Non - Metallic Materials
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Module – 04
Mechanical properties of non – metallic and composite materials
Lecture – 22
Structural composite

Welcome to my course, Non-Metallic Materials. And, today we are in module number 4 Mechanical properties of non metallic and composite materials. And, today part of lecture number 22, I will cover Structural composite.

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Now, if you remember the last lecture these two topics were left out. The first one I will cover structural composites, mostly laminar composites, and sandwich panels that will be covered and finally, I will cover the nano composite.

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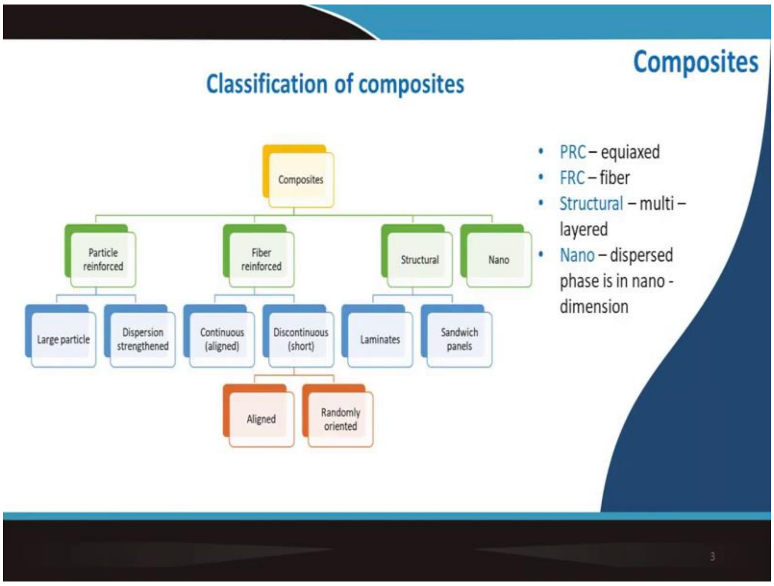

To give you the brief overview of the classification, which already I have described part of my earlier lectures. We have already talked about particle reinforced composite; where both large particle reinforcement and dispersion strengthened reinforcements were covered.

Then, I took fiber reinforced materials, composite materials, and we talked about continuous alignment of the reinforced fiber, and also discontinuous, that is short reinforced fibers. And, part of this short reinforcement, we discussed about the aligned fibers, which were discontinuous and also randomly oriented fibers.

Now, today we will talk about the structural composites and mostly I will be talking about laminates and sandwich panel type composite. And, just to brush up PRC this abbreviation stands for Particle Reinforced Composite, where equiaxed particles, were dispersed in a matrix.

Particularly concrete we discussed, then we also talked about fiber reinforced composites, where fiber is the strengthening reinforcing agent. And, structural composite is multi layered type, we will be talking about it. And, finally, I will talk about the nano composite, where the dispersed phase for the reinforcement, they are of nano scale order.

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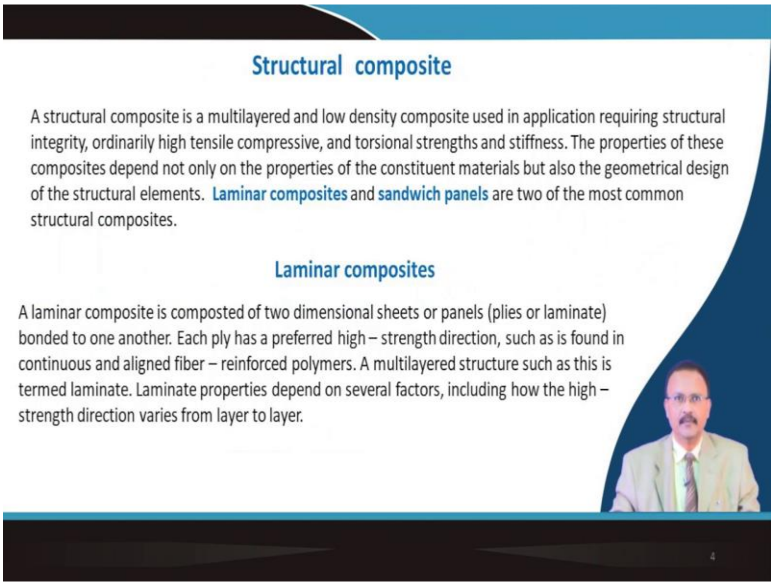

Now, a structural composite mostly it is multi layered and it is having very low density. These composites are having a low density and this is actually meant for structural integrity. And, high strength tensile composite this is one of the characteristics, other than that torsional strength is also quite good and they are relatively stiff.

