Nature and Properties of Materials
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Lecture 2
Classification of Engineering Materials

Now we have done a kind of a summary of how materials have evolved. As of now in today's scenario, if you want to take stock of that what are the materials they are in front of us, it is better to categorize them because there are many materials, okay?

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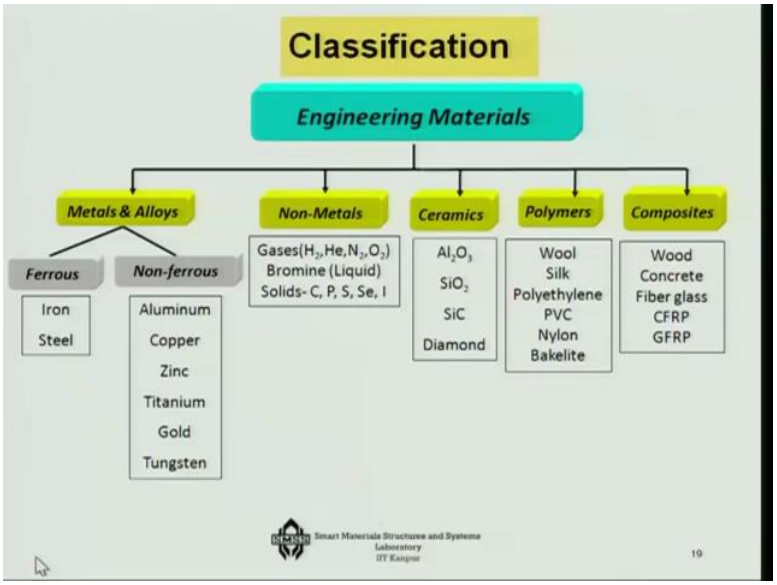

So if I think of categorizing the materials, then 1st thing that I can do is that I can keep the metals and alloys separately, that is one group okay. So starting from the metal age onwards that is continuous gapping. Then I can keep the nonmetals and in fact out of the nonmetals I would say that I can actually go for ceramics and then the polymers and then I can make composites.

Composite are of course, it is either made from you know between 2 polymers, polymer-ceramic or metal-ceramics all sorts of thing, okay. So basically if we think of it that we can keep it as a basic subdivision of metals and nonmetals and further the nonmetals in terms of because the nonmetals generally only talk about basic elements.

But instead of that we can think of the kind of suppose oxides of various types like the ceramics or the polymers or the composites. Now, among the metals also you have the ferrous metals like iron, steel and you have nonferrous metals. As I told you that the

aluminum for example titanium okay, they play a very important role in terms of lightweight category of aircraft alloys.

Aircraft alloys, they play a very important role, okay. Then of course limited amount of copper and zinc, etcetera, tungsten again for very high temperature application it is very good. So there are nonferrous which have uses in certain very specific applications. So I would rather say specific and high performance applications.

That is where you need actually the non metals other than aluminium, these titanium, tungsten, vanadium, molybdenum, chromium, etcetera okay for these types of things. Now, how about the ceramics? Ceramics, they are you no more like in the form of I would say particle or fibres which are used in terms of making either composites or making ceramic products, so alumina, silica, silicon carbide for example is very widely used in making tools.

Alumina and silica has a very wide application in terms of refracted bricks, etc. Diamond is one ceramic which of course has some applications in the ornamentation and some applications in terms of cutting tools because that is one of the hardest materials. Then in the polymer again you can actually subdivide it into certain things like natural polymers like say wool or silk.

And polymers which are synthetic that are human created like polyethylene, this is Poly vinyl chloride which is used for all your PVC pipes is very popular, nylon I told you in the beginning of you know polymer adventure, nylon was one of the 1st products which was used in developing parachutes for example, then Bakelite which is used for making insulating materials for electrical applications, so that is about the polymers.

