Introduction to Solid State Physics
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Lecture – 32
Introduction to Different Crystal Type Part-II

In the last lecture, we had looked at Different Crystal lattices and we were looking at the cubic lattice, the BCC lattice, body centred cubic and the face centred cubic. And then, we came to the diamond lattice which can be described as two interpenetrating FCC lattice whether 2nd FCC lattice.

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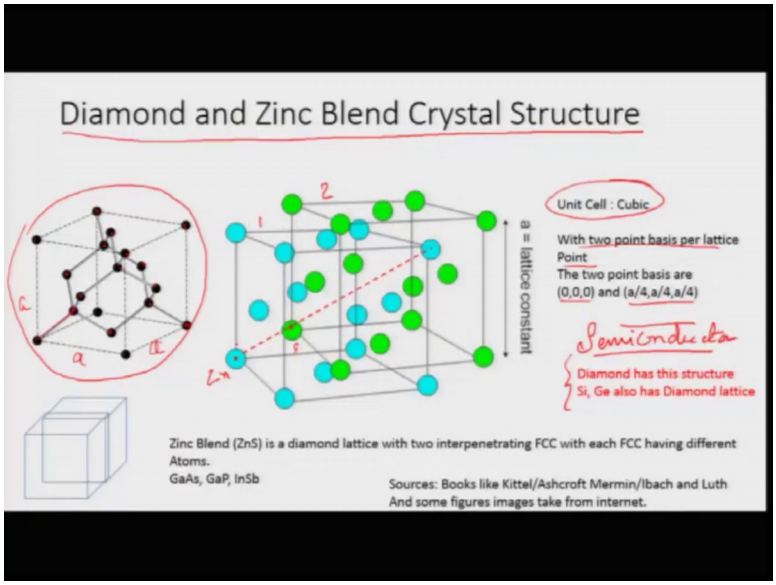

Which is shown in green is displaced with respect to the first along the body diagram and you can describe this diamond lattice with a cubic unit cell which is your conventional unit cell, not the primitive unit cell.

This is a conventional unit cell with lattice constance a and there is a two point basis namely you are describing it with cubic unit cell with two lattice points per unit cell, and these two lattice points are at 0 0 0 and a by 4, a by 4 and a by 4. Of course, in diamond lattice, for example, in the carbon lattice all of these atoms are identical. They are not blue and green they are not separate. For example, in silicon and germanium this is also the case and you get this sort of a structure, but if these atoms in this diamond lattice of

the two interpenetrating lattices, if they have different set of atoms for example the blue atom could be zinc and the green atoms could be sulphur, then you get the zinc blend sulphur zinc blend crystal structure.

This is again the diamond lattice which is made up of two interpenetrating lattices, but now the atoms which sit on these two different interpenetrating FCC lattices are different. On one of them you can have zinc, on the other hand you can have sulphur and you will get the zinc blend crystal structure and different types of compounds actually crystallize into this sort of a structure and again there are some important, very important semiconductors which crystallize into the structure like; gallium arsenide, gallium phosphide, indium antimony and so on.

So, these are the structures these elements actually crystallize into the zinc blend structure which is just a variant of the diamond lattice structure.

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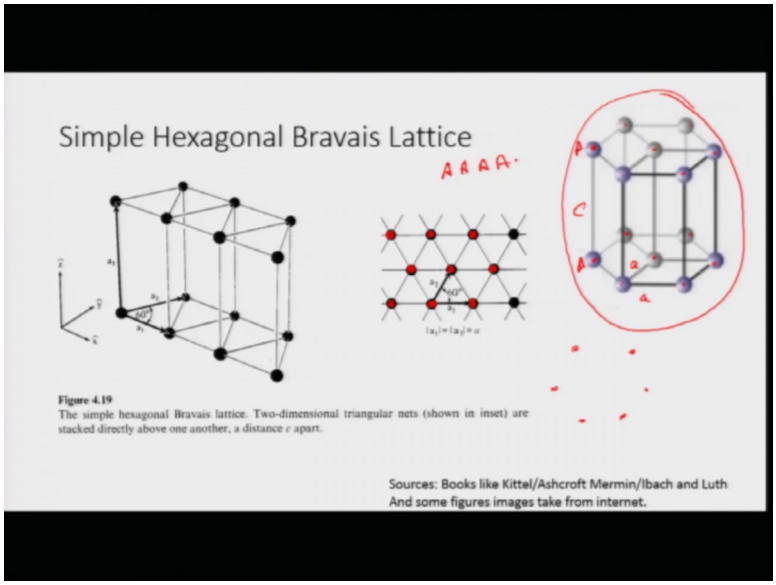

Another structure which we come about in nature and large number of different compounds actually crystallize in this is a hexagonal lattice or a variant, a slight variant of it.