And, these composites basically it depends not only the properties of the constituents material, but also the geometric design of the structural elements. So, we will be talking about it. And, laminar type composite and sandwich panel, these are the two most common type of structural composites.

So, in a laminar composite, this is composed basically of two dimensional sheet or panels. We call it is laminate; they are bonded with each other. So, each of this ply they are having high strength in a particular direction. So, normally they are an isotropic. And, usually as you have seen the continuous fiber aligned fiber reinforced polymer structure, which I have talked about.

Usually, they are directional, but we can make it isotropic as well. And, it depends on various factor this property of these laminates. And, usually they are of having reasonably high strength. And, layer to layer variation is there, because they are bonded structure, but within each of this laminate structure, they are reasonably strong.

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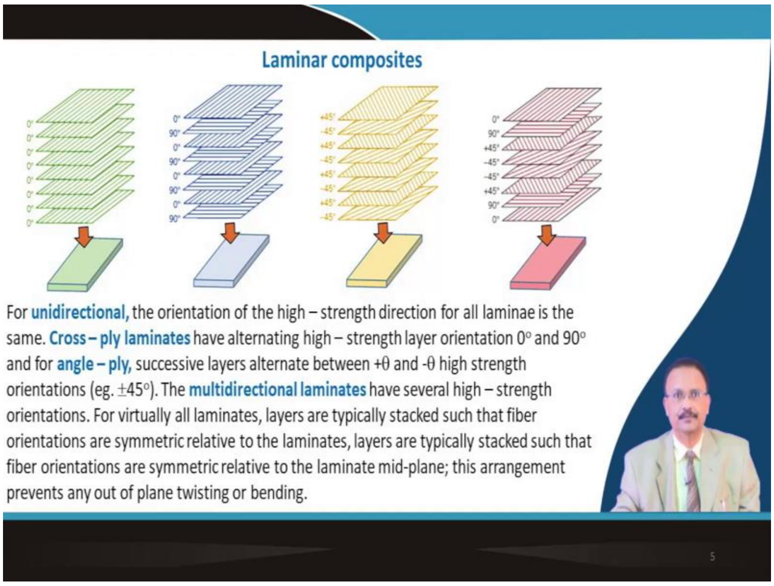

So, if you see the configuration of this laminate structure, you can see the first one this is unidirectional. So, all the fibers of course, they are having much higher tensile strength as compared to the matrix. So, they are all oriented in one particular direction. So, therefore, these are 0 degree, we have mentioned it.

Then, you can have a cross ply laminate, where both 0 and 90 degree. So, they are cross like this. So, this kind of composite we call cross ply laminate. Then various angles are possible. Here, I have shown either plus 45 degree or minus 45 degree of the fiber reorientation.

So, this is angle ply, we defined it as an angle ply. And, finally, the multi directional laminates, they have very high strength and layers are stacked, they are quite symmetric. And, they are typically stacked such that the fiber orientation are symmetric relative to the laminate mid plane, this arrangement prevents any fiber to come out of the matrix.

So, usually if you have this kind of orientation, there are different types of you can denote it in different times 0 degree slash 45 degree, then slash minus 45 degree, then slash 90 degree. So, that composite is defined by this. So, you can just define the composite structure by this kind of notation, which I have not shown in the slide, but in many places you will be finding that this kind of notation is possible.

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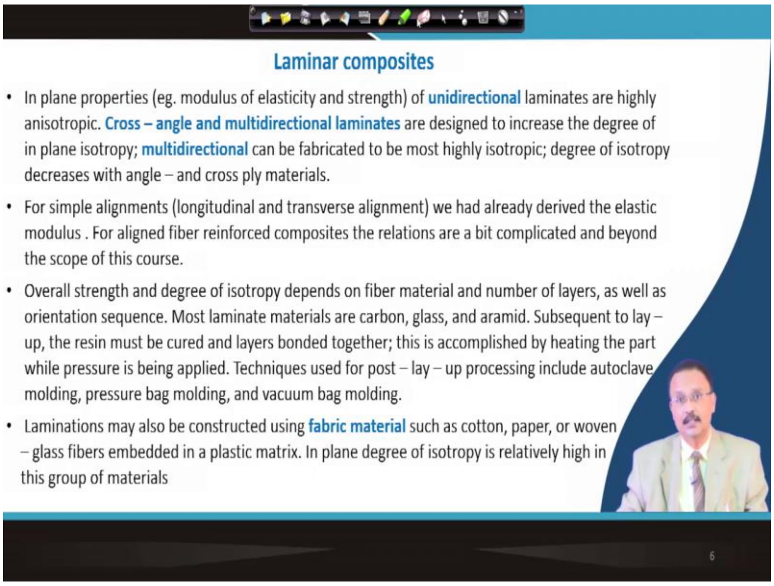

