Processing of Non-Metals

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Module - 5
Polymer Matrix Composites: Processing
Lecture - 2
Composite Materials: Classification and Applications

A warm welcome to all of you to this lecture on composite materials: Classification and applications. In the previous lecture of this module, we have seen the various types of materials. We have seen that what are the needs and requirements of developing new and newer materials, we have also seen the challenge of selection that once we have a wide variety of materials available with us, what is the criteria or what are the properties characteristics that should be taken into a account when we are selecting a particular material and for a particular application.

We have seen the different approaches of developing new materials. If you can refer back to the previous lecture you will see that either the material is modified internally or the material modified by the addition of external, reinforcements to make a new material and new material has properties which are better than the properties of the individual components. Now, this is the basic you can say cracks of the development of composite materials.

Composite as the name suggests already I have told in the previous lecture also that it is made up of 2 or 3 different phases which are combined together to develop a new material, which has got splendid properties or which has got properties better than the properties of the individual components taken individually or taken separately. So, today in this particular lecture we would be seeing that what a composite material is? How are the composite materials defined? How are the composite materials classified and then finally, we will see that, what the important applications are.

Although I may not be a able to show so many diagrams related to the applications but, at least we will discuss that what are the important applications for which the composite materials have been developed.

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So, starting with the lecture first and the foremost are the queries that comes to the mind when we hear the word composite material now what are these queries in the inquisitive mind that what is composite or what is the composite material these queries are, what are the how they are defined how I define a composite material then constituents if it is a composite in the definition I get to know that they are will be 2 or 3 different phases that will become bind to develop a composite material. Now, what are these constituents and the basics of this constituents how will see that which type of materials are these or what are the further classification of the basic constituents.

Suppose a polymer is there a polymer can be can be a constituent or ceramic can be a constituent a metal can be a constituent and how this dictate the final name or the final type of the product which falls under that category composite material.

Then we have the engineering application that I have told you that constituents in that going to the composite may be different, now the constituent basically can be polymers can be ceramics can be metals now depending upon the constituents you will get a new material and what are the important applications of this particular material. So, that is important that we need to understand that composite materials they have been defined in a particular manner. What are the constituents that go into the composite material and why this composite material have been developed that we have seen in the previous

lecture that there are new and new requirements coming every day new and new designs been developed.

New and new service requirements are there and for those service requirements for those designs, we need to develop new and new materials. So, this fall under the broad spectrum of the applications that leads to the development of new materials and then once a new material has been developed there will always be a portion that how it will compare with that traditional or the conventional materials which are already in use, wood is a very good example, of a traditional conventional material which is been used these days in a large number of applications, but, wood is a very important commodity all of us know.

Depending upon the green environment as in the previous slide the focus these days is on green environment, we need to use materials which are recyclable which are biodegradable and which do not have a burden on the environment. So, how the new materials that we are developing compare with the conventional or traditional material that is another important issue, that we need to address.

Another important point is as we discuss in the first lecture of this module that once we come up with the new material. We have to find out ways and methods to convert that material into a final product. The conversion process has to be cost effective the conversion process has to be of high quality that conversion process has to be accurate and precise, which is although you can say one of the subsets of the word quality.

So, we need find out the processing methods that will go into conversion of that particular material into the final product and finally, once we are processing the material or we are manufacturing the material into the final product. How, that process will govern the performance of that particular material when it will be put to use. So, when we are talking of a term composite material, the doubts the questions that come to our mind have been listed in this slide. I will just readout for you what are the important points to be taken into account. what are the definition of the composite materials, what are the constituents of the composite materials, what are the engineering applications which this materials have been developed, how do the compare with the traditionally available material or the conventional material, what are the varies processing techniques and tools which are used for converting them from the row material to final product and

finally, if this processing is going to affect the in service performance of this materials with all these questions in mind now, we go forward and we try to address these problems or these questions by the help of certain slides which have been developed for understanding the basic concepts of composite materials.

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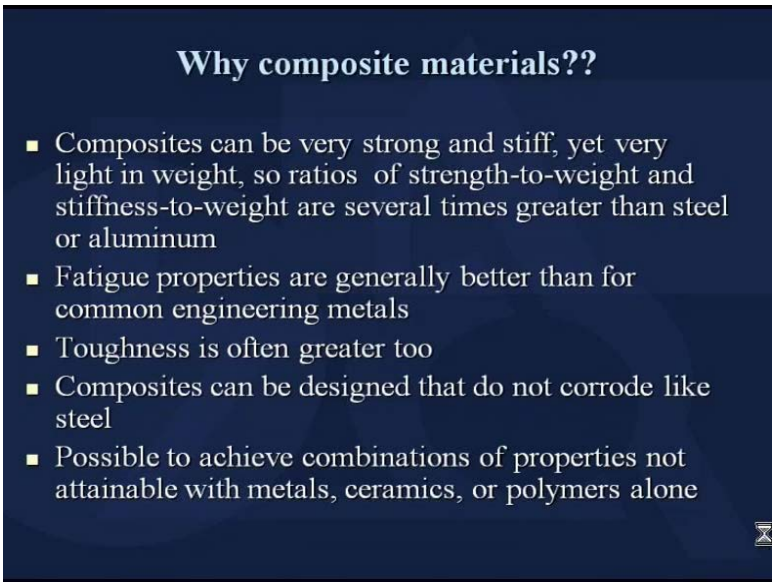

First and the foremost, why composite material this in continuation we have discuss in the last lecture. Composites can be very strong and stiff, yet very light in weight. So, ratios of strength to weight and stiffness to weight are several times greater than steel or aluminum several time means it can be one point five times also. So, composites can be very stiff they can be very strong and therefore, the applications where stiffness and strength are important criteria there composites can replace the conversional materials like wood and steel. As is very clear from the very first point in that particular slide that they are light in weight, the strength to weight ratios stiffness to weight ratios is better with composites as compare to conversional materials like steel or wood sometimes wood is also used as one of the ingredients for a composite material. So, now, here we can compare the composite with steel. So, strength to weight ratio is a; obviously, better with composites as compared to stiff.

The fatigue properties are generally better for common, than common engineering metals. So, this is the comparison we are trying to do that why do we need to develop composite materials are what are the important characteristics or advantages that we get

with composites which are not usually available with the conventional materials. So, fatigue properties are also better than composites next point. Toughness is often greater to composites can be designed that do not corrode like steel. So, they have corrosion resistance property also, possible to achieve combinations of properties not attainable with metals ceramics or polymers alone.

