Basic Construction Materials
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Module - 3
Lecture - 12
Nature of Materials - Part 2

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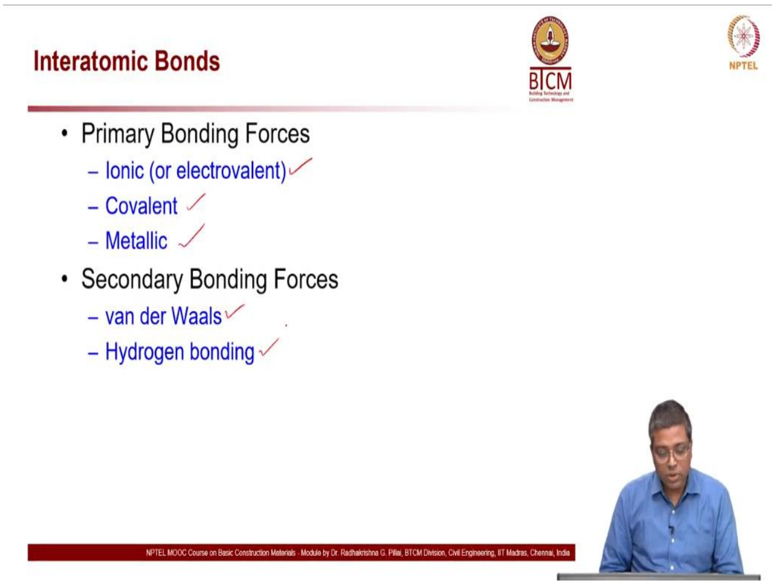

Now, let us, looking at interatomic bonds. There are different types of bonds; 2 classifications, primary and secondary. In the primary, there are ionic, covalent, and metallic bonds. And in secondary, van der Waals and hydrogen bond. So, we will just very briefly go through these also today.

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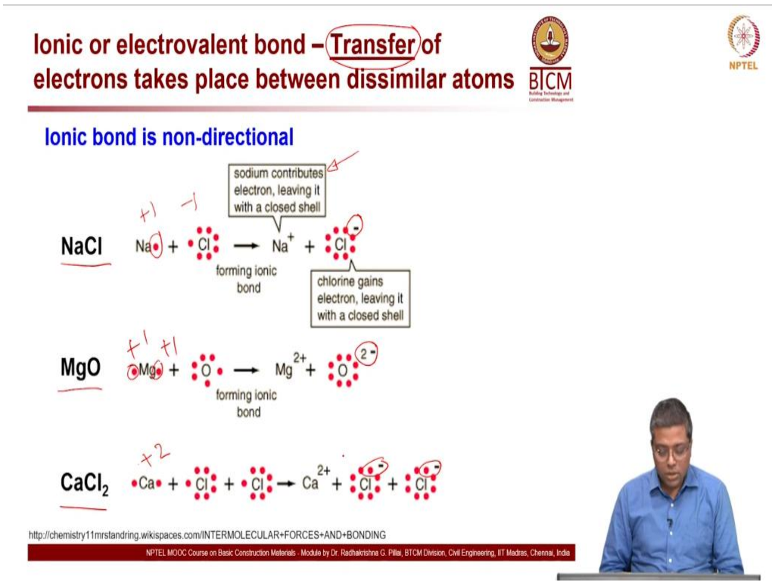

Now, ionic or electrovalent bond, in these bonds transfer of electrons takes place between dissimilar atoms. So, in this example of sodium chloride. So, sodium has a valency of +1, chloride you have -1. Now, on the right side, you can see the sodium contributes to the electron, leaving it with a closed shell.

And that particular electron is taken by the chloride ion. And you have a negative charge in the chloride. So, it is not that they are sharing the electrons, but they are transferring the electrons from one to the other. In the case of magnesium oxide, the valency of +2, both are taken by the oxygen here. So, you get -2. They are so taken completely.

It is not sharing. It is just a transfer. In the case of calcium chloride also, the same thing happens. This is +2. And both are taken by the chloride, in one and one. Like you can see here, one. And then here one. So, just an example, to show how the transfer of electrons happens. And these kinds of bonds are called ionic bonds.