And then if we talk about the composites, then we have wood as a natural composite, okay. And then we have concrete, we have fibreglass, we have CFRP and GFRP. CFRP and GFRP the full form are Carbon Fibre Reinforced Plastic that is CFRP and GFRP as Glass Fibre Reinforced Plastic, so this various types of composites which are very widely used. There are many in fact, but that is kind of a broad classification that we have in terms of the, you know engineering materials that are available today.

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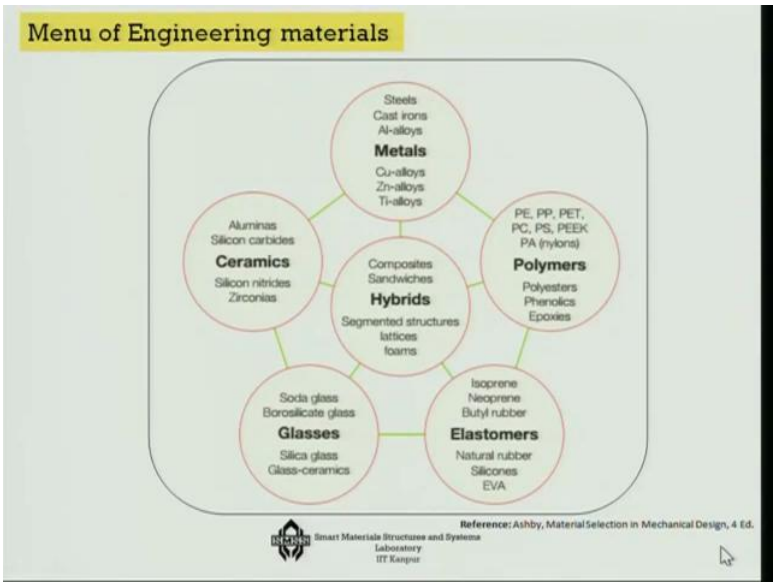

So let us try to classify them we have this very famous you know Pentagon that is developed by Ashby you will see it in his Material Selection a mechanical design book where he has given his very nice circles of materials like metals for example, the steel, cast iron, aluminium alloys, copper, zinc alloys, titanium alloys.

And then if you come to the other vertices, so one by one let us explore the vertices, so metals that is why you know all these things together. If you come to the polymers then you have something like polyethylene, okay high density or low-density polyethylene which is used in terms of making carry bags for example.

Polypropylene; polypropylene is used for making you know various types of things which can resist high temperature like feeding bottles. PET and PEEK that is polyethylene terephthalate or polyethylene ether ketone, they are used in you know in this mineral water bottle packs, right. And then polycarbonate is used in terms of once again making high performance polymers like transparent polymers.

Polystyrene is used again for high performance polymer and polyanalene is one of the polymers which is actually a conductive polymer, so far conductive series of polymers they have a very high use. Then it need not be that the polymers are only used for structural materials, so these are for you know for making products, but they are also used in terms of polyester which is like in terms of fibres.

They are also used in terms of resins; these resins are used as matrices actually, so these are used as matrices for composite materials, so that is what the world of polymers is. Now naturally, Elastomers are also polymers but they are separated out from this list because they are very specifically designed for certain purposes, one of them is shock and vibration absorption.

With the advent of you can say that the automobile and all the transport sector, shock and vibration becomes very important because any machine or mechanism has a shock and vibration problem. So to actually observe that you need some kind of materials which can you know dissipate lot of mechanical energy in the form of thermal energy, et cetera.

Now natural rubber was the 1st candidate towards that direction, but since in nature you know you get only a limited amount of it, so then all other synthetic rubber started like butyl rubber and then other elastomers like neoprene, Isoprene, then the Silicon, etc. So this actually develop the group of elastomers and one way in which the elastomers are characterised is that if you think of metals for example, what is the typical you know I will talk about this later on.