So, what I mean to address here is that, they are as been need to develop the composite materials and this particular need has to be justified, by the particular applications. So, if you considered the important properties prophetical applications, we can see in this particular slide the strength to weight ratios, stiffness to weight ratios fatigue properties, toughness other properties like corrosion resistance all these properties are important; when we take into the account the composite materials. So, composite materials offer numerous you can say advantages over the conventional materials in term of properties, what are the properties like as is very clear if you want light weight applications, materials for light weight applications, we will definitely give advantage to the composite material.

Because, they offer us very important property strength to weight ratio stiffness to weight ratio suppose we want a material for impact resistance, we will always give a advantage to composite materials suppose, we want a material which has to be having very good fatigue properties, again composite materials have been have energy. So, in this particular slide has we have already seen that they are few important properties which have offer by the combination of material together into a composite materials, which are not easily attainable with the conventional materials and therefore, we can say the title of the slide why composite materials. So, composite materials have to be developed in order to satisfy few requirements which are not being met by the conventional or the existing conventional materials.

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Now, what are the relevant advantages of the composite materials these days, composite materials are finding application in a large number of engineering spectrums. So, we can see that what are the major advantage, the first and four most advantage is the tailor made properties. The tailor made properties just to give you an example suppose I want to get a trouser stitched according to my size, what is the processor that I going to follow I am going go to cloth merchant, buy a piece of cloth and then I will go to a tailor and tell him that please stitch a trouser, according to my dimensions or according to measurements.

So, that is the tailor made properties, In composites also they have the tailor made properties, what do the we need by the tailor made property in context of composite materials that if you have a specific requirement or a specific scenario where you want to convert or where you want to change the conventional material by a new material, suppose to the composite material, In that particular application what are the requirements of that application.

You can design the composite material in such a way that it will be able to meet those requirements. So, in a conventional design approach, we flow a very simple processer we have a application; we know that this particular in this particular application the material that is going to bear this much of load and depending upon the load requirement we select that this type this material which can bear this much of load or the failure strength

of this particular material is higher than the load, this particular component has to bear. So, let shows this particular material for this application, but, to contrary to conventional approach in case of a composite material we will design the composite material to bear that particular load we will select the constituents in such a way that they meet the design requirements.

So, tailor made properties mean that, we would be looking at the application and we would be designing our material depending upon the application. So, that is you can say the basic meaning of the tailor made properties. Then the second one is the low weight, as in the previous slide we have seen the strength to weight ratio and stiffness to weight ratios better a, with composites as compared to the other conventional engineering materials therefore, they offer low weight. So, as the title of the chapter goes that composite materials classification and applications I giving simultaneously by discussing the various aspects of composite materials application it gives of low weight or arrow space applications any component or product that has to be made for the arrow space applications weight is the prime criteria.

So, these materials of her low weight; So, when a particular application has to be fit or apply or material has to be found for a particular application and the application is for a example arrow space, the prime criteria is the light weight. So, composites of her light weight therefore, for arrow space applications we will very easily postulate or very easily purpose.

The use of composite materials the third important point on your slide is a good mechanical properties as we have seen in the previous slide, the fatigue properties the toughness the strength to weight ratio, all this come under the mechanical properties, as well as the property which we missed in the previous slide is the impact properties. So, impact fatigue strength all these key keywords are catchwords; these are related to mechanical properties aspects. So, mechanical properties basically are better with composite materials as compare to the conventional materials. So, we can say there this is a another advantage of composites as compare to the conventional materials, then the fourth point on your screen, integral design and parts integration integral design approach means that a complex part can be made into a final product, In case of a composite in a single shot single shot means that these materials sub sometimes they offers some process is which we would be discussing as a course of this particular

module, the process is for making products by polymer matrix composites we will see that composites offer certain advantages in terms of (Refer Time-14:28) and integral you can say approach.

In integral design approach a complicated product can also be made in a single shot or in a bio single process. So, complicated parts can be made by a simple approach of any manufacturing process which can be used for making polymer matrix composites, integral designs can be made. So, which means that there is no need to do a regress comply operations, once the product has been made in a single product or in a single shot and parts integration means that by conventional materials, if we are designing and developing a parts suppose, that particular product is made by five different components and those five different components are now assembled together finally, to get a final product.

In case of composites instead of five components, we will be making the complete design in three components only thus reducing the assembling operations. So, parts integration means that a complete product can be divided into lesser number of parts, if the material chosen for that particular product is composite materials, on the other hand if we would have made the same product with highly conventional material, we may be force to break down that complete product into 7 to 8 or at least 5 different components which would have been developed by 1 or the other conventional manufacturing process is and finally, would have been assembled into the final complete product. So, composite material offers integral designer approach as well as a parts consolidation reducing the number of assembling operations.

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Then the next point is the inherent surface finish, inherent surface finish means, that once the composite product has been made with the help of the particular mold or the die the finish that we will get, would be of a very high quality are of a very superior quality. So, we need not go for finishing operations in the total product development cycle.

The initial steps of a single shot or a near net manufacturing or quite relevant in case of composite materials, the finishing is not finally required and this points specifically addressed to over a chapter on polymer matrix composites at this module is focused on processing techniques for polymer matrix composites, So, these points are particularly relevant for polymer matrix composites in which matrix is a polymeric material, this we are going to come to this classification of materials composites materials into different categories under the same broad family of composites. So, we that we are going to come in we are going to discuss that at later stage.

But, just to understand that no finishing is required if the material chosen for a particular ha application is a composite material, than composites also offer a corrosion resistance as in the previous lecture I have given 1 or 2 examples of underwater applications in underwater applications sometimes, there is a corrode environment. So, the material that has to be or that would be chosen for underwater applications should be corrosion resistance and composites for 1 variable alternative for engineers, who are working in the area of underwater applications. So, because, during the processing stage only some

corrosion resistant in gradients can be incorporate into the composite materials making them corrosion resistant and the last step on your screen of last advantage in screen is a ease of fabrication and installation.

There is a case study in which the whole bridge was converted or was you can say transform over night, why it has been possible because, all the beams and the columns are the structural members of the bridge where not made or assemble or not fabricated at the site, they were made of fabricated processer manufactured in the factory and from the factory the developed components are the develop parts or the develop structural members were brought on site and there were assembled there in the minimum possible time.