So, in laminar composite the plane properties, that is the modulus of elasticity and strength particularly for the unidirectional laminates are highly anisotropic. Because, if you remember that, if I apply a longitudinal stress, then the fiber carry all the load. So, this is much better as compared to the transverse orientation.

So, in this kind of composite they are anisotropic and cross angle and multi directional laminates, they are designed to increase the degree of in plane isotropy. The other two, the second and third one and multi directional can be fabricated to the most isotropic degree of isotropy decreases with the angle and cross ply materials.

So, the simple alignment of longitudinal and transverse alignment, we had already reviewed, derived this equation, the elastic modulus both for longitudinal and for transverse. And, if it is a aligned fiber then it is slightly complicated, if not following that rule of mixture. That is beyond the scope of this particular lecture, but mechanical calculations that one can do to exactly predict the elastic modulus and other mechanical properties of this material.

So, overall strength and degree of isotropy, as I have discussed that depends on the fiber material of course, and the number of layers as well as the orientation sequence. So, most of the laminate materials are carbon, glass fiber, aramid, they are the reinforcing agent. And, subsequently they are layup and in between matrices is resin.

So, this resin must be cured before you put the layer on top of it. And, finally, there are various processing steps involved. So, including a high pressure autoclaving you can do, or pressure bag molding you can do, or vacuum bag molding in order to laminate this whole structure, whole structural stack. So, instead of discontinuous fiber, it is also possible for you to use fabric material.

And, cotton is one of them paper or woven glass fiber embedded in a plastic matrix, they are very common for this kind of composite. So, in plane degree of isotropy is relatively high in this group of materials. So, mostly the matrix is resin type and the fiber may be of various types.

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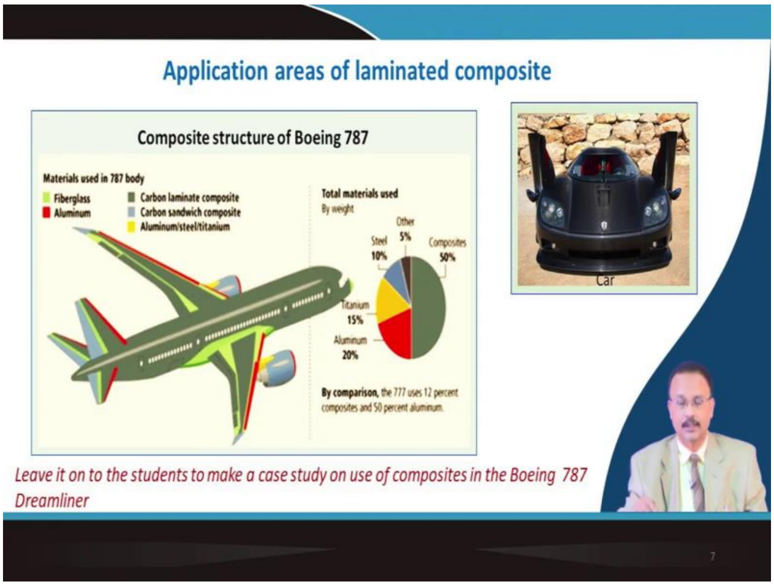

Very interesting structure that, you can get out of this laminated composite. So, I will cite one example as you can see this is the dreamliner flight. And, here you can see that different types of composite materials and other materials, they are being used for this kind of aircraft.

And, as you can see the composite constitutes mostly 50 percent of the whole material including the metal, aluminum, titanium, steel, and other materials they are also used, but mostly it is various types of composite. And, this kind of car the racing car, this also use carbon reinforced composites material.

So, this is very interesting progressively more and more composites are being used in the aircraft. So, Boeing 787 dreamliner is the ultimate flight, which uses lot of composites and other models of Boeing also they use. So, I am just leaving it on you to find this information either from a text book or internet is a good source.