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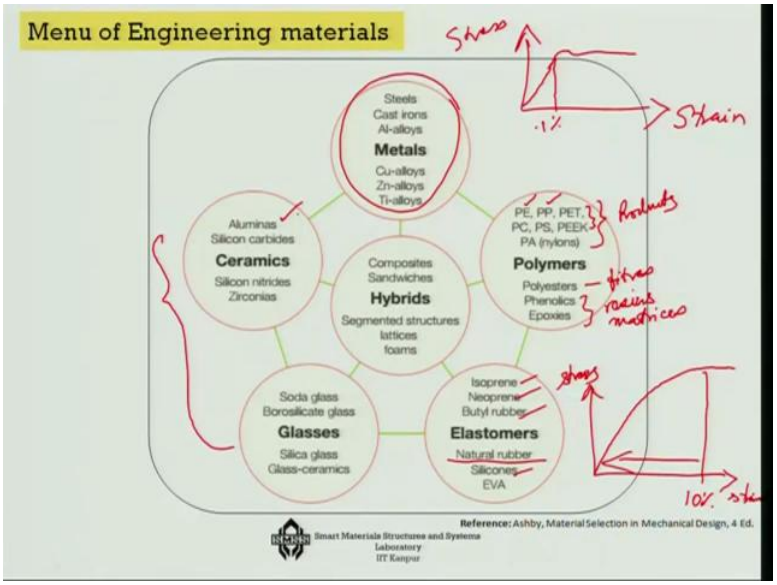

But we will just introduced at this stage that if you look at the stress-strain diagram for the metal, you would see that it goes straight like elastic and linear, then it actually as a yielding and then it goes down. And this is generally this in a level is about 0.1% on the other hand, if you look at the elastomers you know stress-strain diagram, how would it look like?

You would see that it is non-linear, but it will go up to a very large extent. So this is something like you can say you know something like 10%, so that is the kind of you know

stress-strain behaviour that we are talking about, so elastomers in comparison to the metals can deform a lot, large deformation.

That deformation may be non-linear in nature, but the deformation is still elastic that means ones you withdraw the force, you can actually recover back that deformation. And that is very good you know in terms of high stretch ability, so that is used for various applications. Now, the other part of the side of the Pentagon is actually ceramics and glasses.

And we talk about them together, but they are not really together because when we talk about ceramics, ceramics have at a later stage I will tell you, they are very regular crystal structure. So hence on the other hand, glasses are completely amorphous, they are very irregular in terms of their structure.

So that is why ceramics and glasses even though both are very same as per your daily experience you can see that if you put a glass bottle, if it falls down, it breaks into pieces and same thing happen for ceramic pots. So ceramics and glasses share a very common property that both of them are very brittle in nature that even though they are brittle in nature, their basic microstructures are actually different.

For ceramic as I told you that you will get a very regular atomic structure, crystal structure on the other hand, in glasses you will not get a regular crystal structure in it. So in the ceramics there is this groups of Alumina which is used mostly I told you in terms of making (())(12:14) or in terms of refractory bricks. Then there is Silicon Carbide which is also used in terms of making tools.

And then Zirconias, it is a wonderful element which is also used for making something like piezo-electric materials some you know kind of a lead zirconate titanate, so in kind of a hybrid of this Zirconia advanced ceramics, one of the advanced ceramics. They are used also in other cases Zirconia has certain phase transformation which are very good and can be used in terms of developing toughness in dresses.

Then there are glasses and based on the origins, there are these soda glasses, borosilicate glass, silica glass, glass ceramics, etcetera. So glasses of course is very important because of the one of the very important property that they are transparent in nature and that means they can be used in terms of manipulating with the light waves you know in various forms or focusing the light waves in the form of lenses or for passing the light waves.

Or for you know concentrating it in the form of lasers in various other systems, so that is the domain of engineering materials. And you can even have hybrids from taking contributions from each one of them like composites, like sandwiches, various types of segmented structures, lattices, foams, etc. And we will venture into all these carnets of materials a you know as we will be progressing in our lecture.