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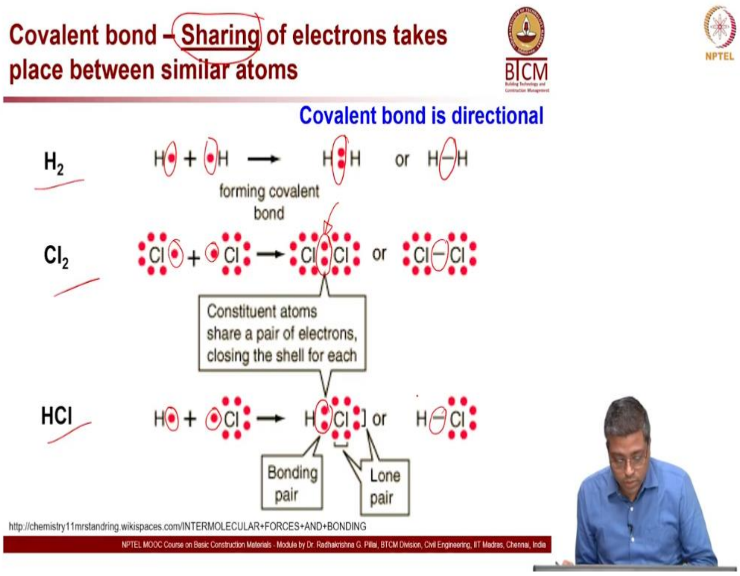

Now, covalent bond. Here, not the transfer, but sharing of electrons is what is happening. So, for example, hydrogen, chloride, and HCl or hydrochloric acid. So, you can see it here. You have one for hydrogen. Moreover, that is being shared here. From each of the atoms, it is shared. So, you get that one as two, as the electron configuration. This kind of hyphen also indicates it.

Now, in the second case, chloride, you have one here and one here. That is being shared or indicated with this, or sometimes by this, just a hyphen. Now, in the case of HCl also, you have this and this being shared. So, you get that full sharing happening. Furthermore, it is also indicated by this.

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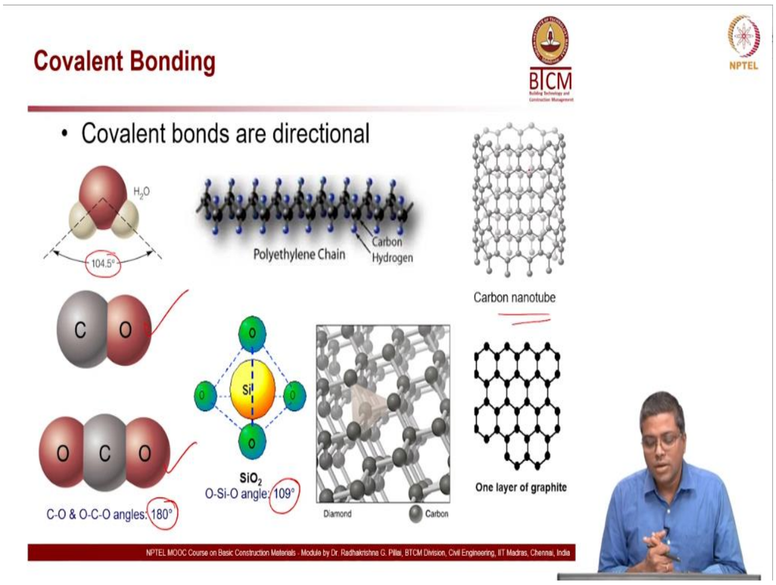

Now, covalent bonds are directional. What it means is, when you talk about these different types of bonds, there are some angles at which these bonds are placed or angles between the bonds. Moreover, they do not change much. They are fixed angles. So, in the case of carbon monoxide or Co2, carbon monoxide or Co2, you have a 180-degree angle. In the case of silica, you have 109. In the case of water, you have 104.5.

So, these angles have some unique nature because of which the other behavior or the rearrangement, etcetera, happens in the different material system, which contains this kind of atomic structure. Now, you can also see the carbon nanotube. It is all directional. They are not. They are very, very well organized atomic structures. That is what I am saying, thereby meaning that they are directional. Just some examples to show you.