So, there are numerous other advantages is related to the composite materials for specific applications. now, what are the advantages just to some advice what we have covered till now advantage is offered by composite materials are the tailor made properties which means they can be made or they can be tailored as for the requirement, they offer low weight they possess good mechanical properties, they present integral design and parts integration thus reducing assemble operations, they provide inherent surface finish they are corrosion resistant and they offer ease of fabrication and installation and they substantially reduce the amount of installation time, when they are put into specific applications like construction industry where there are used for making brides and buildings.

So, in this particular slide we have highlighted that these are the materials being used and are the materials for future and are going to see even higher order applications or even wider applications in the near future, Now, what are the basic definitions of composite materials we have just seen the advantage is that why we are going to use composite materials and what are specific advantages related to the composite materials now we come on to the defining or now are come on define the material like how the composites are defined.

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So, according to Komanduri, composite materials form a material system composed of a mixture or a combination of two or more macro constituents that differ in form and chemical composition and are insoluble in each other. So, this is a very comprehensive definition of the composite materials, you can see there are two three importance points to address in this definition, they form a material system composed of two or more different material or macro constituents. So, it means that a composite is a combination of two or three different macro constituents, now these macro constituents' different form and mechanical composition. So, chemical composite at chemically and physically these two materials can be different or the macro constituents that going to form a composite materials can be different chemically and physically and finally, they are insoluble in each other from that point I want to address another thing that we will be seeing in the subsequent slide.

There is a interface separating the reinforcement and the matrix or till now we have seen that there are two or three different macro constituents instead of highlighting them as matrix and reinforcement which we are going to any way cover in the next slide, we can just say that there are two macro constituents, they are combining together to make a composite materials, but, they are insolubly in each other, which means suppose this is one macro constituents, this is the another macro constituents when these two macro constituents are joining together they are insoluble in each other which means that there is a finally, which is a interface separating the two macro constituents. So, basically a

composite in another definition can be said as a combination of two or three different phases with the recognizable interface separating them and these two macro constituents are insoluble in each other. So, this is a very basic definition of composite materials.

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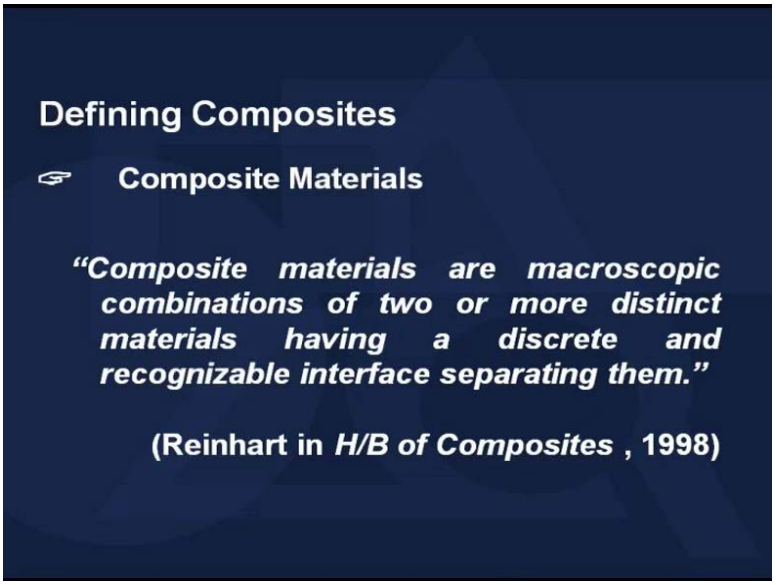

We can see another definition of composite material. On your screen you can see composite materials are macroscopic combination of two or more distinct materials having a discrete and recognizable interface separating them. So, again the emphasis is on the constituents they are two or three different constituents, which can be mixed together, but, there are insoluble in each other and there is a distinct interface separating them in this subsequent slides will be see a large number of diagrams showing the different types of composite materials, but, till now we should be able to understand that composites are basically a combinations of two or three different materials or macro constituents which do not going to one another their insoluble in each other and when they combined together they form a third material and when this two materials are in contact with one an another there is a thin interface which separates the two macro constituents. So, this is the very basic definition of a composite material.

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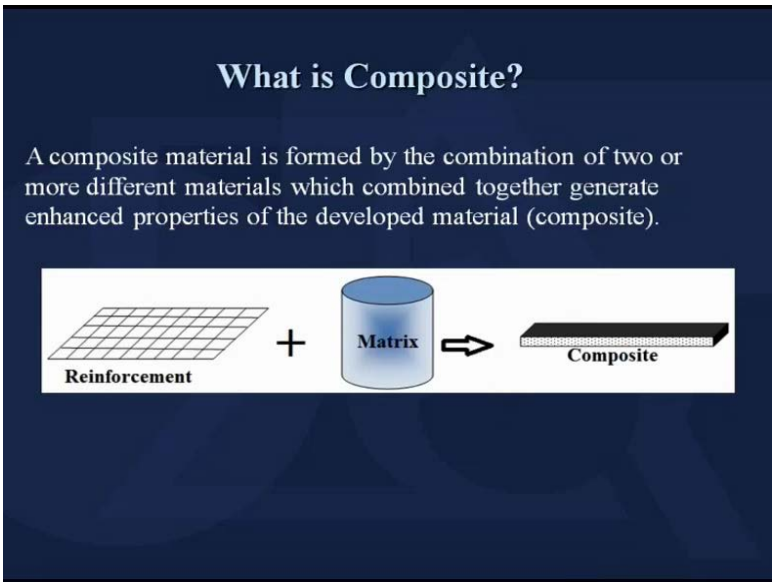

So, what is a composite, again now you can seen a composite material is formed by the combination of two or more different materials which combined together generate enhanced properties of the develop material which we have already seen, that why we are combining two materials together because, we want to develop a material which has certain properties which, we cannot attain by the individual macro constituents or the individual constituents for example, the roof there are bars and there is concrete. So, why this steel bar and concrete have been blended together they have been blended together because, we need certain properties which are not easily attainable by the bars alone or attainable by the concrete alone. So, both their two constituents have been combined together to make a third material which is offering as certain properties which are not attainable with individual constituents.

So, here in on your screen you can see a very simple diagram of very simplistic view of a composite material. So, there is reinforcement and there is a matrix. So, any composite material will have two constituents now, we are coming on to defining the constituents till now we are saying composite is made up of two or three different macro constituents what are this constituents called and what are their rules, that we are going to see now the macro constituents are basically called the reinforcement and the matrix. So, one of the macro constituent is a reinforcement another one is a matrix and when the reinforcement and the matrix join together they make a composite material. So, what are the rules of the matrix and reinforcement that we are going to see now?