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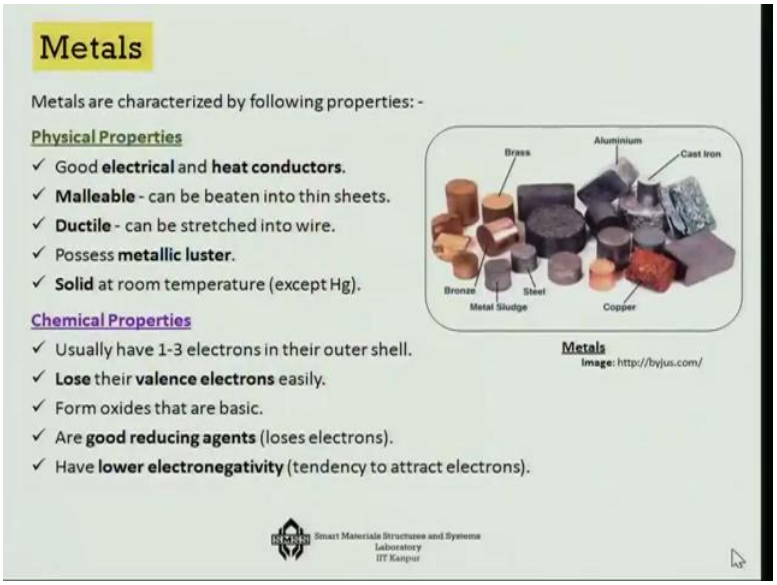

Now, when we talk about metals this is very well known to you but let us just recaputalize, recapitulate you know because this is an introductory lecture. What do we mean by this metal? What are the basic physical properties? Like you know when we talk about metal, they have a very good electrical property or heat conduction, they are very malleable, you can make a thin film out of, beat them into a thin sheet.

They are very ductile; they possess something called a metallic lustre that is why some of the metals are used for ornamentation. They are generally solid at room temperature except mercury. And in terms of the chemical properties what you notice is that they are very I would say benevolent or kind in terms of giving away their electrons. They lose their valence electrons very easily that is why the metals actually form some kind of a cloud of electrons from all the metallic atoms together and hence there is a pool of electrons which is constantly available to conduct electricity that is what the good part of it.

Now they form the oxides which are basically basic in nature, the easiest example is the calcium oxide that you know that you get when they actually these palms type of thing okay that is basically nature. So similarly, all metallic oxides are basically nature. They are basic

and hence they are good reducing agents, okay because they losses of electrons and they have lower electronegativity. So the tendency to attract the electrons because they have lower electronegativity so you know that is something that you will see is more in terms of the non-metals. So that is what the group of metals is.

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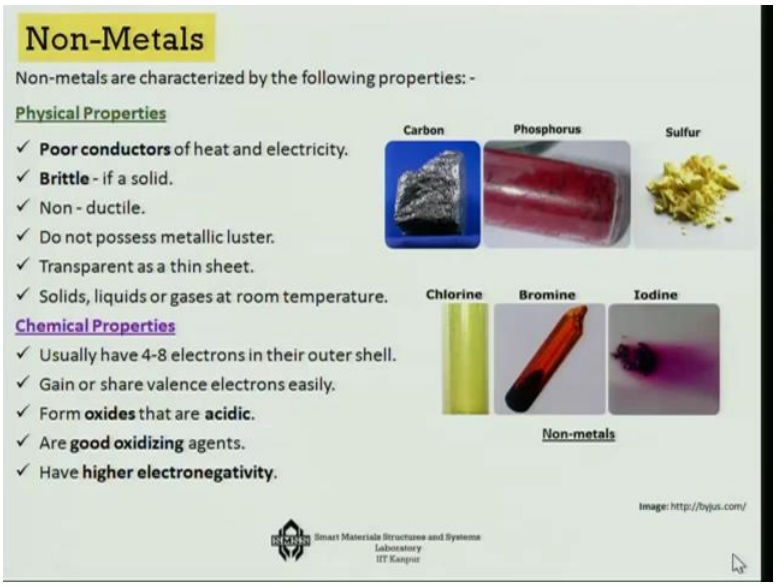

Now if you look at the non-metals, then whatever metals do not have, most of the things non-metals are having. They are poor conductor of heat and electricity and they are very brittle and they are non-ductile, they are not malleable, you cannot make very thin sheets out of it, they do not generally do not possess metallic lustre that is for sure.