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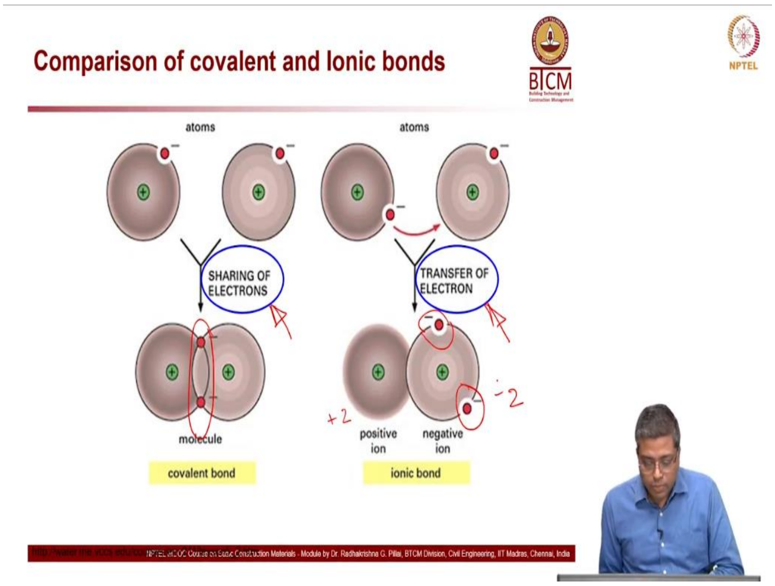

Now, just again, comparing, we already looked at ionic and covalent bonds. Just to emphasize the difference. In the case of a covalent bond, you are sharing the electrons. In the case of an ionic bond, you transfer the electron from one atom to the other. So, you can see it here. In this case, this is being shared. Whereas here, both, on the right side, both these are taken by the negative ion and leaving a +2 charge for the negative ion and a -2 charge for the positive ion. I mean, sorry, the other way. Yeah. Okay.

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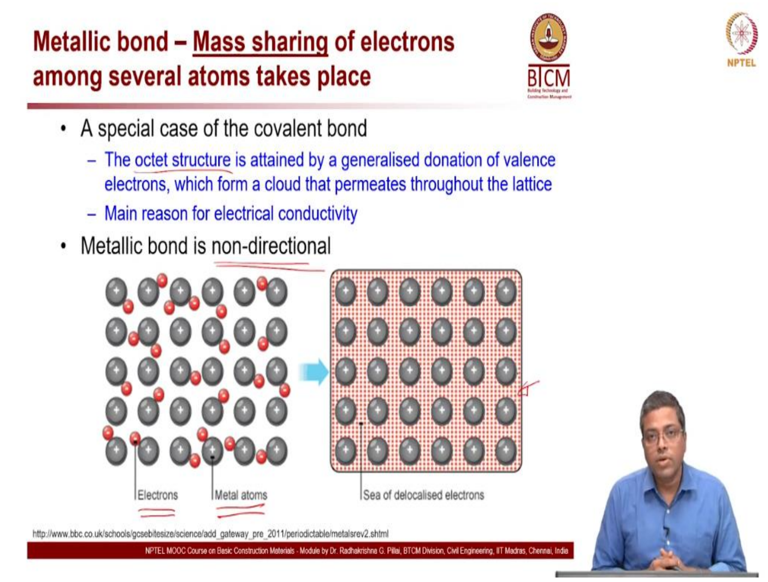

Now, metallic bond. So, this is mass sharing. It means sharing, but on a large, larger scale of, in larger scale. There, sharing of electrons among several atoms takes place. We can also look at it as a particular case of a covalent bond. The octet structure that 8 electron thing we were talking about earlier is attained by a generalized donation of valence electrons which form a cloud that permeates through the lattice.

And this is why; you have a lot of electrons available in the entire lattice structure. And that is why we are able to get the high electrical conductivity also because you have electrons available which can transfer charge from one point to the other, by, through conduction. Now, a metallic bond is also non-directional. So, you can see what I just mentioned in this picture at the bottom.