And, just make a case study that, what kind of composite they are used after once you go through all these lectures, then things will be clear to you that what are the various types of composites, and where exactly these composites are used in this two special aircraft. So, I just leave it on you as an assignment or as a case study to identify the composites and correlate with the class lecture, whatever you have learnt part of this course.

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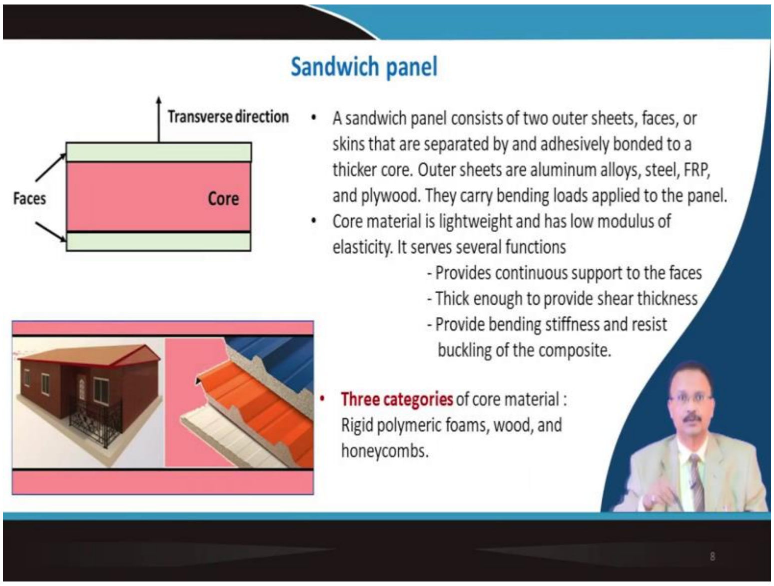

The second types of structural composite is sandwich panel type. And, you can see that, basically it is having a core, which is having a thicker structure. And, on top of this core you have a relatively stiffer, outer sheets at the face. So, actually this face strong material they are separated by this core material, which are relatively softer. So, this outer sheets they are usually aluminum alloy steel can be used, fiber reinforced plastic can be used, plywood can be used.

So, they carry the bending load, most of the bending load is carried by it. And, the core material is a light weight material. So, it has relatively low modulus of elasticity. And, basically it serves three purposes. Number 1 is it provides a continuous support to the face that is obvious here.

And, also it is thick enough to provide the necessary shear thickness. Shear thickness is due to the thicker layer of the core. And, provide bending stiffness and resist buckling of the composite, which is important for various applications. So, here you can see this kind of rooftop. Nowadays, that is quite popular where a polymer or metal sheet a corrugated one that forms this outer structure.

And, the core is relatively soft material and followed by another corrugated sheet. And, this kind of thing is being used as a building materials. So, this is a quite interesting for this kind of sandwich panel kind of composite. So, the core material they can be of various types. Either they can be a rigid polymer foam, which is light weight to make the structure quite light for the rooftop application. They are strong, but they are light weight, wood can be used and honeycomb structure also can be used.

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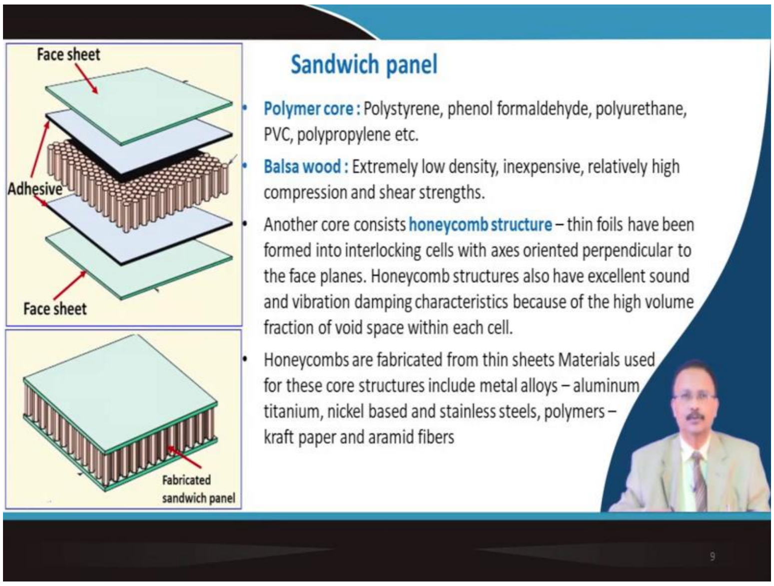

So, this is the actual structure of this kind of sandwich panel. As you can see the first one is the face sheet, the first part. The second one is the adhesive layer and then you have this core layer. Here typical core is of honeycomb structure; then again you have another adhesive layer and finally, the face layer. So, all of this are laminated they are pressed to form this kind of light weight, but strong composites.