Some of them like for example, these you know this kind of crystals like say diamond for example or some such thing, they actually have very high degree of internal reflection and hence they create a kind of lustre, it is not metallic lustre but it is generated because of the total internal reflection as you call. They are many times transparent as a thin sheet, they are available unlike the metals as solids, liquids and gases at room temperature.

In all the phases you will find them. Usually they have 4 to 8 electrons in their outer shell and then they form oxides that are acidic in nature, so unlike metals which forms oxides which are basically nature, they are that is why good oxidising agents and they have a much higher degree of electronegativity, so that is the nature of the non-metals.

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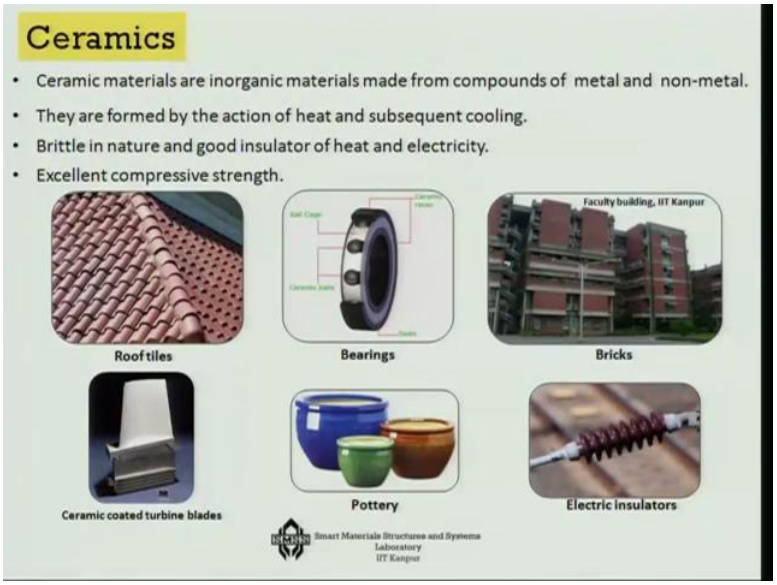

Then specific group of non-metals I would say is the ceramics. So these are inorganic materials in which basically both metals and non-metals come together. And mostly they are for example oxides okay, the iron oxide or the Carbide like the Silicon Carbide. They are formed by the action of heat and subsequent cooling and they are generally brittle in nature and they are good insulator of heat and electricity.

They have excellent compressive strength that is why you would see that most of the earlier structures like you consider pyramid or you consider the Tombs, they are actually made ceramics because they have excellent compressive strength. In fact, you would see that you know some of the applications here like the roof tiles for the bricks, where it is the compressive strength which is explored.

On the other hand, certain very interesting applications are there for example, the turbine blade. Here it is the high temperature you know properties that they do not crib very easily, so at the high temperature they maintain the geometric you know shape, so that is explored in this context. Potteries once again you know they are basically explored in terms of that they do not react much, so you can actually put a lot of materials into them.

You can use it in terms of storage system. And in terms of bearings you see frictional property that is utilised because you can have ceramic which can have a very low wear and tear, so that is very good in terms of the fictional property. And in terms of electric insulators you must have seen these examples where it is the insulation property, the electric insulation

property that is utilised. So thus there are many interesting areas where ceramics are having truly I would say you know unique applications, next comes the polymers.

