Introduction to Composites
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Lecture – 10
ARAMID and Boron Fibers

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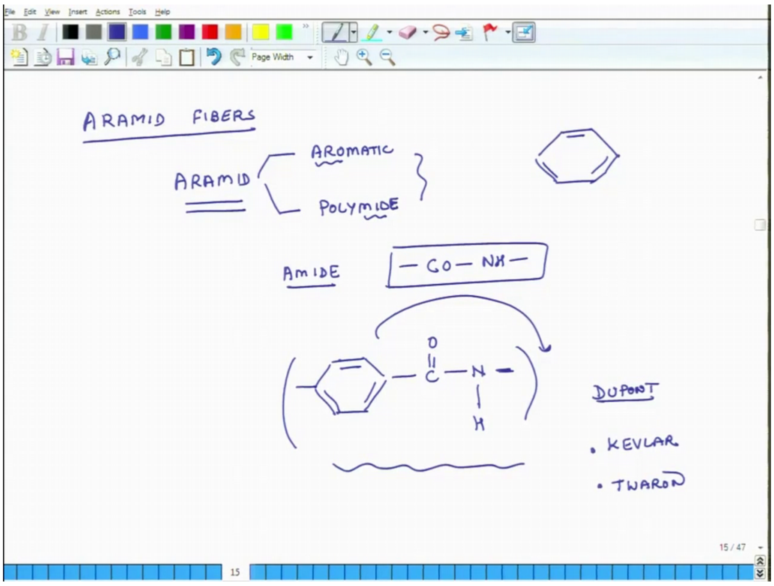

Hello, welcome to introduction to composites. Today is the fourth day of this week; and today we will discuss some other types of fibers starting with ARAMID fibers. So, we will start with discussion on ARAMID fibers. So, what is ARAMID? It has two components aromatic and polyimide, so ARAMID, it is a short form for aromatic polyimide. See, you take AR from here and MID from here, and you get this word ARAMID. Now, what is so polyimide means it has several amide units in the structure.

So, what is amide? Amide unit what does it look like it looks like this. So, CO dash NH dash, this is an amide unit. And aromatic is typically associated with phenyl ring. So, it will be something like this. So, aromatic unit will be something like this. So, these are this is a phenyl ring, so it will be something like this. So, this is the aromatic component, then you have a carbon atom, this is the CO; and nitrogen atom, hydrogen atom and this entire unit repeats itself. So, nitrogen has a valency of 3. So, this entire thing can come here and it repeats itself. So, this is your constituent. So, fibers which have this kind of a structure are known as ARAMID fibers, they are known as ARAMID fibers.

Now, this is the scientific name and the first time such type of fibers, they were developed they were developed by a company known as Dupont, so US based company. And this is the first time they develop this type of fibers; and they give it a name called Kevlar, Kevlar fibers. And then later Japanese company after few years they also develop this type of fiber and the structure chemical structure of these fibers is apparently same, but they give it a different name. So, these are brand names Kevlar or Twaron, Twaron fibers; and then there were other names NOMAX and things like that. So, this is there. So, this gives you some overview, but from a technical standpoint from a scientific standpoint Kevlar or Twaron is a ARAMID fiber, so an ARAMID fiber. There is also a definition what is an ARAMID fiber.