So, for the polymer core usually polystyrene is used phenol formaldehyde that is used, polyurethane that is another thing, or in some cases this balsa wood, that is having extremely low density inexpensive and relatively high compression and shear strength.

So, that is also used as core. As, I said that it can be a honeycomb structure a thin foil is formed into interlocking cells as you can see here, the axes is perpendicular to the face of the plane.

So, it is axially oriented something like this. So, it has lot of it is a basically a porous structure like beehive structure you know it is porous, but it is very regular. So, this can be it can entrap air.

So, it can be used as sound proofing also the panels in the studio acoustic studio that is used, so, because of their high volume of free space available. And, material used for this core structures, they are various types of metal alloys including aluminum, which are light weight, titanium is expensive but sometimes it is also used.

Nickel based material, stainless steel, or it can be polymer, it can be even craft paper to make this kind of corrugated composite, in packing material also you have seen that this kind of honeycomb sandwich panel is used. So, commercially they have quite lucrative to make this kind of composites and they are having good commercial values.

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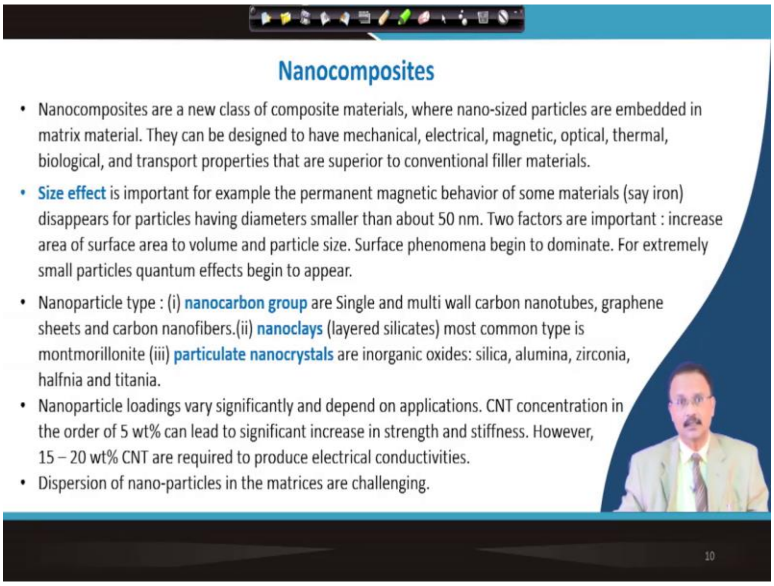

Now, the final thing that, I would like to address is the nano composite. So, nano composite as you understand this is a new class of material, where the reinforcing agent it is in nano size. Dimension nano is a bit blurred, but whatever below 100 nanometer people call it nano, but what is more important is a size effect. Not only the specific size, but if that specific size is altering the property that is more important.

So, this nano composite they have found a wide range of applicability, electrical properties, some of them I will review in this lecture. Magnetic optical thermal properties, biological functionalities, and also its transport property of the conducting charge, that is also important for this kind of nano composite. So, as I have told size effect is important some material, those material are permanent magnet.

For example, I will be taking it in forthcoming classes the magnetic properties of nonmetallic materials. You will find that ferrosoferric oxide, is a ceramic oxide, it shows ferric magnetic characteristics, but once the dimension is below a certain limit, we call this is the size effect around 50 nanometer or so then the properties changes. So, actually two important factors are important for this type of nano composite.

First whenever you are dispersing it the surface area is increased many times as compared to the bulk dispersion. And, the surface phenomena is begin to dominate, for extremely small particle you can even consider the quantum effect and this quantum effect is beyond the scope of this particular course. But, very very exotic properties, very many more exotic property one can achieve out of this nano composite.

So, usually for our purpose we use nano particles which are carbonaceous type. And, already I have introduced the carbonaceous material part of my earlier lecture. So, it could be either single or wall carbon nanotube, graphene sheets can be used, carbon fibers can be used, that is one type of material that is used for the strengthening agent for this type of nano composite.

Second class of materials are nano clay mostly montmorillonite is used or in some instances vermiculite is also used, the clays are having layered structure it can be easily you can separate this clay structure, the layer by layer structure you can separate it. Or particulate nano crystals of silica, alumina and zirconia, halfnia, titania, nanoparticles also can be dispersed.

