say the we are should be less under normal conditions. So, high hardness, high temperature resistance, resistance to we are resistance to various types of corrosive environments requirements. So, these are some of the important advantage is which are offered by the ceramic materials and last on your screen you can see it has unique electrical characteristics which we have already see in our slide where we have compared the ceramics with the metals.

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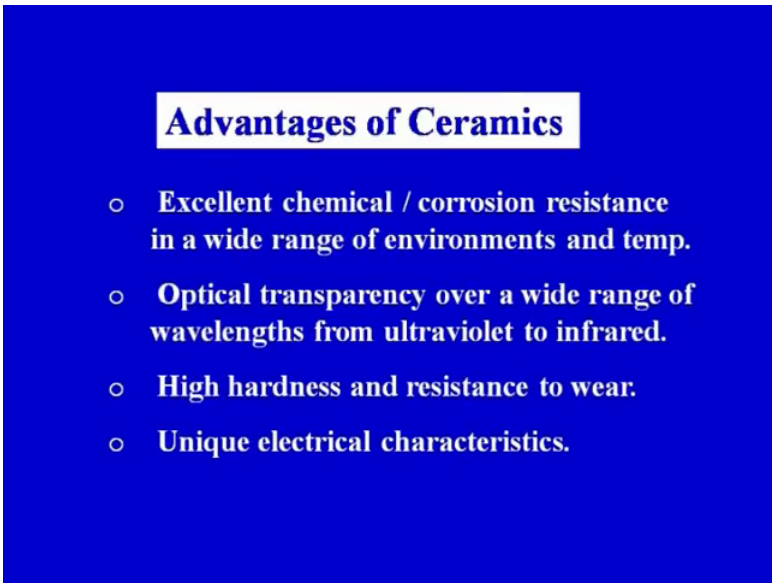

We seen that the electrical or we can say conductivity of ceramics is less as compared to the metal. So, when the conductivity is less they can be use for insulation purpose. So, the ceramics can also be used for insulation purposes is and the advantage with ceramics is that they have unique electrical characteristics. Why? Because we have seen in our previous slide there are few properties in which the ceramics have higher as compared to the matters.

Now, just give brief review what we have discussed and that slide again i am revising hardness, young's modules and the temperature resistance is or the melting temperatures is higher in case of ceramics as compared to metals. On the contrary, we have seen the electrical conductivity, the thermal conductivity and the density is lower for the ceramics as compared to metals once again because this is important when we will go to the ceramic metals composites because we have to see that were the ceramic matrices composites can be used. So, we should understand the basic properties of ceramics.

So, when we compared a ceramic with the metal there are few property which is higher in case of ceramics. So, what are those properties is that is the melting point the hardness and the young's modules. What is lower? T he density in case in ceramic is lower, the electrical conductivity is lower and the thermal conductivity is lower. So, ceramics are ceramics matrixes can composites can be used for electrical insulation as well as for thermal insulation. So, therefore, will see lot of ceramics products in electrical insulation

industry. So, these are the some of the advantage is and these advantage is advocate the use of ceramics in a large numbers applications were electrical insulation or thermal insulation is the require were light weight is required or in certain case is where the hardness is more we can use it for wear resistance application also.

So, why I am emphasizing on these? Because now we are going to move into for a different spectrum, where we are going to address the limitation of the ceramics. So, before going to the limitations we should very clear in our mind regarding the advantages of the ceramics because of limitations of ceramics we lead to the development of concept of completely new class of materials, new family of materials which is the today's topic are which is the topic of our discussion today.

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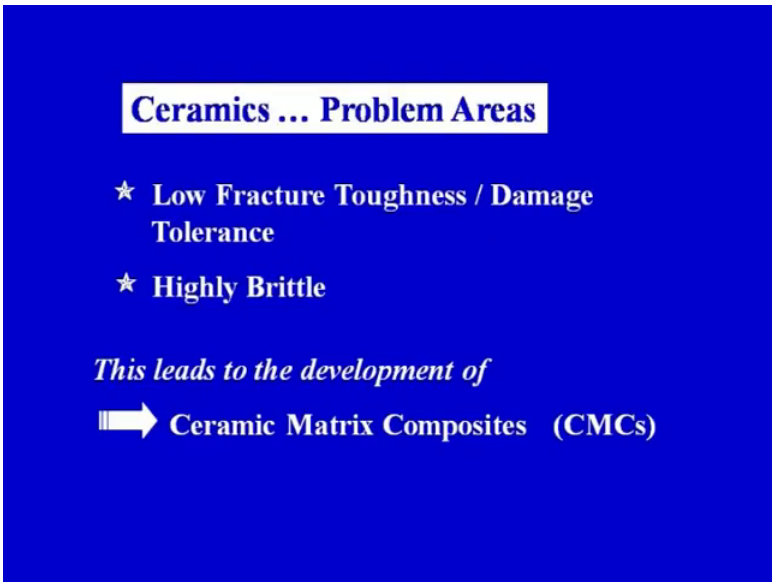

Now, what are the problems area related to ceramics? If you have understood I have revised also what are the advantages and how ceramic compound with that of metals. That point we have already emphasized 2, 3 times. I think it is very clear that what the advantages of ceramics are. Now, every material has got certain disadvantage of certain limitations also. So, ceramics have got certain limitations also. Now, what are these limitations?