You have a lot of these red circles, which are all the negatively charged or negative electrons. And then, this plus sign, the gray color circle. They are all metal atoms. So, electrons and atoms are all everywhere. So, you have a lot of; on the right side picture, you can see more; you have a lot of these electrons available around the atoms. Okay, so that is a metallic bond.

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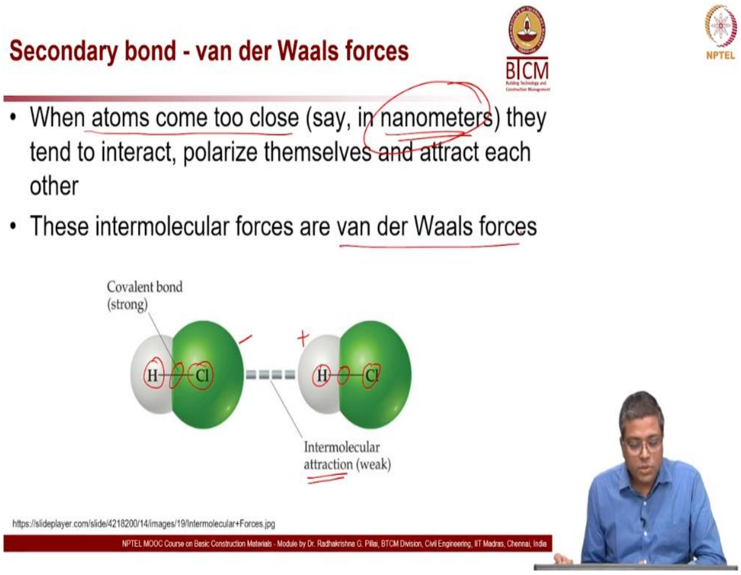

Now, we will talk about the secondary bond. So, until now, we were talking about the bonds which are very primary in nature or strong bonds; covalent, metallic, and ionic bonds. Now, two secondary bonds we will talk about. One is van der Waals forces and then hydrogen bonding. So, what is van der Waals forces? This is generally known as the weak bond. Now, why, what it, what is happening, or why such bonds are formed?

When atoms come too close, now, what is this too close? On the scale of a nanometer, so, very, you are talking in the atomic scale. They tend to interact, polarise themselves and attract each other. So, you can see the picture at the bottom, where you have a HCl, two HCls, hydrogen chloride, or hydrochloric acid. So, you can see H, Cl. So, this has a very good covalent bond.

Here also, on the right side, same thing; a very good covalent bond. But when these two HCls are coming closer, in the scale, like in nanometers or so, then there is a possibility of an interaction between them. There is an attractive possibility. Why? Because you have H plus here, and CL is minus here. So, you have plus and minus ions or positive and negative ions coming closer. And then they may form this weak bond. And even though it is weak, it has an influence on the material properties in different states. Okay, yeah, and these are called van der Waals forces.

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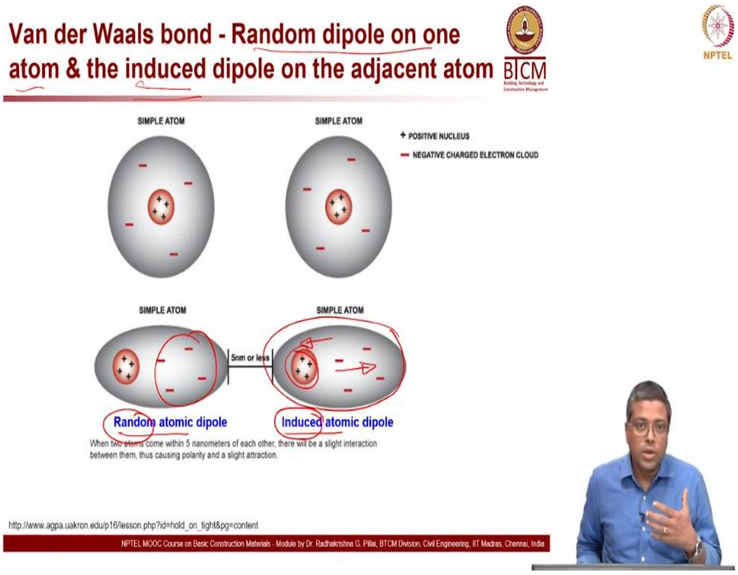

Now, just a little bit more explanation on this. You can see random dipole on one atom and the induced dipole on the adjacent atom. So, look at the left side of the graph. So, here again, the distance is written as about 5 nanometers or less, which means very, very close. At that time, on the left side, you see a random atomic dipole. On the right side, you see induced atomic dipole.