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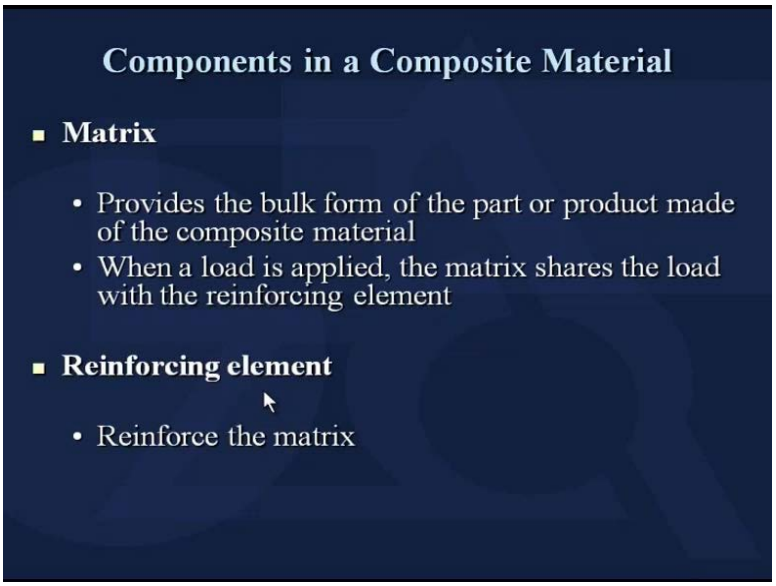

What is the need of the matrix provides the bulk form of the part or product made of the composite material. So, majorly the major portion will be the matrix or the Continues phase would be the matrix provides the bulk form. So, you can say it will give shape or the size to the composite when the load is applied on the composite the matrix shares this load with the reinforcement. Again we can see the example of roof in the roof that concrete is the matrix and the bars are the reinforcement. So, whenever some load will act on this particular roof that concrete will shared this load with the reinforcement or in a very plain term, we can say it will transfer the load among the various reinforcing agents or the reinforcements or the different types of reinforcement, as may be the case in some other composite materials. So, we need to understand that composite material is made up of different constituents and these constituents are called that matrix and the reinforcement.

Matrix has got its own purpose, it is on you can say requirement and the reinforcement has got its own purpose and reinforce and it is own requirements. So, when this matrix and the reinforcement join together, they lead to a new material which is called as a composite material. So, what is the need of the reinforcing element is the matrix. So, the major load bearing member in a composite material is the reinforcement and the matrix provides support to the reinforcement sometimes the reinforcement may be a abrasive in nature, If we can say taken example of a number of ropes held together, when we apply the load one rope is rubbing against the another rope and there are abrasive in nature one

rope may abrade the surface of another rope and this particular fine this particular mechanism may further lead to a abroad erosion or may further lead to the failure of the ropes inutility, but, if there is you can say matrix separating the individual ropes, individual ropes they not be touching each other and the erosion will not be there or the one to one interaction will not be there because, there will be a separation between the two ropes with the help of a matrix.

So, that is one example where we can say the rule of matrix is to support the reinforcing elements and provide or transfer a media between the load bearing or transfer media of load acting on the various individual reinforcing elements and reinforce reinforcing elements, have a prime aim of taking the load or the major portion of the load or the maximum load. So, reinforcing elements take the load and matrix provides support to the reinforcing elements and help to transfer for the load among the, varies reinforcing elements.

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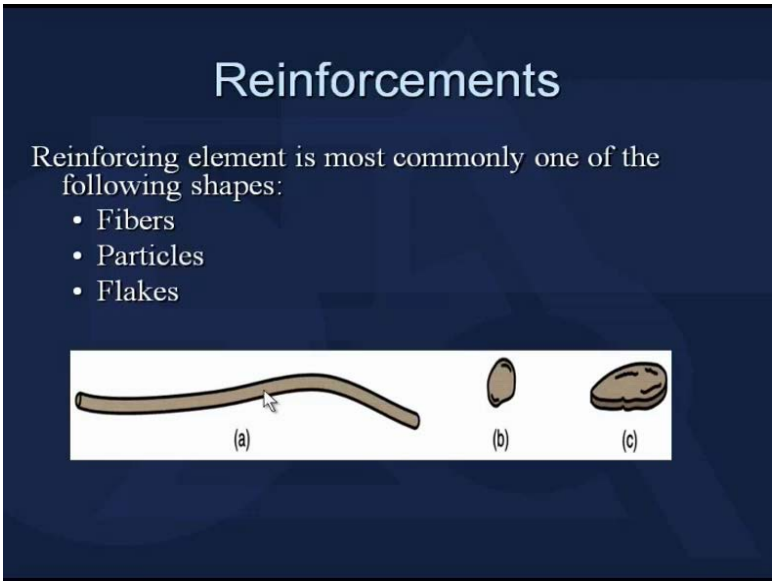

Now, what are the different types of reinforcements how the reinforcement can be given to the matrix? So, the reinforcements can be given in the form of a fiber, it can be in the form of a particle or it can be in terms of flakes. So, you have a continues bulk form matrix and you put some fibers into this matrix or you can put some particles into this matrix or that matrix flakes into this matrix and this will give you another material which is a composite material, you have a bulk form you are adding certain reinforcement into

that bulk form and the final material that you are getting is a composite materials reinforcement can be classified into some other categories also, that we will see in the subsequent slides the reinforcement can be continuous nature it can be discontinuous, it can be further be classified on the basis of it shape, it can be classified on the basis of chemical nature similarly, the matrix can also be a different types it can be a polymeric matrix you can use ceramic material as a matrix material you can use a metal as a matrix material. So, you can have different types of matrices you can have a different types of a reinforcements and when you combined this matrix and reinforcement together, you will get a composite material.

But, there would be a recognizable interface, which will separate the matrix and the reinforcement just to understand suppose I break a composite material and see I should be able to distinguish between the reinforcement and the matrix and then only we can say it is a composite material otherwise, it can be a kind of alloy also. So, there is a difference between an alloy and a composite. Now, how can you say that a particular material is a composite material how can we distinguish between an alloy and composite material? So, these are few brand guidelines which will help us to specify any material as a composite material just to discuss this point.