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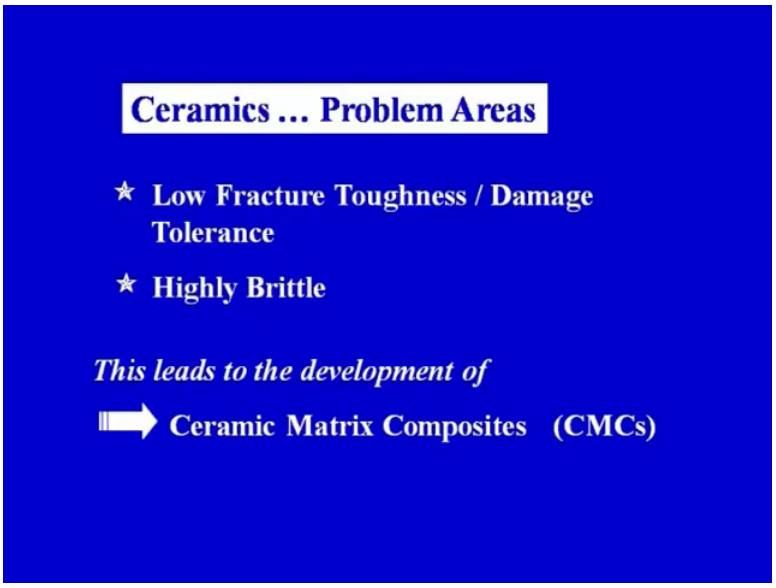

Low fracture toughness or damage and they are highly brittle. These are the 2 important we can say limitations of the ceramics. So, we these important limitations can be overcome with the development of the concept of the composites materials. So, low fractures of materials and highly brittle behavior of the ceramics has to be addressed somehow. These two important limitations have to be overcome.

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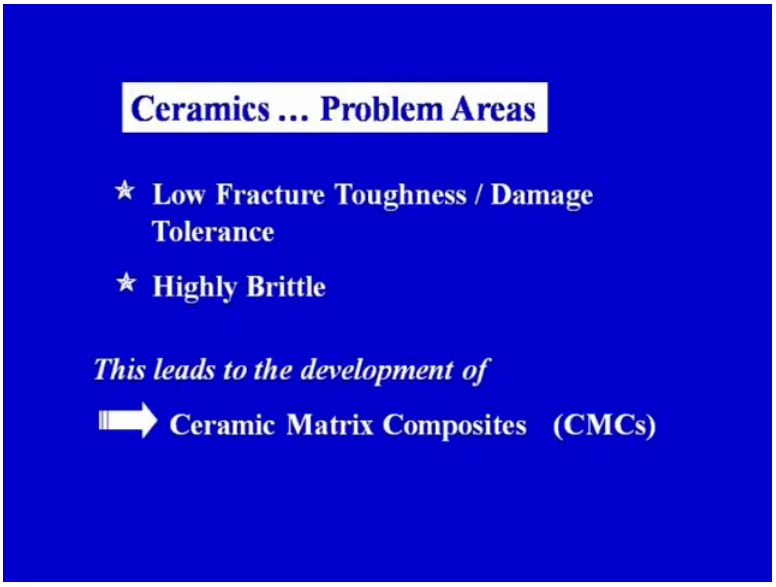

So, this leads to the developments of ceramics matrix composites or the CMCs, in brief we can call them as the CMCs. So, we can see that CMCs is now what is the mandate of

development of ceramic matrix composite I have revised 2, 3 times. Ceramics have got certain advantage which is metals. We have compared that ceramics and the metal. The ceramics have got certain advantages. The advantages also we have seen proffered area of application of ceramic also we have seen, but there are few limitations with this ceramic. Now, limitations are also highlighted on your screen low fracture toughness or damage as well as their highly brittle.

Now, we want to minimize these particular limitations, which are mentioned on the screen. In order to minimize these limitations and take advantage of the advantages of ceramic or new concept of composites is developed. And, the composites with the ceramic has the matrix material are called the ceramic matrix composites. Now, we will see, what is the basic concept behind the development of the concept of ceramic matrix composites. Although these we have already seen that what is the matrix, what is the reinforcement in our previous module, which we are seen the polymer matrix composite but in context of ceramic matrix composites. Again we will see that the basic concept of ceramic matrix composite. So, basically composite materials consist of two important macro constituent that is the matrix and the reinforcement.

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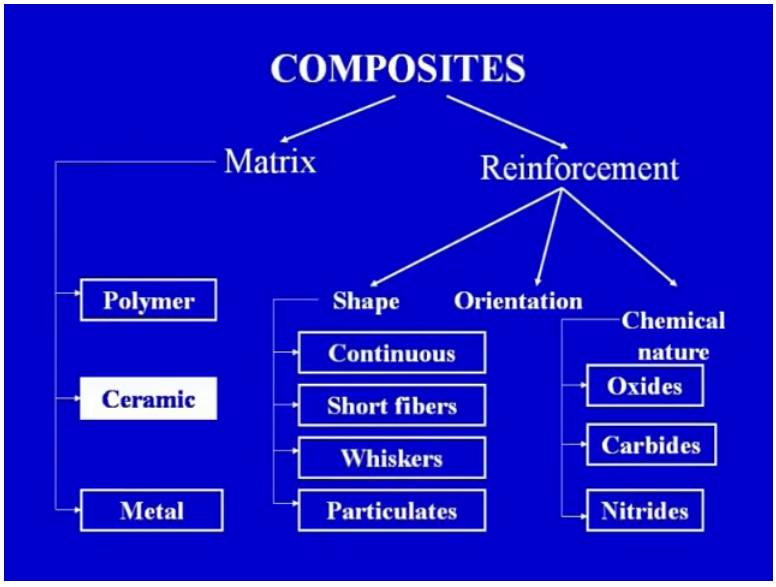

So, the matrix can basically be of the polymer we can have a polymer matrix composite, we can have a ceramic matrix composite and we can have a metal matrix composite. Since, our course focusing on processing of non metals. So, our focused is on polymer

matrix composite and ceramic matrix composite. Polymer matrix composite we have already covered in previous module; this particular module would be focusing on the ceramic matrix composite. So, basically a composite are made up of 2 matrix constituent which are called the matrix and reinforcement. These two are combined together to make a composite material. And, in case of ceramic matrix composite the matrix would be made up of any type of ceramic. The different type of ceramics we have already covered in our previous module and we would be covering in this particular module also.