So, what is happening is, it is actually the same picture. So, on the left side, you can see this negative charge is polarised, I mean, towards the right side. And the positive charge is polarised towards the left side of this atom, right. Now, what will happen is; when this happens, the atom on the right side, that is this one, this gets induced. Because now you have more negative charges here, so this will have some influence on attracting all the positive charges to the left side on the right side atom.

Now, because of this movement of the positive charge to the left, the right, the electrons will move to the right side on that. So, the negative. So, this is induced dipole. First thing happening on the left side; is random. Because of that, , it induces polarisation on the right side atom. So, that is what difference between random and induced atomic dipole. I just wanted to mention this aspect also when we talk about the van der Waals bond. And because of this, the material behavior can change a little bit.

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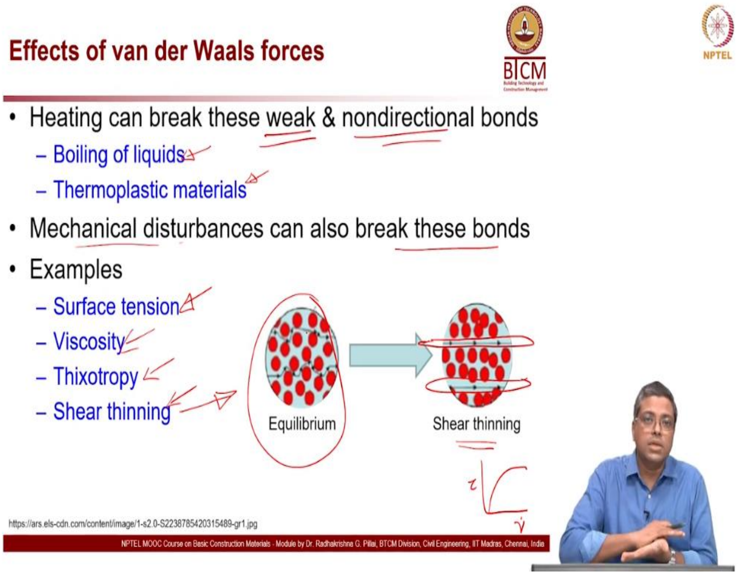

So, I can talk a little bit about some examples of how these van der Waals forces affect material behavior. Now, one thing is, when you heat any particular material, what will happen is; first, when the material absorbs the heat energy or the heat energy or when the temperature increases, there will be vibrations caused in the atomic level. And at that time, the first bonds which we will be breaking are the weakest bonds.

Like weak and non-directional bonds will break first. And mostly, those are the van der Waals bonds. Now, while boiling liquid, this is what happens. And also, in the case of plastics, when you heat the plastic, it starts flowing. The plastic material starts flowing. And then, flowing means permanent deformation. And that is happening because of the breakage of these weak bonds.

And also mechanical disturbances. Let us say you are mixing something. In the case of thixotropic materials, they can also lead to the breaking of these weak bonds. So, first bond, the type of, among all these covalent or ionic or metal, metallic bonds or anything, the first type of bonds that break are the weakest bonds. And usually, they are the van der Waals forces.

So, they significantly influence surface tension, viscosity, thixotropy, shear thinning, etcetera of various materials, which we use in construction. Now, for example, I will just explain this shear thinning behavior here or thixotropy; you can relate to that. So, here you can see the first image, where you have some, two black things are also going here, in between these red circles.

So, I can say, when, this is an, in equilibrium. Now, when I try to disturb that material, let us say you take an example of a pudding or something if I try to disturb the material. You try to disturb it, so then it starts breaking, right. The material starts breaking. And where do they break? That breaking is happening along these lines. You can see it here. These are the two lines in this example where the breaking happens.