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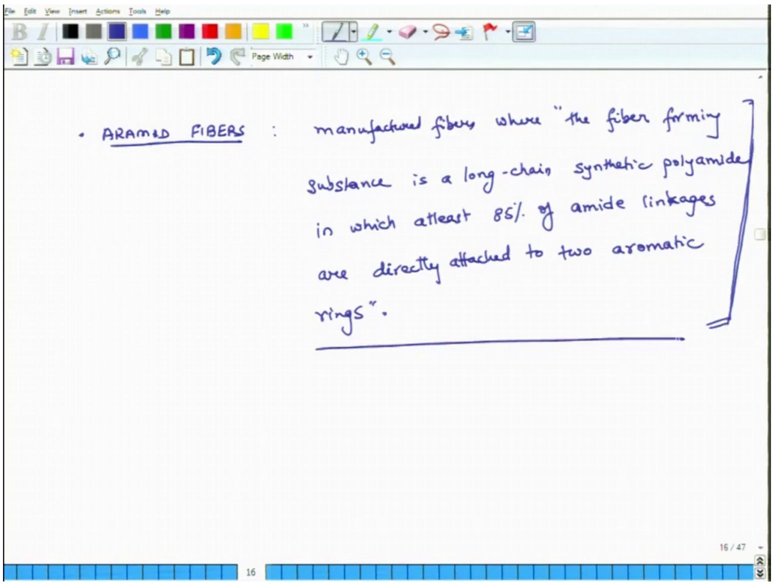

So, ARAMID fibers, and this is a definition developed by US organization known as FTC - Federal Trade Commission. And it says these are fibers manufactured fibers, so they are not natural fibers manufactured fibers where and this is I am coating the fiber forming substance is a long chain of synthetic polyamide in which at least 85 percent of amide linkages. So, what are amide linkages, we have discussed this, this is an amide linkage. So, at least 85 percent linkages are directly attached to two aromatic rings, so that is so this is an aromatic ring. So, if you connect another link here, and you repeat that, then you get a aromatic fiber. So, this is what the definition official definition of the structure is. Now, this is about chemistry, but what more important is what is so special about these fibers, these are synthetic fibers and they have some very important properties very interesting and unique fibers different from graphite fibers and glass fibers.

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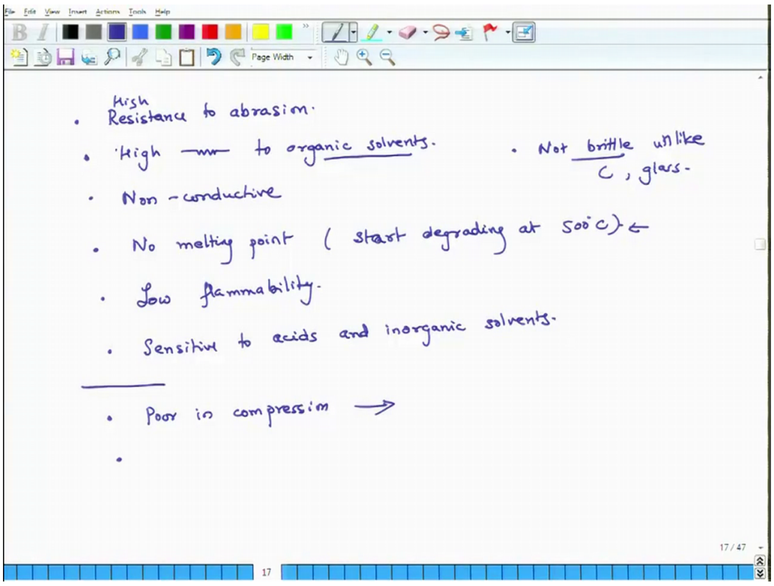

First thing - resistance to abrasion, they do not. So, if you take a piece of Kevlar fiber and you rub it against some rough surface they do not wear of very easily, they do not wear of very easily very important for. So, this is high resistance I am not saying just little resistance or high resistance high resistance. So, resistance I will indicate by this symbol, just to save time, high resistance to organic solvents. So, you put them in ethanol or methanol or carbon tetrachloride or we know some of these organic solvents, they do not dissolve easily, a lot of times several plastics they get affected by organic solvents, but these are very resistant. So, in that sense they are very robust compounds.