But before going to the details to the types of matrices, which are used or the ceramic matrices we are used for making a ceramic matrix compounds. We need to understand the basic concept that in ceramic matrix composite the matrix would be made up of a ceramic material a type of ceramic can be different. Different types of ceramic are there but the matrix would be ceramic that is the bulk would be provided by the ceramic material. Then, the reinforcement further be divided into 3 categories.

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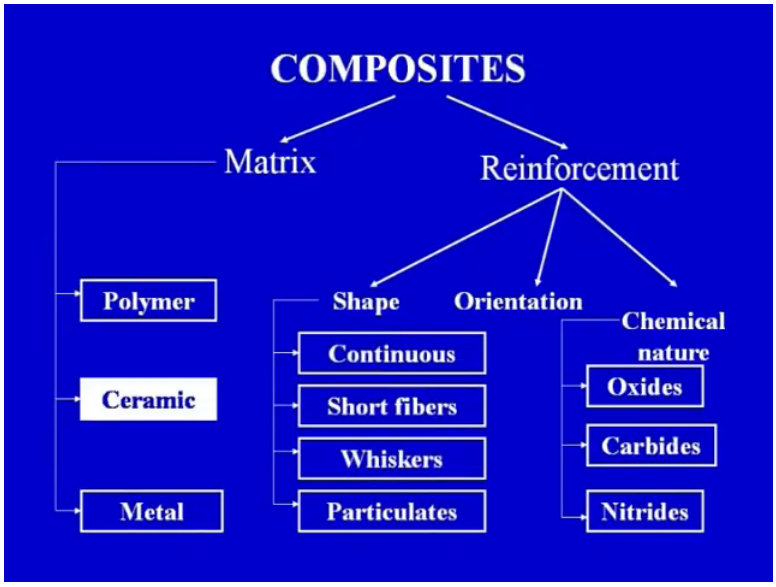

We can have shape on the basis of shape, we can have a different type of reinforcement. On the basis of orientation of the reinforcement we can have different types of composites, we can have aligned reinforcement, and we can have a random type of reinforcement. So, on the basis of orientation the composites can be different. And, on the basis of the chemical nature of the reinforcement we can have different types of

composites. So, reinforcement can further subdivided into 3 sub category on the basis of shape, on the basis of orientation and on the basis of chemical nature.

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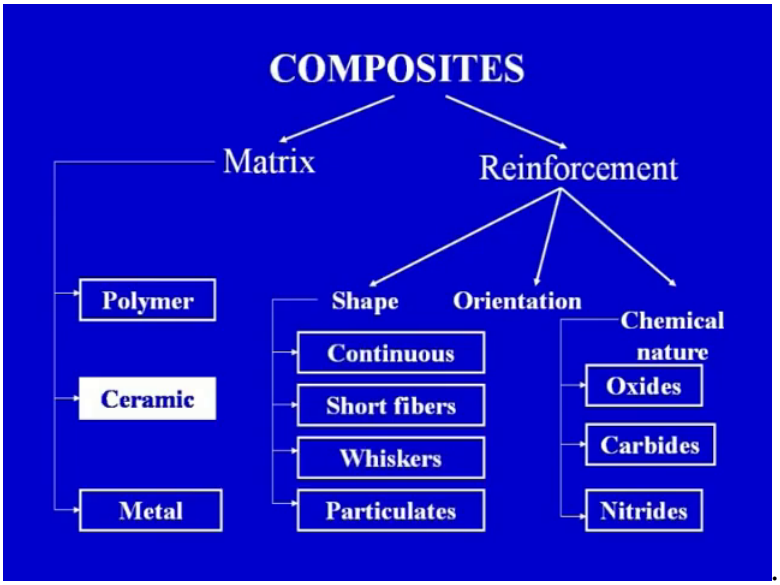

So, one by one we can see on your screen on the basis of shape: we can have continues reinforcement, we can have short fibers reinforcement, we can have whiskers as a particular shape of the reinforcement and we can have a particular type of reinforcement. So, majorly in ceramic metric composites the reinforcement can continuous reinforcement or it can be in the form of particulate or whiskers. So, we can have different shape of the reinforcement that would go into a ceramic material. Depending upon the material of the reinforcement also we can have a ceramic as a reinforcing material also.

So, we have a ceramic as the matrix, we have a ceramic as the reinforcement and we can have a ceramic; ceramic composite material; in which the matrix is also a ceramic material and the reinforcement is also a ceramic material. So, the 2 ceramic are now combining together to make a composite material. Why we are combining the metrics and reinforcement together? Because we want to take advantage of the ceramic material. We have already seen that the ceramic offer a lot of advantages as compare to the other engineering material.

So, we want to take those advantages but it has got certain limitation in terms of (( )) and damage tolerance as well as they are highly the ceramics are brittle. So, in order to

overcome those limitations we are adding a reinforcing face, and we are developing a new material or we are developing a new concept, which is minimizing the limitation of the monolithic or we can say only ceramic. If use an only ceramic it has got certain limitation we are reinforcing it whether reinforcement limitation are many mined. So, on the basis of shape we can have different types of reinforcement

We can have a continuous reinforcement, we can have short fiber reinforcement, we can have whiskers the reinforcement, and we can have a particulate as the reinforcement. On the basis of orientation I have already told we can have all the reinforcing elements in 1 direction. We can have an aligned reinforcement or a directional reinforcement. The reinforcement can randomly distribute in the metrics there also be we can also have random reinforcement.