What is the hexagonal lattice? A hexagonal lattice or a hexagonal Bravais lattice is formed by this hexagonal collection of points which are arranged on the edges of a hexagon. You have these points which are arranged at the corners of a hexagon and this

is important. If you recall I had shown you a honeycomb lattice structure. The honeycomb lattice structure is somewhat like this hexagonal lattice, but with the central lattice point missing here you have the central lattice point ok.

So, the hexagonal lattice structure is formed by a set of points, the hexagonal Bravais lattice is formed by points which are arranged at the corners of a hexagon. Again the lattice parameters and the lattice constance are the same ok. So, you have this two dimensional hexagonal Bravais lattice and now on top of these atoms or these lattice points you can place another at a distance see away ok. These could be a and a you could place another at a distance c away and you will get the hexagonal Bravais lattice.

Now if you see this points are sitting directly above the lattice points on the hexagonal lattice below and you can describe your unit cell with your hexagonal Bravais lattice ok. So, these form now your lattice vectors a 1 a 2 and a 3 and with this you can describe your just like you have the cubic unit cell and BCC and FCC are described the variance of cubic cell. The BCC and FCC are described in terms of the cubic lattice. In the case of hexagonal lattice, different variance of the hexagonal lattice you can describe in terms of the hexagonal Bravais lattice and these are the primitive lattice parameters for this hexagonal lattice.

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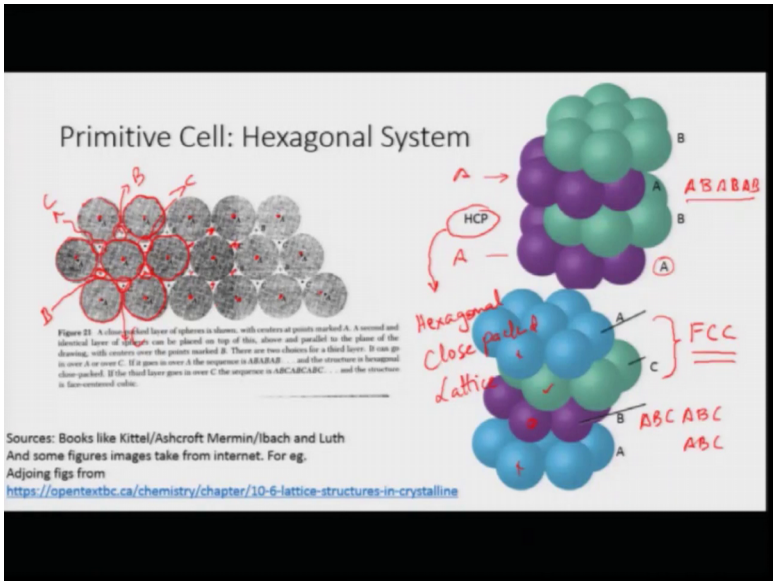

Let us go further and first let us consider the hexagonal lattice system. So, suppose I have these balls ok. You can think of these spheres, and if I join them, then this spheres

will arrange themselves into a proper hexagonal lattice; so, this is the two dimensions. So, on the plane of the paper you can take these balls all of same diameter and you can collect each of them ok. You have seen this in while playing carrom also that if you take the small cylinders, your coins and if you arrange them, then they will form a hexagonal lattice.

so that is a hexagonal Bravais lattice that you get on a plane. Now, if you notice that there are gaps in between these balls. These balls will certainly not join up with each other and there are gaps that you get in between the balls ok. Now one can identify two different types of gaps. One is the B type of gap, this is B type of gap and this is A. This is of course of B type of gap, this is also B type of gap and these are C type of gap. Now, we want to make a three dimensional structure, I have made on a plane or hexagonal lattice.