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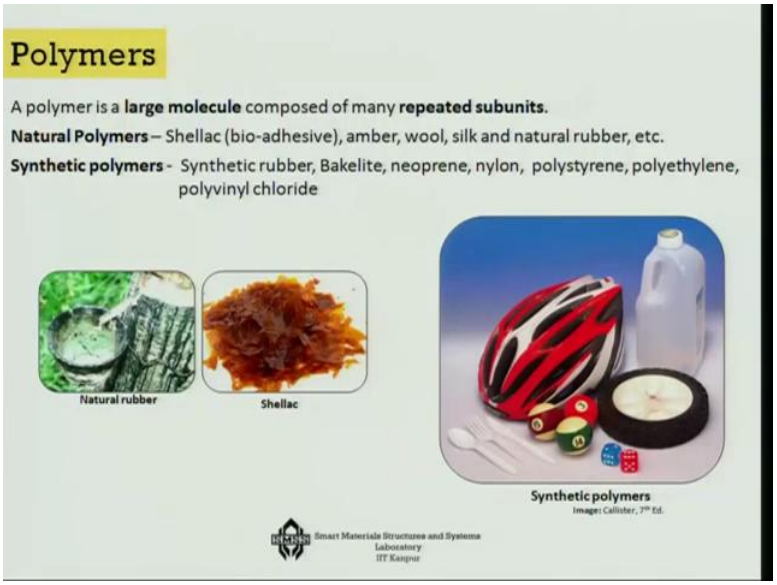

The natural rubbers that was the you know once upon a time the only polymer, but then there are many other things wools, silk, et cetera and then synthetic polymers, I talked about synthetic rubbers, bake lights, neoprene, nylons, etcetera and the old world today is around the polymers. So I will more describe about the polymers later.

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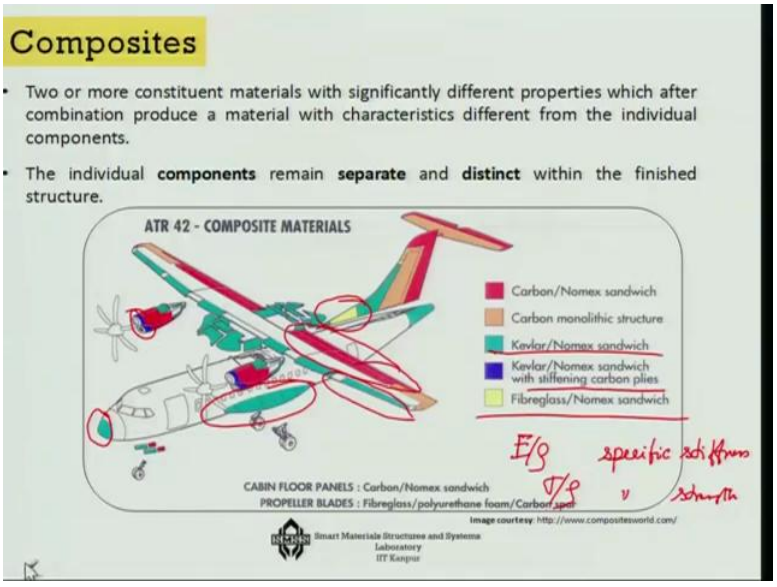

The composite, in the composite the idea is that it must have 2 or more constituents in which one is the major constituent, which is like the matrix and the other one is a minor constituent

in terms of the volume fraction or the weight fraction, but it is not a minor constituent in terms of strength or in terms of the modulus of elasticity or in terms of other you know interesting properties like high-temperature performance, etcetera.

So that is the idea in the composites that you mix 2 materials, basically mix one extra material on a matrix to improve substantially the property of the basic material. Consider for example, like this is an aircraft okay. So for this aircraft you know if you look at the wing part of the aircraft, there you will see the maximum use of the composites. So these red areas, they are generally Carbon Fibre Reinforced Plastic, okay.

Then you have other areas where you will see that like the belly part of it or the wing tip part of it where you will see that the Kevlar is used. Then you will also see this kind of a thing in the tip part. In the high temperature zones, you may see this close to the engine that there is this Kevlar sandwiched with stiffening carbon plies.

And in certain less important areas in terms of structural strength, but very important as a connecting material we will see fibreglasses used. So one of the few advantages that composites give us is in terms of what you call the lightness and in terms of the strength and modulus of elasticity. So we actually say this in terms of specific stiffness, specific stiffness means you know modulus of elasticity with density and specific strength. So that means once again with respect to the weight, the stiffness that you get or the strength that you get is very high in the composites. Thank you.