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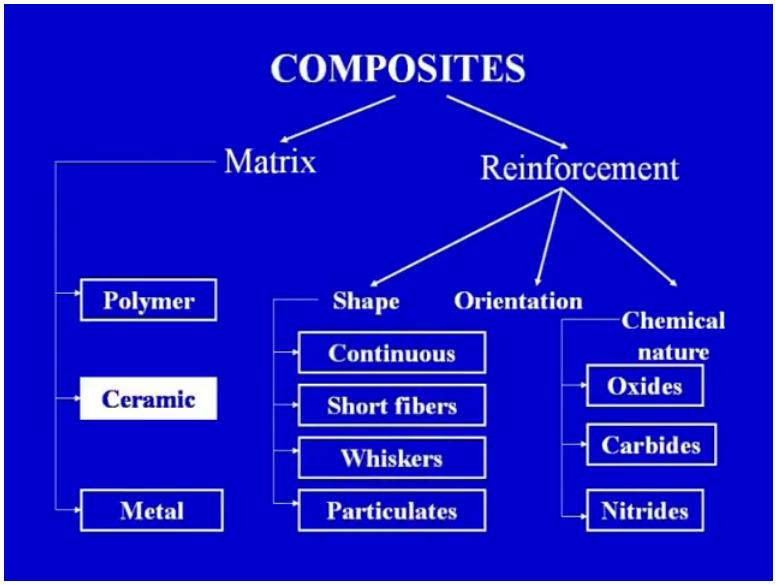

So, we can have aligned reinforcement, we can have a random type of reinforcement. And, on the basis of chemical nature we can have oxides. For example, aluminum oxide we have carbide such as silicon carbon and we can have a nitride of certain elements. So, basically the chemical on the basis of the chemical nature of the reinforcement and we have got wide variety of the materials which can used as the reinforcing materials in the ceramic matrix. So, we can have oxides, carbides and nitrides as in the reinforcing material in the ceramic matrix. So, in order to some arrays the ceramic metrics composite.

We can have a matrix, we can have or we have a ceramic matrix which is reinforce with the additional reinforcement. And, the reinforcement can be on the basis of shape it can be continuous short fiber whiskers or particulate. On the basis of orientation it can be aligned, it can be random. On the basis of chemical nature, we can have oxide, carbide and nitride the example already I have given. So, this is a basic concept of the ceramic matrix composite. Now, ceramic matrix composite from this concept we can come on to a very simple definition of the ceramic matrix composites.

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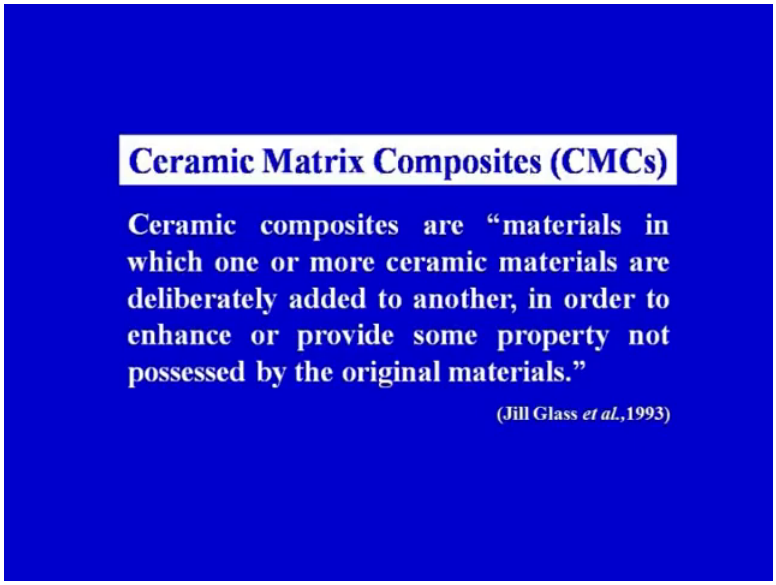

On your screen you can see the ceramic composite are the materials in which one or more ceramic materials are deliberately added to another in order to enhance or provide some property not posses by the original materials. So, original materials have got certain properties but they have got certain limitation also. In order to overcome those limitations we add additional material, which may be ceramic may not be ceramic. And, we try to develop a concept of material which aims at overcoming the limitations of the original or the basic material. So, the definition also state that only the basic summary of the definition is that the material in which one or more ceramic materials are deliberately added in order to enhance are provide some property which is already not protest by the original materials

So, this is a basic definition of ceramic matrix composites. So, by now I think the audience might gone have idea; that why we are trying to develop a new material when

already we have got science and technology a well developed science and technology in case of ceramic. So, all those ceramic the science is known what are the basic constituent in the ceramic is known. How the ceramic can be made into product is known. Why we are advocating the use is ceramic matrix composite? Because of certain limitation of the ceramic we are adding additional fee or additional material into the ceramic or the basic ceramic material in order to overcome those limitations which are present in the original materials

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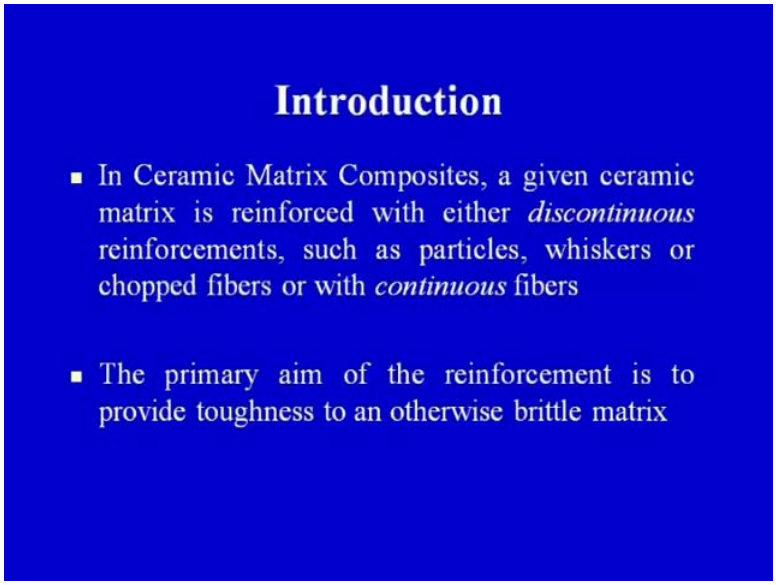

Now, again the introduction of the ceramic matrix all though it has been explained in detail with the help of diagram. That the matrix is the ceramic materials the reinforcement can be of different type. On the basis of the shape of the reinforcement, on the basis of the chemical nature of the reinforcement and on the basis of the orientation of the reinforcement we can have different types of ceramic matrix composite. So, all those things now been highlighted in these points.