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Let us first take point number 1 if a material has to be classified as a composite material both the constituents are present in reasonable proportion as we have already discussed

that the resultant properties of the composite or the resultant of a combination of the two macro constituents, there are two macro constituents or may be three, now the resultant properties should be dictated by a all the three macro constituents it should not be finally, dictated by one macro constituents on one macro constituent only.

So, therefore, the reinforcement or the matrix or the proportion of the reinforcement of the matrix should not be less than 5 percent or the material which is present in lesser quantity should be more than 5 percent of the total quantity. So, basically both constituents are present in reasonable proportion the proportion of the material or the matrix of the reinforcement which is lesser should even be higher than 5 percent, it can be a ratio 60 to 40 .60 percent proportion of reinforcement 40 percent proportion of matrix or it can be visa versa 60 percent proportion of matrices and 40 percent proportion of reinforcement.

So, it should be reasonable it should not be like 99.99 percent of matrix and only point 0 1 percent of reinforcement. So, that type of material we cannot broadly classify as a composite material than the second important point the composite properties are noticeably different from the properties of the constituents. So, the resultant properties that we are getting out of a composite material should be substantially different from the properties of the individual components or the in individual constituents, that going to making a composite material.

The last point a man made composite is usually produced by intimately mixing and combining the constituents. So, what does this mean, there is and there are 2 points to address first one is a man made composite, this is a new term. So, composites are natural also naturally occurring components also that we going to see the subsequent slides. So, naturally occurring composites are like wood is one example human bone is another example of a naturally occurring composite, but, there are synthetic composites also and our focus majorly is on processing of synthetic composites.

So, manmade composite is usually produced or for that material we can very easily say a synthetic composite is usually produced, by intimately mixing and combining the constituents. So, what does it mean this means that the constituents are mix together, but, they are not soluble in one another again, I am emphasizing when they are mixed together they form a composite material, with the interface separating the two

constituents now by now, we know what are the two constituents the constituents are the reinforcement and the matrix. Let me give you another example of a composite material from history the mud walls which are these days are also made in the villages have some vegetable waste or some wheat straw rice husk, added to the mud in order to improve its property now what is the role, of this rice husk or wheat straw or any other vegetable waste which is put into the mud.

So, we can very easily now align in our definition of composites materials with this examples, the mud access the matrix and all other ingredients or constituents that are put in mud act as the reinforcement. So, this reinforcement is vegetable waste or rice husk or wheat husk. So, this access the reinforcement now what is the need of adding this reinforcements, re in the mud one of the most important point that can be an explained in a very simple and lucid manner. Is the arrest of cracks which may develop in mud? So, if a crack develops in mud and it will travel along the past of least resistance and finally, it may result in the damaged to mud wall, but, if we have reinforced mud with these important reinforcement like rice husk or wheat husk or vegetable waste the crack will encounter any of these reinforcement, then the crack needs to have a energy higher than the failure energy or the failure required in these particular materials of reinforcement materials.

So, that the crack and break this reinforcement into two or three parts and further progress along its desire directions, but, that do not happen too often once the crack is travelling in the mud it will encounter any of the reinforcement and it will be rested their; it may not have that much of energy to break that reinforcement two or three parts and move forward.

So, the important point to address here is the reinforcement is added to mud in order to improve its resistance to cracks or crack propagation or in order to improve its strength or life. So, the reinforcement also acts as the crack arrester. So, if there is a crack it would be arrested by the reinforcement and it will give a more or higher level of service life to that particular product, which has got some reinforcement as compared to a single phase material or a mud, If there would have been no reinforcement that mud wall would have failed catastrophically whereas, because of the reinforcement the cracks few cracks have been arrested and the mud wall did not fail catastrophically because, of the reinforcement which has been added.

So, to classify any material as a composite material these are the three important things that have to be taken into account, on your screen you can again see or I will read it for you both constituents are present in the reasonable proportion, composite properties are noticeably different from the properties of the constituents and a man made composite is usually produced by intimately mixing and combining the constituents. So, if any material has been made and it satisfies these three requirements then very comfortably and easily we can say that yes it can be one of the examples of composite material.

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Again and again I have used this two words very commonly that natural composites and synthetic composites. So, synthetic composites basically a man made composites and natural composites are those which are existing in nature.

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So, one of the natural composite one example, I am showing on screen that is wood. So, in this we have a matrix and the reinforcement the reinforcement is in terms of in type of a fiber. What is the matrix in wood? the matrix is lignin matrix and the fiber is the hemicelluloses fiber. So, here you can see one particular block of wood, in this wood a manual rings are see. So, a wood has got different properties along the length of the greens and across or in the radial direction. So, the properties are different in the radial direction and in the longitudinal direction. Therefore, we can see that wood is a naturally occurring composite material because it has a matrix it has got a reinforcement in the type of in that in the type of fibers which are hemi cellulous fibers.

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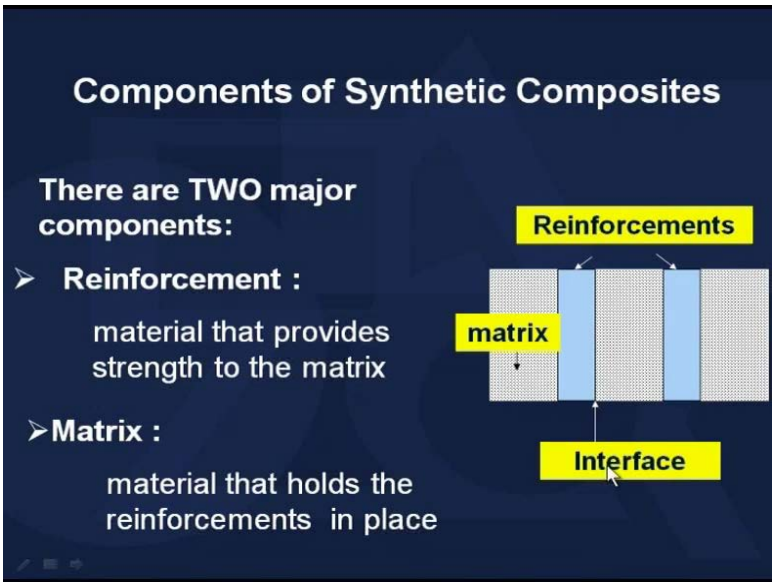

Now, what are the components of the synthetic composites, in the previous slides we have seen that composite material are made up of two or three different macro constituents, there is a recognizable face separating them then we have seen that there are two important types of composites naturally occurring composites in which wood is one of the examples and there are synthetic or manmade composites. In synthetic composites now we are seeing that there are two major components in synthetic component already we have seen matrix and the reinforcement.