So, the material starts flowing. It flows easily. Or the force required to further flow the material is to induce the further flow of the material is relatively less. And that behavior is what we call shear thinning. I covered this in the previous lecture on materials, the concepts for materials engineering. So, you can look back on that. Viscoelasticity, where we discussed, we talked about what shear thinning is.

So, this was something like this. And then you have shear stress, shear rate, and the material behaving like this. So, here, the weakest bonds break first. And that allows the material to flow.

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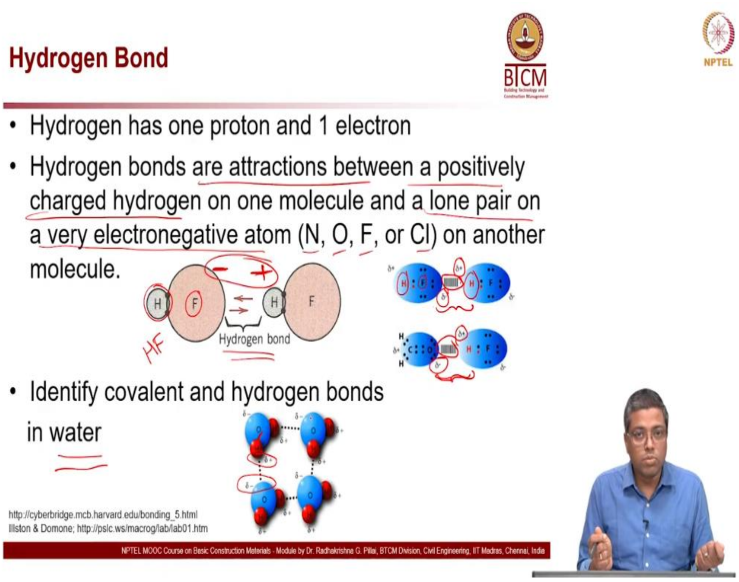

Now, the hydrogen bond is another secondary bond we are talking. And this has 1 Hydrogen has 1 proton and 1 neutron. And these are attractions between a positively charged hydrogen; that is here; on 1 molecule and a lone pair on a very electronegative atom. Typically, you have nitrogen, oxygen, fluorine, or chlorine on another molecule. This is a very highly electronegative atom because this positive hydrogen gets attracted to this negative atom.

And then, the hydrogen bond is formed. An example is shown here in this drawing here, where you have an example of HF. So, you have a hydrogen here; fluorine. And then you have a negative charge forming on this side. And here you have positive charge forming, right. So, because of that, there is this interaction between these two negative and positives. And that is what is a hydrogen bond.

A similar example, I mean just to more clarity. You can see here an identical example, hydrogen and fluorine. But you have this one here. And more negative energy here, more negative. And then, because of the hydrogen presence on the left side, you have more positive energy there. And because of this delta minus and delta plus, you have this hydrogen bond-forming right here.

In the same case, in case of this formaldehyde and hydrogen fluoride, you have the same plus and minus charge on the face. And which leads to the formation of the hydrogen bond. So, these black lines here indicate the hydrogen bond. Now, look at the picture at the bottom, where you have a hydrogen bond and covalent bond shown in the case of water. Now, which is the hydrogen bond here?

So, you can see, for example, this H+, positive charge here. And this oxygen has a negative charge on that side. So, this dashed line, the black dotted line, we can call a hydrogen bond. And which is the covalent bond? That is this between the hydrogen and the oxygen in the same molecule. So, within the molecule, you have a covalent bond. But across two molecules of H 2 O, you have hydrogen bonds.