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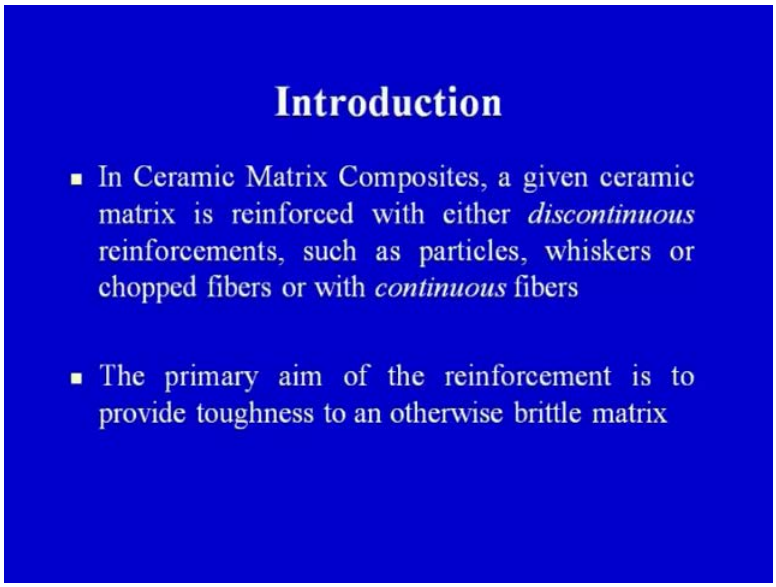

So, point by point we will address and if needs is there I will give certain example, also. In ceramic matrix composite given ceramic matrix is reinforced with either discontinuous reinforcements such as particles whiskers or chopped fibers or with continuous fibers. So, if you see the diagram if you remember the diagram. What we have discussed in previous slide? The matrix is a ceramic material and the reinforcement on the basis of the shape can be a different type it can be discontinuous type or it can be of continuous type. So, in continuous type we can have fibers. And, in discontinuous type we can have particle whiskers or short fibers or chopped fibers. So, on the basis of the shape of the reinforcement we can have different type of ceramic matrix composites.

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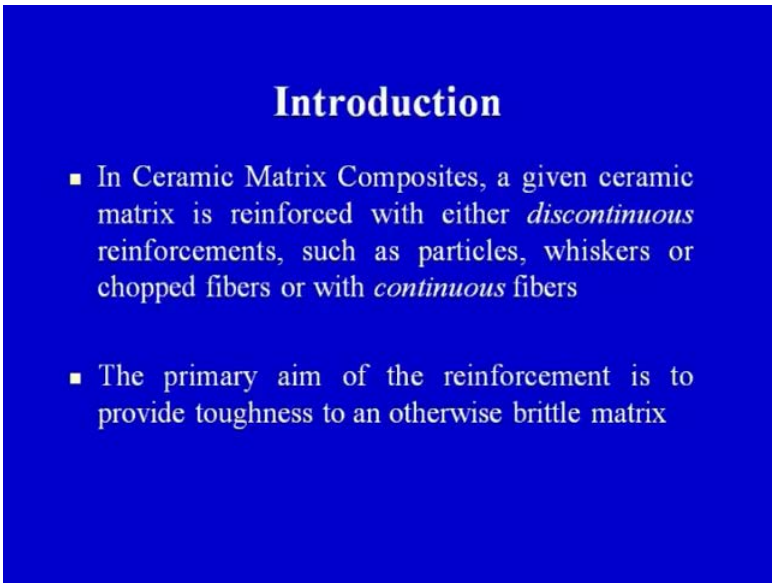

So, the primary aim of the reinforcement is to provide toughness to an otherwise brittle matrix. So, this particular point addresses the limitations of the ceramic, if you remember what are the two important limitations of the ceramics which we already seen in today's lecture. The two important limitations are the fracture toughness and the brittle behavior of the ceramics. So, the primary aim of the reinforcement is to provide toughness to when otherwise brittle matrix. So, the reinforcement address is both the issues of toughness and the brittleness

So, if we are adding a reinforcement which can be discontinuous or can be a continuous reinforcement. So, when we are adding the reinforcement it is addressing both the issues of the toughness as well as of the brittleness. So, we can say that deliberately we are adding reinforcement into the ceramic matrix. In order to improve its properties and to do away with the limitations which are present in the monolithic material or in the original ceramic material?

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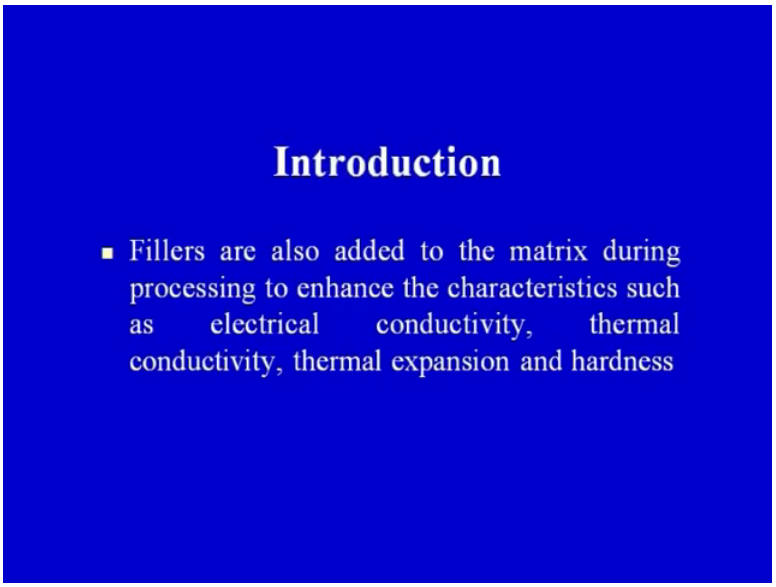

Fillers are also added to the matrix during processing to enhance the characteristics such as electrical conductivity, thermal conductivity, thermal expansion and hardness. So, what are the fillers? So, basically we can say in any composite there are three constitutes; one is the matrix which provides the bulk, another is the reinforcement which in our case we have seen it can be discontinuous or continuous reinforcement, we can have continuous fiber or chopped fibers and the additional phase is are the fillers. So, fillers are added in order to gives specific requirement or in order to gives specific properties to the composite material.