So, the loading of these nanoparticles they are important and that depends on what type of application you want out of this nano composite. CNT concentration in the range of about 5 weight percent that can lead a significant increase of strength and stiffness of the composite. But, if you want the electrical conduction for certain application, then you will have to increase its weight percent up to 15 to 20 weight percent of CNT should be added.

The problem of this nanoparticle is the dispersion, lot of techniques are adopted, and which is part of research issue, that how in a matrix you can evenly distribute it. But, as I understand that if due to the finer particle size it is having enormous surface energy. So, it will try to attract other nanoparticles to form a soft agglomerate. And, they will not be dispersed very evenly inside the matrix. So, the way you are dispersing it is really important to get the full advantage of this nano composite materials.

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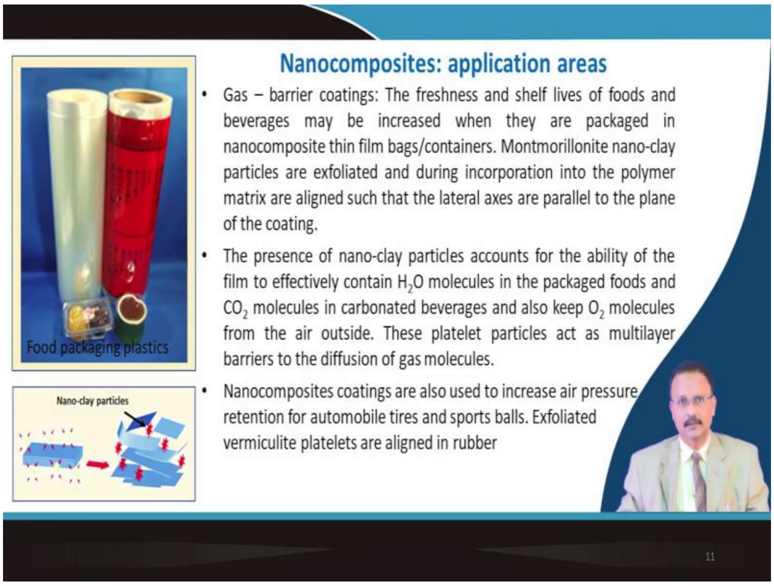

So, applications area of this nano composite, they are really very versatile. And, some of them I will just introduce in the course and you can just think of other exotic properties, the first one is the gas barrier coating. So, for example, this kind of polymeric film you are familiar with and usually the beverage is covered with this food items are covered with this.

So, it keeps the freshness of the food and beverage and when you use it as a packaging material. So, usually montmorillonite nano-clay particles, they are used as a dispersing agent and they are exfoliated. So, this is the kind of exfoliation you have a clay particle here. So, either chemically or by ultrasonic wave it is possible for you to exfoliate this layer structure and disperse it inside the composite. So, that they are favorably aligned to the composite plane.

And, this nano clay particles account for the ability of the film to effectively contain the H 2 O the moistness of the food item, they it will not let it to go out. So, it obstruct the diffusion of this gaseous molecule. For the beverage also carbon dioxide will not get out. So, the so, called fizz of this cold drinks, they will be intact if you just pack it once you take it out of the bottle.

So, that is there and also it will not allow the oxygen from the ambient to get in to the food item oxidize it and make it still. So, that is also another advantage. This type of clays, they are nowadays also being introduced in elastomer. So, for example, in tire it maintains the air pressure, because it retards this diffusion this exfoliated clay particles.

And, also for tennis ball it is important that it retains it is pressure. So, for those kind of application instead of montmorillonite, we use another type of clay which is vermiculite platelet us. They are aligned in rubber matrix and this kind of application one can get.