Non-conductive, so you cannot use graphite fiber in situations where you want low conductivity because graphite has a very good electric conductivity electric as well as thermal conductivity. So, these are non conductive both for electricity as well as temperature. No melting point, so lot of synthetic materials they melt. So, it does not mean that if you use this fiber at 1000 degree centigrade it will perform well that is not the point, but they have no melting point and they start degrading only at 500 degrees centigrade. So, start degrading at 500 degree centigrade. So, suppose you have to make some brake liners there is a lot of friction there and you want wear resistance you can put in Kevlar there, and it will be stable up to 500 degree centigrade, so that is a very strong advantage, so this is there, so very stable material very stable material.

Low flammability, so again it is you put them in fire it is not that they will just burst into flames, they will degrade slowly. So, it does not create any catastrophe, low flammability. But they are sensitive to. So, I had said organic solvents, but for in organic solvents like acids and inorganic solvents. So, we should be careful where we use these things.

They have some weak points also. So, if you take Kevlar fiber you pull it, it will be pretty strong, but if you compress it, it is poor in compression. And this happens so in one direction and outward direction it behaves in one way, in inward direction it behaves in another way. So, again this is an anisotropic and then oh so the other strong point is that they are not brittle unlike, unlike what Graphite fibers and glass, glass is also brittle. So, they can bend and flex.

So, in a lot of applications where you need all these things, they are used. In a lot of tennis rackets, in sports equipment; in places where you need a lot of abrasion resistance, these fibers are also very tough. So, what does toughness mean that they can observe a lot of energy. So, these fibers are used to make bulletproof jackets because you fire they can take a lot of energy, they can take a lot of energy so that there used in applications like that.

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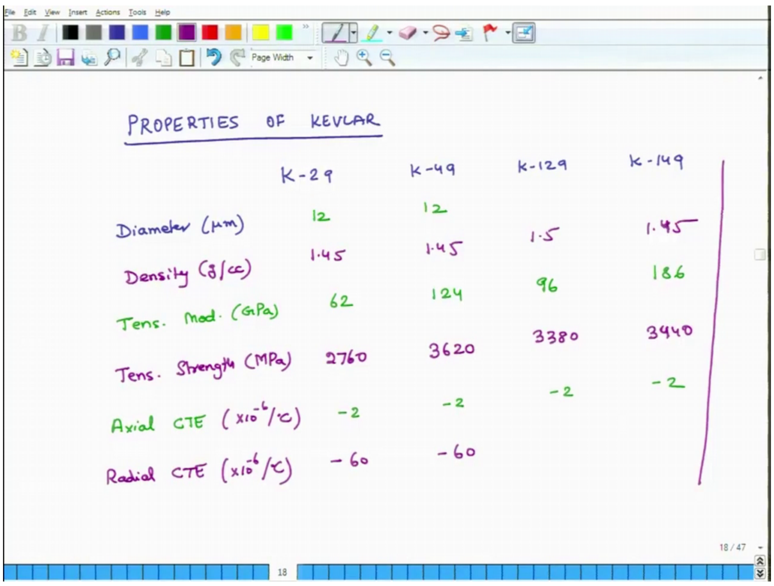

Let us look at some of their properties. So, in the market if you say I want in ARAMID fiber maybe not many people will know, but you say I need Kevlar fiber, it is very popular name. So, these fibers come in different varieties Kevlar-29, Kevlar-49, Kevlar-129, Kevlar-149 several flavors. So, let us look at diameter in microns 12, 12; density grams per cc 1.45, 1.45. So, it is not significantly different. But in the modulus, tensile modulus GPa, there is a significant difference, so that is where these things start mattering. 62, this is twice of that – 124, 96 and 186. So, this company has made different flavors of Kevlar whatever modulus you want they will give you that is the point. Tensile strength, tensile strength in MPa, 2760, 3620, 3380, 3440. Axial CTE - coefficient of thermal expansion in the axial direction in the length direction it is minus 2, minus 2, it is pretty much the same this.