So, we can see that what are the properties, which can be enhanced with the addition of the fibers? So, we have seen that the electric conductivity is poor as compared to metals in case of ceramics; electrical conductivity is poor in case of ceramics, thermal conductivity is also poor in case of ceramics; and the hardness is good. So, even if you want to further improve the hardness of ceramic we add certain fillers.

If you want that, you should try to manipulate the thermal conductivity and the electric conductivity of a ceramic material; we can add certain fillers into the composite material. So, basically we will have a ceramic matrix we will have reinforcement and we will have the fillers. And we will try to develop a concept of a ceramic metrics composite which would try to address to certain specific applications where the ceramics by themselves are not able to meet are there not able to satisfy the requirements. So, basically the

concept of ceramic matrix composite is being developed to overcome certain limitations of the monolithic ceramics. So, we can add certain fillers to further improve the properties of the ceramic matrix composites.

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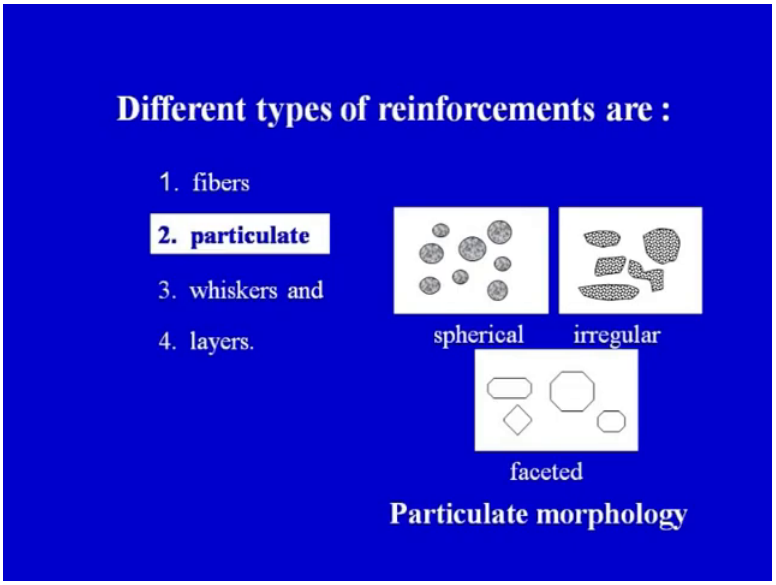

Now, what are the different types of reinforcements? On the basis of shape of the reinforcement, we can have different types of reinforcement. So, we can have already seen that we can have a continuous fiber in the reinforcement and we can have particles in the reinforcement, we can have whiskers in the reinforcement. So, different types of reinforcements can be added into the ceramic matrix.

So, this is one particular example we can see we can a fibers as the reinforcement ,we can have a viscous as the reinforcement and even layers can also be added as the reinforcing place are the reinforcement material. But in this particular slide we a just going to see the particular reinforcement. So, on your screen you can see we can have a spherical particle as the reinforcement, we can have an irregular shaped of a shape of reinforcement and we can a faceted type of reinforcement. You can see in this 4 species. Here we have spherical all the reinforcement particles all though the size of the particle is different but the shape is spherical in all the species. Whereas, here we have an irregular shape somewhere we have this particular shape the shape is different from the other shape of the reinforcement.

So, the reinforcement we are putting in a ceramic matrix it is in the form of particulate or in the form of particles. The particles can have different shapes on your screen you can see the particles are spherical particles or they can be irregular particle of they can have certain specific space is that they can be called as faceted particle and all this is called the particle morphology or particulate morphology. So, this is one particular examples of how the reinforcement will go into the ceramic matrix. We can even have continuous fibers in the ceramic matrix and the reinforcement in this particular case would be continuous fibers.

So, the generic name would be ceramic matrix composite only but the reinforcement would be continuous in the form of fibers as is case number 1 in on your screen. So, we can have a continuous fiber also as the reinforcement, we can have whiskers also as the reinforcement, we can have different layers also as the reinforcement. But this particular slide gives an idea that how the particles can be added as the reinforcement. So, we can just say that this white background represents the basic ceramic material and this grey spherical particle represents the reinforcement which has been added into the basic ceramic matrix. So, white portion represent the matrix white portion represent the matrix and the grey version represent the reinforcement in case of the ceramic matrix composite.

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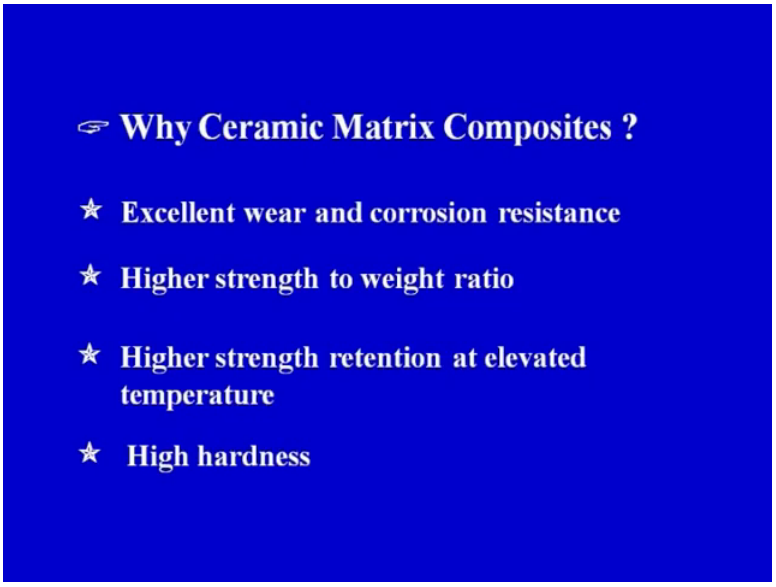

Now, why we should use ceramic matrix composites? When already the ceramic are available with. So, the important applications are where we require excellent wear and corrosion resistance. So, ceramic metrics composites are widely used for wear assistant property and the corrosion resistance properties. Wherever we want light weight application higher strength weight ratio is one property; which advocates the use of a material which as high strength weight ratio for light weight application. As we have already seen in our comparison of the ceramic and metals in the beginning of today's lecture we have seen in the density of ceramic is lesser as compare to that for metals.