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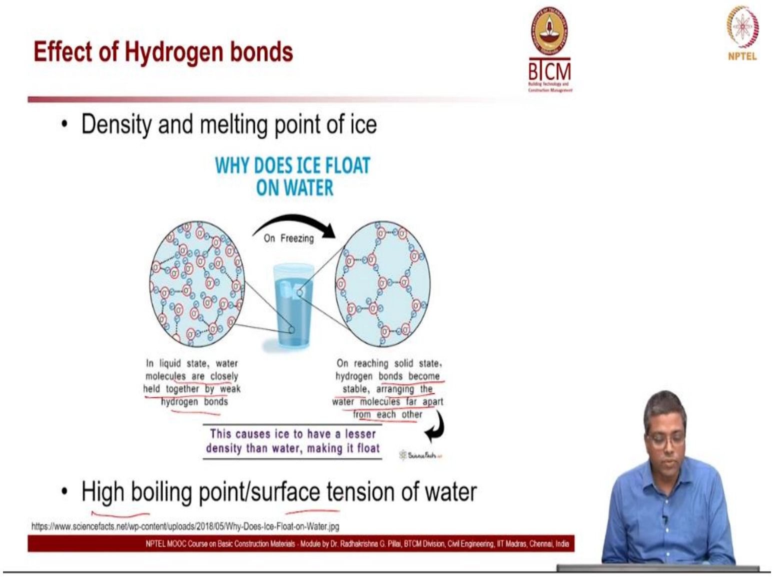

Now, you know it very well, when you have ice formation, it ice floats in water. Why does it float? It is all made of the same H 2 O, but something is floating in water because of something. And then the reason is the density of the ice decreases as ice forms. And why that is happening is coming back to them; the reason is, hydrogen bonds are formed. In the case of water on the left side, we can see that we have these different bonds in the case of liquid water.

However, there is no properly organized fashion. So, in the liquid state, water molecules are closely held together by weak hydrogen bonds. On the right side, when the ice crystals are formed, you have well; I said ice crystal, right; you have a well-structured molecule there. Or the atomic structure is there, you know, well-structured. So, they become stable. Because of this particular structure, they become stable and arranging the water molecules far apart from each other.

You look at the left side picture and the right side picture. If you look at the left and left, you can see lot more molecules than the one on the right side. So, the density of ice is less. Because of the lower density, it starts floating in the water. You cannot really push the ice into the water. It is very. It is not possible because of this atomic structure. And also because of these type of bonds present, it also ask for high boiling point, surface tension, etcetera.

Because you need, when you say high boiling point means, you need more energy to break these bonds first. So, that is also adding to the high boiling point. So, this kind of bond affects the mechanical and other properties of the materials.

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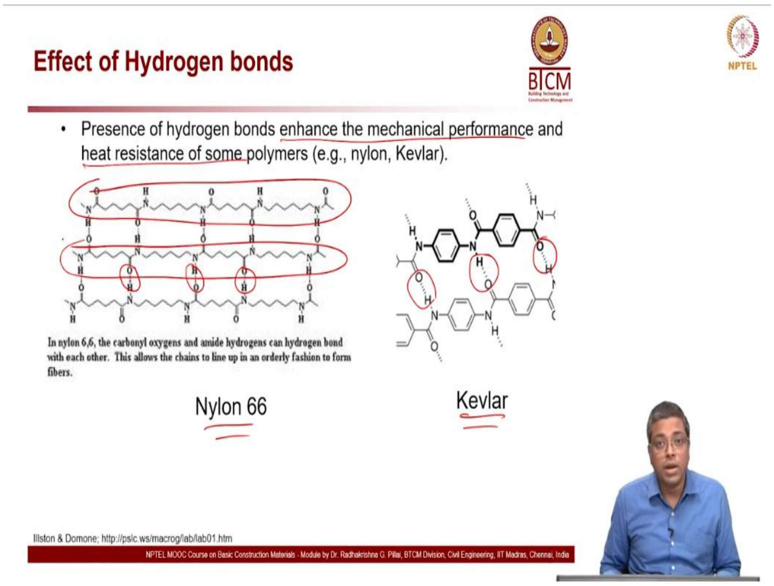

Now, hydrogen bonds can also enhance the mechanical performance and heat resistance of some polymers. Here is an example of nylon and kevlar. Kevlar is very, you know, it is used for a bulletproof material. It is a bulletproof material, developed for that purpose only. Now, you can see it here. Where is the hydrogen bond here? This is one; this is one; this is one; between oxygen and hydrogen there, you can see, like that, connecting these different chains.

So, you can see, this is one chain; this is another chain; then there are hydrogen bonds between the chains. They really help in changing the behavior or in enhancing the behavior of these materials.