So, the reinforcement material that provides strength to the matrix and matrix is a material that holds the reinforcements in place on your screen you can see that this is suppose a composite material, these two are the reinforcement and this is the matrix and this thin black line along this cursor shows the interface. So, the interface is separating the matrix, this is the matrix this gray color and this light blue color is the reinforcement. So, the rein the interface this is the black line which is showing the interface the interface is separating the matrix, this is the matrix and this is the reinforcement. So, the interface separates the reinforcement and the matrix. So, basically synthetic composites or manmade composites have two important macro constituents those are the reinforcement and the matrix. So, matrix forms the bulk and the reinforcement provides the strength and the reinforcements are the major load bearing members of the composite, now what are the different types of the reinforcement that go into the composite material.

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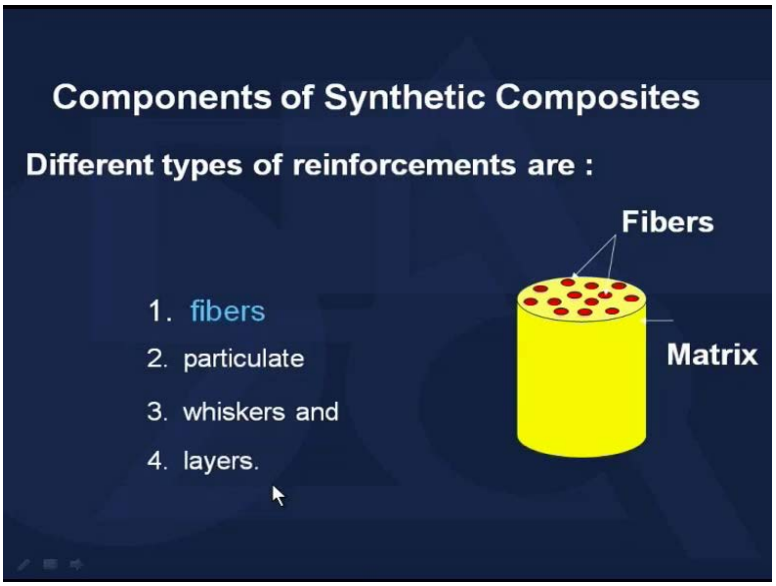

The first and the foremost is the reinforcement in the type of fibers or in the shape of fibers, then you can a particulate type of reinforcement you can whisker type of reinforcement and we can have the reinforcement in the terms layers. So, in this particular diagram you can see this bulk is the material, it is a cylindrical shape and this red portion shows the ends of the fibers. These fibers are running all along the length of the matrix now you can see I will just draw a diagram, to just explain the running of this particular fiber in the bulk of the matrix.

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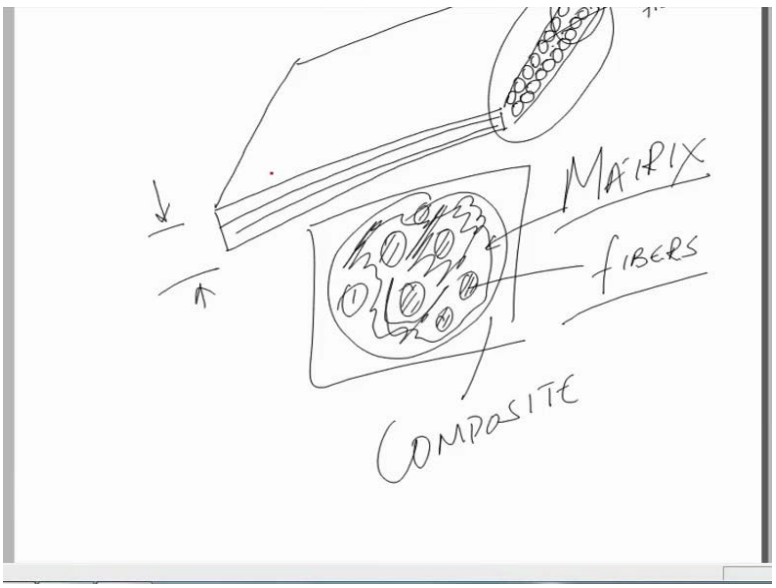

So, you can see if this is a plate which is made up of a composite material, we can see the fibers running all along the length and we can see the ends of the fibers, as you can see on your screen. So, these are the ends of the fibers which are running along the length. So, this is the direction of the fibers and if I highlight this particular area and I take a block from here and I highlight it in this manner, here we can see these are the ends of the fibers and in between the portion that I am highlighting now is the matrix.

So, this is the matrix and these fibers these are the fibers. So, we have the fibers and we have the matrix. So, we can see that matrix and the fibers they have been combined together in order to make a composite material and this inutility is called composite material. So, we have the matrix we have the fibers and we have a composite in this particular example, all the fibers are continues fibers along this diagram we can see here this is the thickness of the composite and all these lines represents the fibers and one end we are seeing the edges are the ends of the fiber. So, this is you can say one example of a composite material in which the fiber the reinforcement is in the type of fibers.

So, you can see on your screen now, the fibers and the matrix. So, all around the yellow portion shows the matrix and the red portion shows the tips of the fibers. So, the reinforcement in this case is in the terms of fibers.

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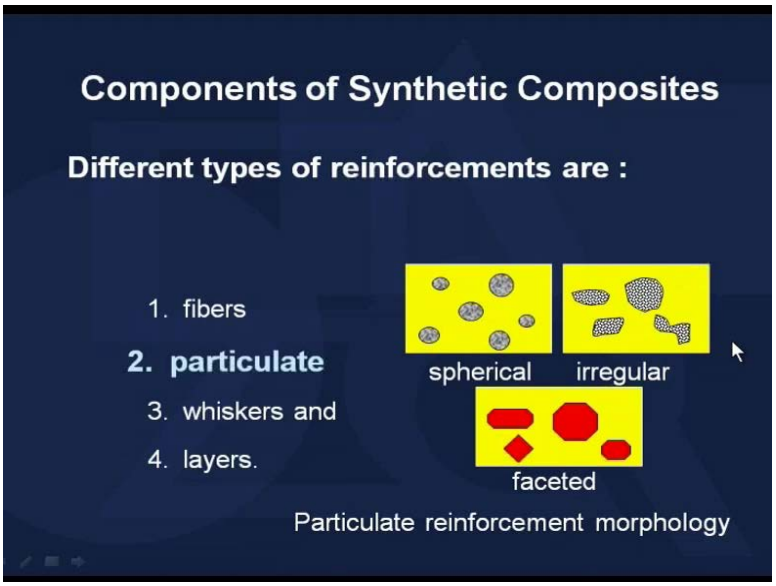

Then in another case, we can have the reinforcement in terms of particulates in this particular slide you can see the matrix is being representing by the yellow portion and the

reinforcement is in the terms of these particulates; now particulates can have a simple shape they can have, they can be spherical in nature or you can they can have irregular shapes in this particular a composite you can see the major portion this is the matrix and the reinforcements are basically in different shapes or irregular shaped particulate reinforcement.