So, there for the ceramic matrix composite can also be advocated it in those applications were light weight is the requirement. So, they can be used for excellent wear and corrosion resistance properties, they can be used for higher strength to weight ratio were light weight application are there higher strength retention at elevated temperature. So, if you remember from the basic manufacturing processing is one of the important properties of the cutting tool material is the hot hardness. So, what is hot hardness? Hot hardness means that the cutting tool should retain it hardness at the elevated temperature. So, elevated temperature is the temperature in wherever the tools in contact with the work piece. So, at that particular zone the tools should retained its hardness at elevated temperature.

So, therefore ceramics or the ceramic matrix composites are the material which retained their hardness even at elevated temperature. So, they retain strength and the hardness they although in this particular point it is return; that higher strength retention at elevated temperature. So, which means that they should be able to retain their strength at higher temperature? So, one of the advantage of ceramics as compare to that for metal was that they have a melting point.

So, this particular property while downs from the particular property of the ceramic. So, one of the important advantage is that they can retain their strength at higher elevated temperature; and more over ceramic matrix composite have very high hardness. So, why should we use the ceramic matrix composites? So, there are four important we can say catch points or key points that we should keep in mind. So, first important catch point is the excellent wear and corrosion resistance; this property coming from directly from ceramics.

If you remember we have today revised 2, 3 times is the basic property of the ceramics. And, we have seen that they have very high hardness, wear resistance is good and as well as chemically they are inert. So, when they are chemically inert the basic material there are basic ceramic is the chemically inert they composite that we are going too made; with that particular material as the ceramic, as the ceramic ought to be chemically inert.

So, therefore it will be resistance to corrosion it would be chemically inert, the wear resistance would be good, strength to weight ratio is higher which means it can be use for light weight applications, high strength retention at alleviative temperature and high hardness. So, again I have revised the salient advantages or the salient properties that the ceramic matrix composites posses or the important characteristics of the ceramic matrix composite. So, these are the important points we should always remember in context of the ceramic matrix composites.

Because these will further advocate or these will be further lead to specific applications of ceramic matrix composites. So, when we know the characteristics or the important advantages of a particular material; we can definitely advocate the use of that particular material in certain specific applications. So, where ever light weight is required, wear resistance is required, resistance to corrosion or the chemical inertness is required and high hardness is required. We can very easily advocate the use of the ceramic matrix composites.

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So, we have seen four important characteristics but these are another which is boiling down from those characteristics only. So, those were highlighted the characteristics like high strength to weight ratio which means used for light weight applications, resistance or high corrosive resistance which mean high chemical stability and non catastrophic failure. So, non catastrophic failure means that they will take some load and they will have some deformation before the actual catastrophic failure takes place. So, the stress strains behavior is of a monolithic ceramic is different from the stress strain behavior shown by the ceramic matrix composites; why because of the presence of the reinforcement or the additional reinforcement in the matrix. So, the monolithic ceramic or simple ceramic will have a catastrophic failure.

Whereas a ceramic matrix composite will not have a catastrophic failure; it will certainly under goes on strain before it finally fails. So, if we have seen the stress strain curve possible in the next particular lecture we will see the stress strain curve of a monolithic ceramic and for that of a ceramic matrix composite. So, this would be different therefore the ceramic matrix composite will show on non catastrophic failure. Where as a ceramic material because it is highly brittle will show a catastrophic failure. So, therefore ceramic matrix composites have some scenarigic properties of the 2 faces which have been combined together.

And, they possess certain specific advantages as compare to those of ceramics. So, therefore, from the very beginning we have seen why we need to develop a concept of a ceramic matrix composite. We started our discussion of CMCs from the point where we ended up with the limitation of the ceramic. So, wherever the limitations are there on account of fracture toughness of damage tolerances and because of highly brittle nature of the ceramic there are certain limitations. So, those limitations are overcome by the concept of the ceramic matrix composites.

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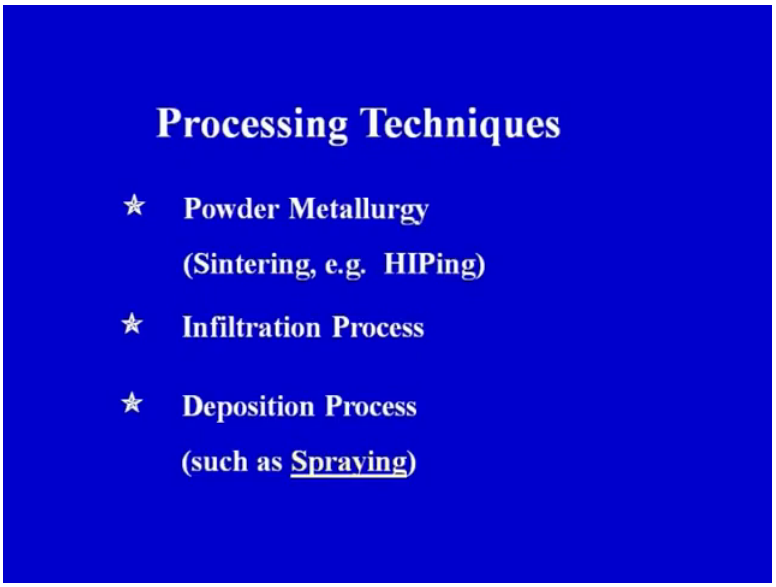

Now, what are the various processing techniques that we are going to cover in our module of ceramics or ceramic matrix composites? So, these are some of the important processing techniques that are the powder metallurgy. In powder metallurgy we will see the sintering or hot isostatic pressing. So, we will see what are the basic process details of powder metallurgy? What are the different types of powder that can be used?