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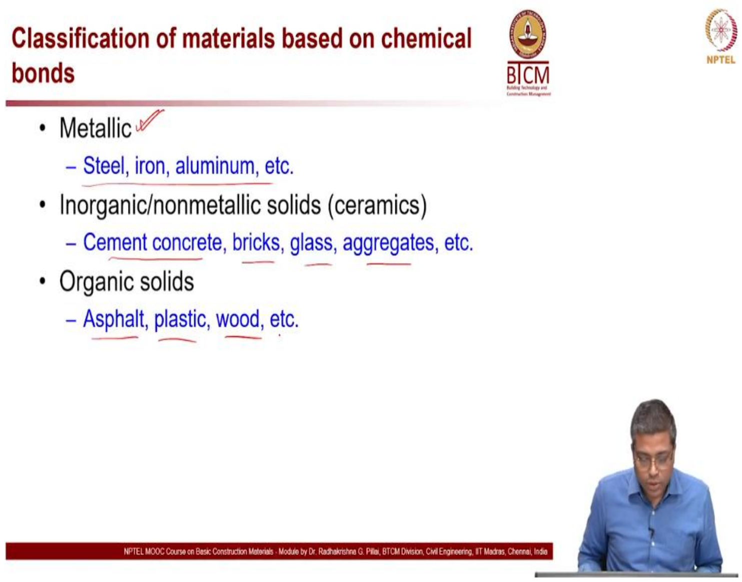

Now, we covered these different types of bonds. And these types of bonds can be used to classify, or different materials can be classified based on the type of bonds present. For example, if you are talking about metallic materials, steel or metallic bonds, you know, steel, iron, aluminum, etcetera, they have a metallic bond. And in the case of cement, concrete, brick, glass, aggregates, they are all typically ceramic materials.

And they will have other types of bonds, not really the covalent bond or ionic bonds etc. And other organic solids you have; asphalt, plastic, wood. They also have differences. So, these materials have a different set of, you know, they can be classified based on the type of bonds that are present. And then, the behavior is also very different. So, in future lectures, we are going to first look at how metallic materials behave.

And then, looking at their microstructure, with a different types of defects in the metallic materials. And then, we will look at inorganic and organic, inorganic, and nonmetallic materials. And then finally, we will also look at how the organic solids or organic materials behave.

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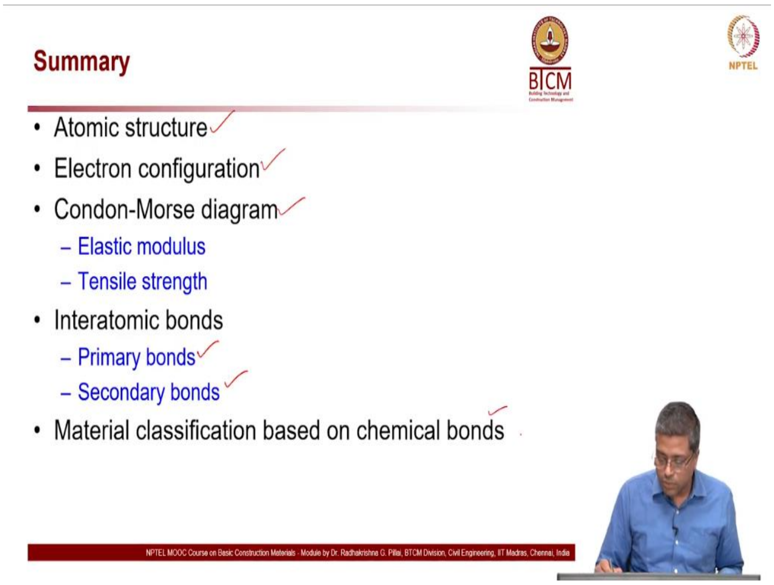

I think, for today, we are going to close. To summarise, we looked at atomic structure; we looked at electron configuration. It is essential to recap some of the knowledge which you already have. And then, we looked at the Condon-Morse diagram; how it can be used to relate to mechanical behavior like elastic modulus or tensile strength, etcetera. And then, different types of bonds also we discussed.

Furthermore, material classification based on chemical bonds will talk in more detail in the coming lectures. Think, with that. We will close this lecture. Thank you.