But here is the thing radial CTE. So, if you heat Kevlar its strings and you would think it will become fatter, but it becomes thinner also. So, its minus 60 and minus 60. So, this is again units are into 10 to the power of minus 6 per degree centigrade. So, once again I am producing this tables, and I am not just showing in displacing it because if I write them slowly that information sings and when you start appreciating all the small details. And here what we see is that they are different types of Kevlar fibers and based on what here you need you can actually select a specific type of Kevlar fiber. So, this is about ARAMID fibers, this is about ARAMID fibers.

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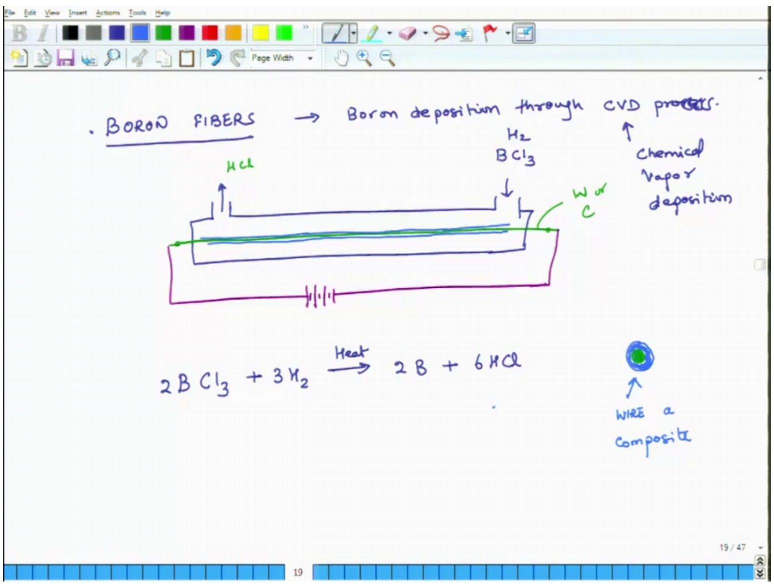

The next thing we are going to discuss are boron fibers. So, what is boron? It is a type of metal. What are the different types of fibers we have considered, we have considered glass – nonmetal; we have considered graphite – nonmetal, then we have considered Kevlar - nonmetal and polymer it is a polymer based fiber. But then we have metallic fibers and boron is one of these types of fibers. And first thing is that because it is a fiber its strength will be very high compared to the bulk material. So, these types of fibers boron is very light in density. So, where do they use this types of fibers, a lot of times you use boron type of fiber in matrix made of metal. So, you have metal-metal, matrix is also metal and fiber is also made up of metal.

So, suppose you have some light metal aluminium and you want to make it stronger, what you can do is you can embed it with boron fiber. So, it will remain light and it will still become very strong. And it will have all the other properties of metals as in high thermal conductivity, high electric conduct and so on this things like that. So, they are different types of metallic fibers, you have fibers made from metals or boron, aluminium, steel. But amongst all metallic fibers these are the most popular, boron fibers of the most popular.

How do you make them? So, you make them through a chemical reaction. Before that I will draw an apparatus. You have so this is a hollow tube. And in this, you take a very thin wire; and this wire is of.

Student: Tungsten.

Tungsten. So, this is a tungsten core. So, this could be either tungsten or it could be carbon, tungsten core or carbon core. And then you deposit boron on it on this tungsten wire. So, how do you deposit boron on it through a process known as CVD. So, boron deposition through CVD process through CVD. What is CVD, chemical vapour deposition. So, the way this happens is that there is a chemical reaction going on. You insert boron chloride gas, and you also insert hydrogen gas in it. And when boron chloride and hydrogen mix at a high temperature, you produce boron and we will show that reaction.