And, how these powders can be converted into the tangible product? What are the products that can make out of the powder metallurgy technique? We will see the infiltration process. What are basic process details of the infiltration process? What are the specific applications areas of the products need by the infiltration process? And, also we will see the deposition processes is such as spraying.

So, these are some of the processing techniques which are used for processing of ceramic matrix composites; which we would be covering in this particular module on ceramic matrix composite. So, broadly the process is can be divided into three categories: that is the powder metallurgy techniques are the powder metallurgy root, infiltration process and the deposition process. So, these are three broad categories of process is which are used for processing of ceramic matrix composites.

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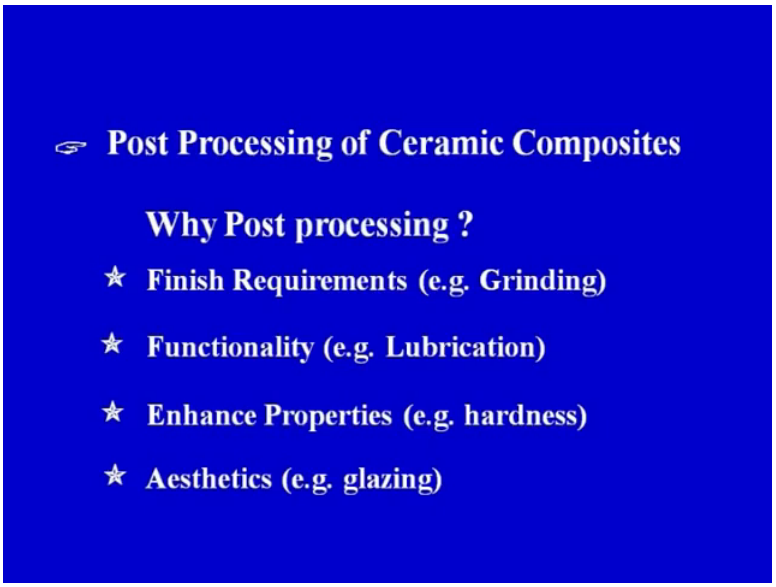

And, once the product is ready it is post processed. So, the post process processing of ceramic composite is done. Why post processing is required? Sometimes we want to have specific surface finish requirements. So, therefore, grinding can be done. Sometimes functionality has to be added into the product. All of you might have hard the self lubricating bearings. So, in case of self lubricating bearing sometime lubrication has to be additional function which has to be provided or the product has to posses this property of self lubrication. So, functionality has to be improve therefore, post processing is required. Also, sometimes we need to enhance the properties of the product which has been made by one of the process is which we have already seen in the previous slide like powder metallurgy, infiltration or deposition process.

So, we convert the basic material into the final product by any of the process is which were outlined in the previous slide. And, once the product is ready it has to be post processed. And, sometime for enhancing the properties we go for post processing of the product. And, finally, in some cases we need to improve the quality sorry the aesthetics of the product or we want to make the product pleasing to the eye. So, in those cases when we want to improve the aesthetics sometimes we require the post processing.

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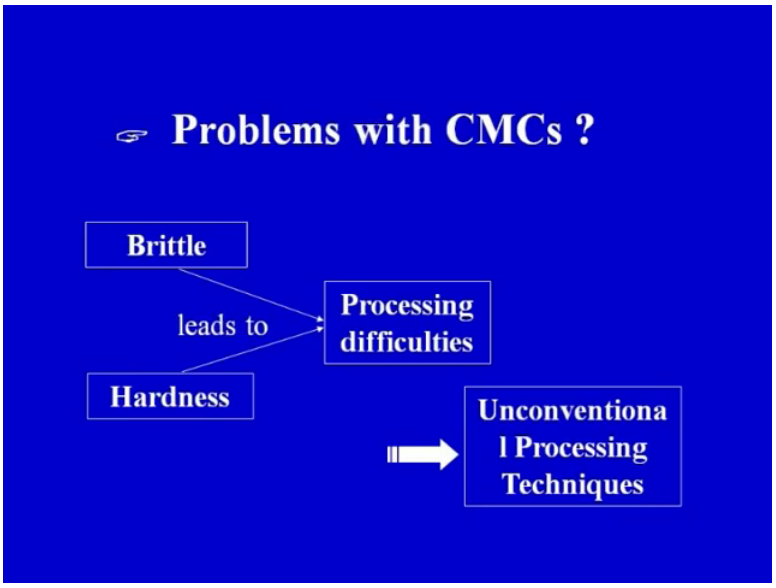

Now, what are the important problem areas with the ceramic matrix composites? So, one of the important limitation is they are brittle, they have high hardness and these lead to certain processing difficulties. So, sometimes we go for unconventional processing techniques. So, we are going to cover in this module the processing techniques which are used for processing of ceramic matrix composites.

So, with this we come to the end of today's lecture; just to review what we have covered today. We have just out lined the basic concept of the ceramic. We have just defined what are the ceramics? We have compared the ceramics or the properties of the ceramics with those of metals. We have tried to develop the concept of ceramic matrix composites based on the limitations of the ceramics. And, then we have seen that what are the advantages or why we should go for ceramic matrix composite?

And, finally, we have seen what are the important techniques which are used or which are the important processing techniques which are used for processing of ceramics matrix composites. And, finally, we have seen that there are certain limitations on account of the properties of the ceramic matrix composite and we have to overcome these limitations. And, we have to develop certain processing techniques which have rather been already developing which we would be covering in our subsequent lectures in this module. So, in our next lecture we would focus on the processing aspects of the ceramic matrix composites. Thank you.