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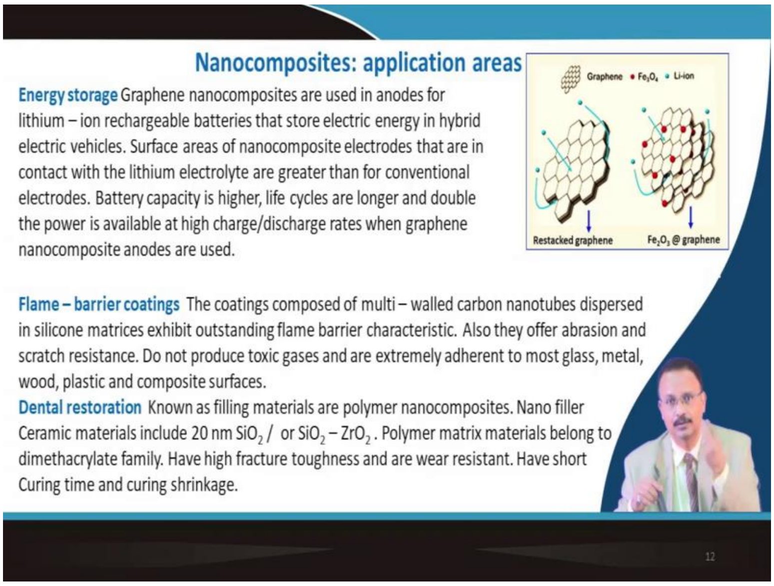

Another thing which is coming up quite extensively is in the area of energy storage. You know the graphene is being used or reduced graphene oxide, which is having reasonably good electronic conductivity. They are used with the anode material, I have cited one example, which is ferrosoferric oxide Fe 3 O 4 and this is embedded in a graphene sheet.

Of course, it is not a single graphene sheet, multi graphene sheets are there and you embed this ferrosoferric oxide.

And, you use it for lithium and intercalation as an anode material. So, in lithium and rechargeable battery although I will take it separately part of my other lecture, you know that lithium comes in during charging it comes out of the cathode, and it is inserted in the anode material. So, if anode is an intercalated compound like clay based material, which is a layered structure, then lithium can peacefully come and it can sit in between the layer, but ferrosoferric oxide it is an oxide material.

So, lithium actually reacts with this. So, it is a conversion type of reaction that takes place. So, the structure is completely destroyed and iron oxide is formed of different balance state FeO or Fe_2 O_3. And, then you have this iron oxide is embedded in lithium oxide. So, each time lithium coming in and going out, there is tremendous volume expansion takes place.

So, if you use bare ferrosoferric oxide, then this scramble the electrode is scrambled. So, you embed it in a graphene layer, graphene sheet. So, that acts as a buffer layer. So, these composites are quite good. So, here the graphene is having two different functions. The first one it imparts the necessary electronic conductivity within the electrode itself.

So, the power rating of this battery is very high. And, second one is it buffer the stress which is arising because of the lithium coming and going this conversion reaction. So, it is proved to be a very good material and various other type of research is also going on. It can be used as a flame barrier coating so, it will not catch fire.

So, usually a multi layered carbon nanotubes, they are dispersed in silicon matrix, that exhibits outstanding flame bearing characteristics, which is used nowadays as a wear shield, Havel's they use it. And, the toxic smoke will not come out of this. So, they are flame retardant coating. For dental restoration also you know the some kind of plastic mass is used.

So, that is basically a polymer nano composite as a nano filler ceramic material, which is typically 20 nanometer silicon dioxide or SiO_2, ZrO_2 composites are used mixed powder or composite powder. And, polymer matrix material belongs to dimethacrylate family.

So, they are very strongly very quickly cured up and very short curing time and shrinkage is also not that prominent. So, in case of a cavity you can use it as a dental restoration material. And, as I have already described the crown made out of glass ceramics is used to cover the bad tooth. So, this is quite interesting.

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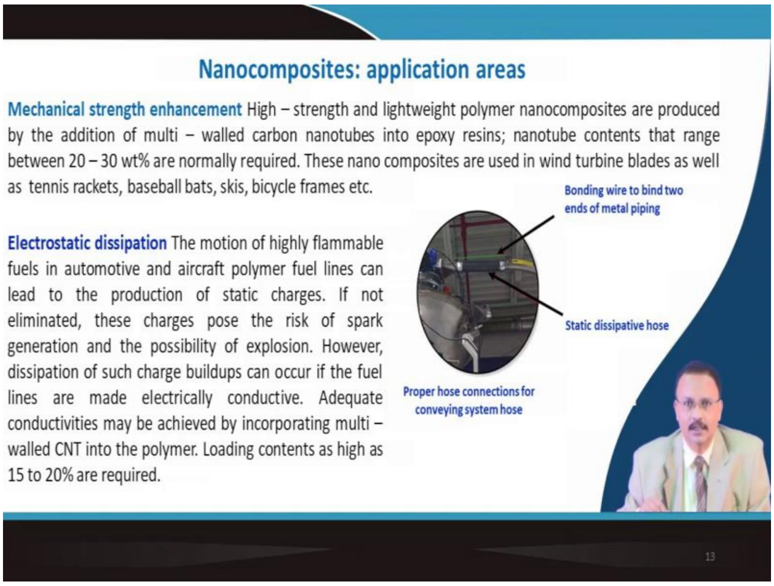

Mechanical strength enhancement takes place with a light weight polymer nano composite that is basically again use carbon nanotube into epoxy resin. And, here we use about 20 to 30 weight percent are normally required to make this kind of nano composite. And, wind terminal sorry wind turbine blade for generation of the electricity or also tennis racket, you know or baseball bat they are used out of this composite.