In third case we can see faceted type you have deferent phases suppose I take this particular reinforcement, in this particular reinforcement there are 1 2 3 4 5 6 7 and 8 faces in this particular reinforcement there are 1 2 3 and 4 faces. So, within that shapes of the reinforcements, we can have the fibers as the reinforcing members, we can have the particles as the reinforcing members and particular reinforcement morphology is shown here the different particles can have different types of shapes we can have spherical particles, we can have irregular shaped particles or we can have faceted particles.

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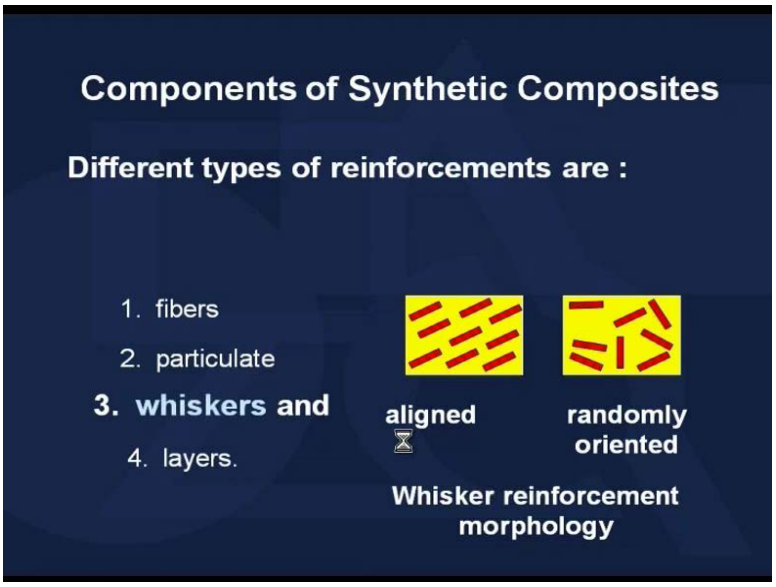

Also the reinforcement can be in terms of whiskers, in this particular slide you can see the reinforcement is in the terms of whiskers. So, all the whiskers are aligned in one direction here and they can be randomly oriented whiskers in this slide also the yellow portion shows the matrix and the red portion shows the whiskers or the reinforcement those reinforcement can be aligned in a particular direction depending upon the specific requirement of the part or it can be randomly oriented.

So, whisker reinforcement morphology is shown here. So, till now we have seen the reinforcement can be in terms of fibers the reinforcement, can be in terms of particles and the reinforcement can be in terms of whiskers.

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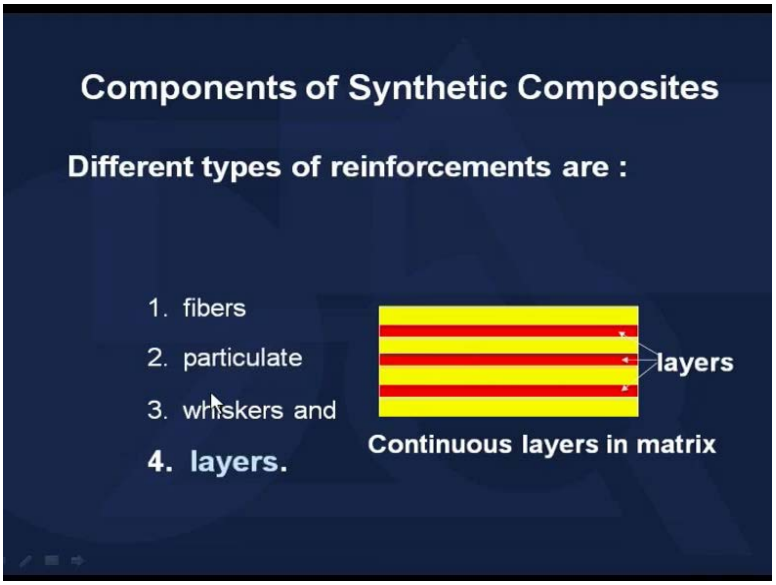

And finally, the reinforcement can be in terms of layers also. So, you can see we have different layers of fibers and this yellow portion indicates the matrix. So, continues layers are put in the matrix to make a composite material. So, this is one of the important types of polymer matrix composites in which the reinforcement is in the form of the layers, the layers are made up of fibers, the fibers basically can be glass fiber those can be carbon fiber those can be paramide fiber or other different types of fiber, but, these are three main types of fibers which are used as reinforcing materials in the polymer matrix composite.

So, the reinforcement can be of different type if we take examples of the particulate type of reinforcement which is very common in metal matrix composites, the matrix is in the form of a metal and the reinforcement is in the form of particulates, one of the examples can be aluminum matrix reinforce with silicon carbide particles, the size of the particle is very small to the few microns. So, reinforcement can be of different types and the matrix can also be of different types.

So, here we can see this particular reinforcement is the reinforcement in terms of layers. So, we have seen that the matrix can be a different types on the basis of the chemical

composition, but, once the matrix has been identified the reinforcement can be given in different shapes, we can a fibers as the reinforcement, we can have particulate reinforcement, whiskers as the reinforcement and finally, complete layers of the reinforcing material.