So, what is the chemical reaction boron will I have write it a little lower. Boron chloride, so 2 molecules of boron chloride plus 3 molecules of hydrogen, it gives you boron 2 boron plus 6 molecules of hydrogen chloride, but here you have to apply heat. So, the way heat is generated is that this is tungsten, so it is a metal thing and you connect it with some external potential difference. So, only on this wire boron gets generated at other places because the temperature is not high boron does not get generated and slowly boron deposits over the core. So, the core has to be metallic, so that is why either it is tungsten or it is carbon graphite fiber. So, this is there.

So, this is what goes in hydrogen and boron chloride and what comes out is HCL. And slowly you deposit a layer of boron on top of this green thing which is either carbon or tungsten. So, if you look at the cross section, you have a core, and then you have a boron. So, you have a boron ring or boron metal around graphite or tungsten core. So, in that sense, this wire is itself composite. So, the wire itself is a composite. And you can make these wires in different diameters so cores. So, based on the core size, the diameter of the wire can be dictated. So, this is there. And very quickly let us look at some of the properties of this material.

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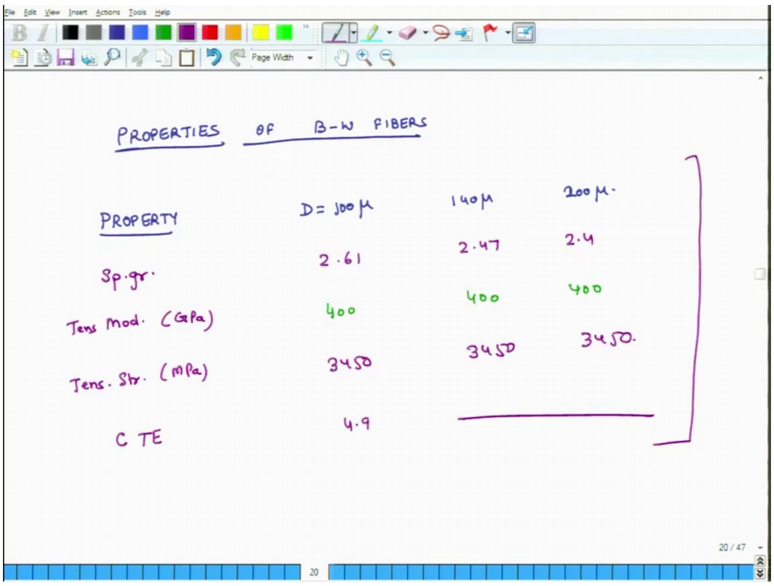

Properties of boron tungsten fibers, so property, and then diameter D is equal to 100 microns, 140 microns, 200 microns. So, 200 microns will be what is 0.2 millimeters, so it is a pretty thick wire 0.2 millimeters, it is thicker than are here. So, let us quickly see some of these properties. A specific gravity, so a specific gravity is unit less, so this is about 2.61, 2.47. 24. And the reason this density is going down is because as you put more and more boron on the outside tungsten is very heavy boron is very light as you put more and more light material the density will go down.

Modulus tensile modulus in GPA, so tensile modulus does not pretty much the same 400, 400, 400. And strength MPA, so that is also pretty much the same 3450, 3450, 3450 so nothing interesting here. And CTE is again 4.9 and it is a same thing, but an important thing to remember in case of boron fiber is that it is a composite. So, if you have the core as graphite, and outside is boron, boron will expand graphite will contract. So, there could be high stress as at the interface of these two things, high residual stress in the boron itself, in the boron fiber itself. So, those are some of the important considerations to think about when you are working with these kind of fibers.

And once again where do we use this type of fibers metallic fibers, metallic fibers have significantly high strength we have seeing some of these strength value I mean we are seen 3 GPA so significantly high strength. We use these types of fibers in a lot of cases in metal matrices. So, you have metal fiber and metal matrix, and you have a very light structure and still it can take a lot of loads and things like that. So, that closes our discussion for today. Tomorrow, we will do a couple of more types of fibers and with that we will conclude our discussion on fibers. So, till then have a great night, and I look forward to seeing you tomorrow.

Thank you.