Another good use is electrostatic dissipation once with a hose pipe you are putting oil into aircraft or in automobiles, then there is due to the static electric charge there is a possibility of explosion. So, if you can increase the electronic conductivity of this kind of polymer composite by adding CNT. Typically, 50 to 20 percent addition is required. So, then this charge can be dissipated and various the possibility of this explosion is grossly reduced.

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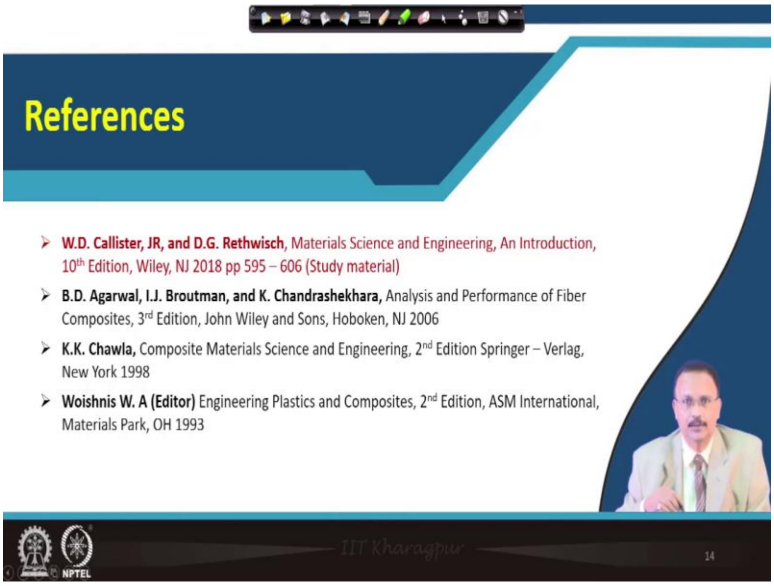

So, there are various other activities also for this kind of composite. So, I have the study material for this particular lecture is the book by Callister and I have marked it red and apart from that the book by B.D. Agarwal or Chawla is also quite good.

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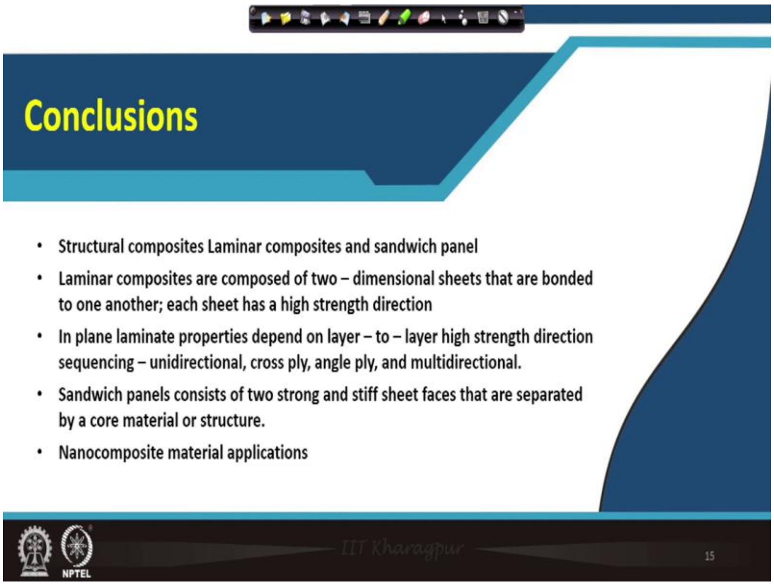

So, in this lecture we talked about structural composite laminar and sandwich type. Laminar composite composed of two dimensional sheets, they are bonded to one another in the high strength direction. And, sandwich panel consists of a strong stiff sheet faces that are separated by a core, which are softer in nature. And, finally, we talked about nano composite and their perspective applications.

Thank you so much for your attention.