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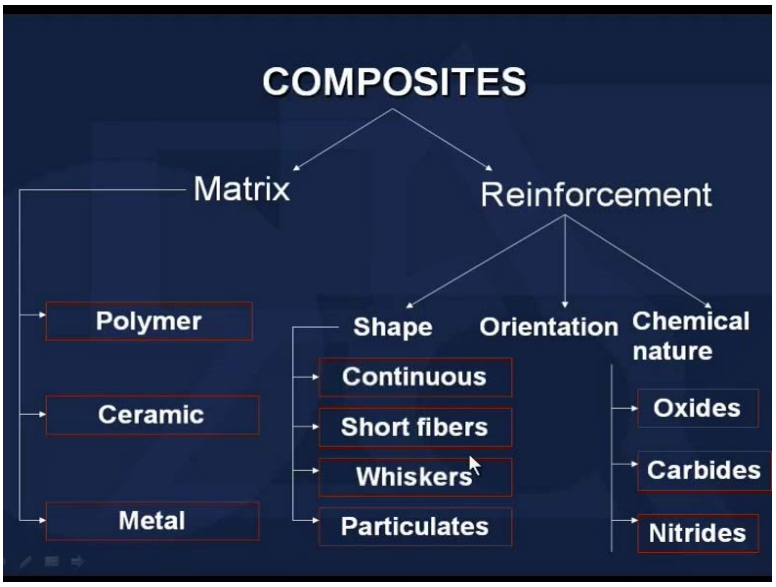

Now, let us see the summering of what we have covered with the help of this particular slide. So, we have the broad category of composites materials, composites are broadly made up of matrix and reinforcement. The matrix can be of three types which can have a polymer matrix we can have a ceramic matrix and we can have a metal matrix. So, any of these three materials can be taken as the matrix material and it can be reinforce with different types of secondary materials or different type of other macro constituents.

Now, on the basis of the shape you can have continuous reinforcement, we can have short fibers as the reinforcement, we can have whiskers as the reinforcement and we can have particulates as the reinforcement, based on the orientation in the previous slide we can see we can have aligned type of reinforcement and we can have a randomly oriented reinforcement; on the basis of the chemical nature we can have the reinforcement in terms of oxides, we can have reinforcement in terms of carbide, we can have reinforcement in terms of nitrides, one of the example I have already given we can use silicon carbide as the reinforcement material, we can take the aluminum as the matrix

material as it is a metal. So, we will get a metal matrix composite. So, here we can see we can have a polymer matrix composite.

We can have ceramic matrix composite and we can have metal matrix composite in our series of lectures, we have focusing on two important types of materials those are ceramic matrix composites and the polymer matrix composites.

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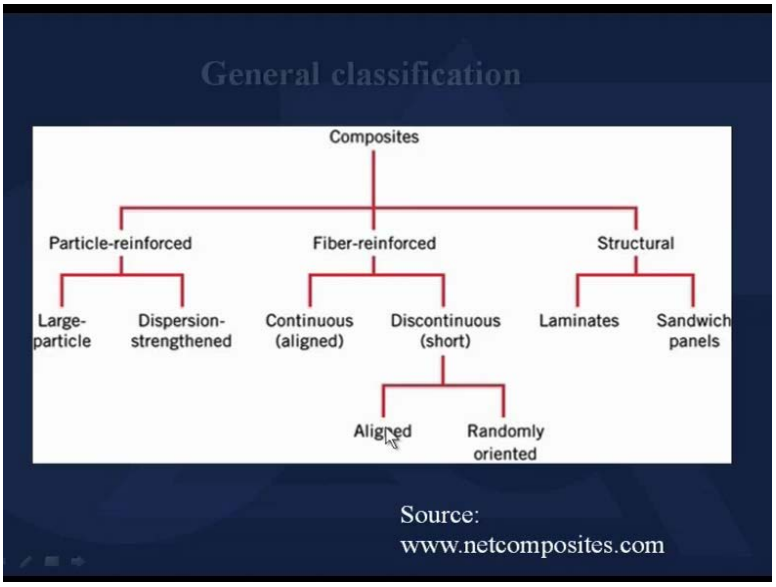

So, again this is another classification of composites particle reinforced, fiber reinforced and structural composites, structural composites in terms of laminates and sandwich panels. We can have re fiber reinforce in continuously reinforcement and discontinuous short fiber reinforcement, which can be further be aligned or randomly oriented which have already seen; we can have particle reinforcement in terms of large particles or dispersion strengthened reinforcement. So, we can see we have a matrix and we have a reinforcement matrix can be of different types reinforcement can be of different type, reinforcement can further be sub classified into based on their shape based on their orientation and based on their chemical nature.

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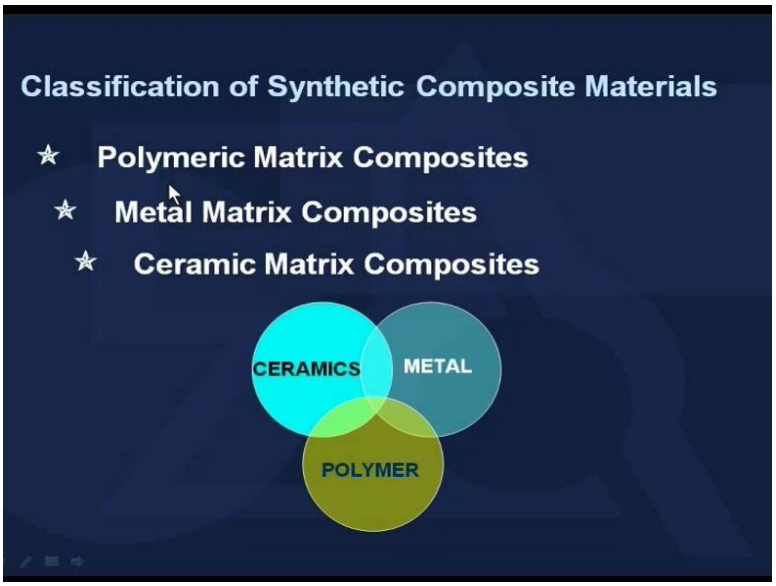

So, broadly we can classify the synthetic composite materials into three categories. So, that is polymeric matrix composites, metal matrix composites and ceramic matrix composites. So, you can see ceramics metals and polymers. So, these three types of composites are broadly used and in our series of lectures we would be focusing primarily on polymer matrix composites and metal matrix composites.

So, we have seen that how composite materials are classified. So, we will stop the today's lecture at this particular point in the next lecture we will start our discussion with the various processing techniques of polymeric matrix composites, to just to have a abroad overview or summery of what we have covered in today's lecture we have seen the classification of composite materials, we have seen composite is made up of two or three different macro constituents and we have named this macro constituents has matrix and reinforcements, we have seen what is the role of the matrix, what is the role of the reinforcements, then further we have seen that what the different types of reinforcements which can be given into a particular matrix and we have seen what are the different types of matrix materials which are used for making the composite materials. So, the next lecture we will discuss the basic techniques for manufacturing of polymer matrix composites.

Thank you.