Now, if I want to make a three dimensional hexagonal lattice in the third dimension, what I will do, I will put my 6 set of balls over this point A ok. This point A which are the centre of these balls, I can place another collection of these balls exactly in the same tight configuration of these balls. If I take another arrangement of these balls and place it directly over the point A, all these points a such that they completely match each other. The lower and the upper layers are all matching over sitting one on top of each other, then I will generate the three dimensional hexagonal Bravais lattice which I have shown you here. This is the three dimensional hexagonal Bravais lattice where over the point A, I am stacking the layers one on top of the each other.

So, this is known as AAA stacking where all the layers are being put over the points A. Now, I have identified these gaps in between B and C type of gaps ok. Now over the B type of gaps if I place my set of balls, now the next layer of balls if instead of placing it over A, I start placing it over these B gaps only over the B gaps and then, the third layer which I put will be above the A points.

The type of structure i get is like this A, this is the A layer. Of course this is the lowest A is the A layer the B atoms or the B lattice points are put over these points only over the B points. We do not put any points over C and then, the third layer that you put in. So, these are the two A layers, they are directly one on top of the each other and the B point

is slightly displaced. This type of structure is AB AB AB structure and this is called as a hexagonal close packed structure.

Hexagonal close packed lattice it has the layering which is AB AB AB type. Now, as you might have guessed that I can put points over B but, so I can make a layer by putting points over B. I can make a third layer by putting points over C and then, point A. So, I can create layering where I have a layer, I have these balls which are put over the B layer and I have balls which are put over the C layer and then, again I repeat over the a layer namely these two are exactly on top of each other. B layer is slightly displaced and the C layer is again displaced in another direction. So, I have stacking ABC ABC ABC I can put these balls one on top of each other and I can create a different type of a stacking of these lattice points.

And this sort of stacking actually leads to a very surprisingly to the FCC lattice ok. So, the FCC lattice has ABC ABC ABC stacking. If you stack these points which are shown here in this ABC ABC ABC configuration, you will end up with an FCC lattice, but if you (Refer time: 10:00) AB AB AB stacking with these balls you will get an HCP lattice.

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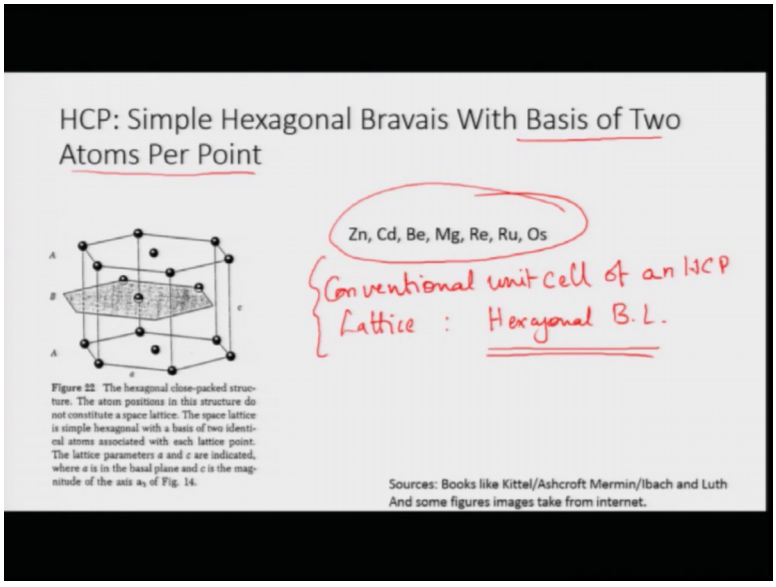

So, hexagonal close packed lattice can be actually described by a conventional unit cell of an HCP lattice is nothing else, but the hexagonal Bravais lattice which is this hexagonal structure AAA type of a stacking, but it now has an additional layer in between this layer which is the B layer has been put in between the two A layers.

So, this leads to your hexagonal close packed structure which has a basis of two atoms per point. You can show that again this has a basis of two atoms per point. Its conventional lattice is the hexagonal Bravais lattice with AAA type of a stacking and you have put in B layer in between that will give you the additional atom in that layer. And there are different types of materials again which actually crystallize into the HCP structure. Quite a large number of elements crystallize into the structure; for example, zinc, magnesium and so on crystallize into your HCP structure. So, this is also a very well known structures seen in nature.

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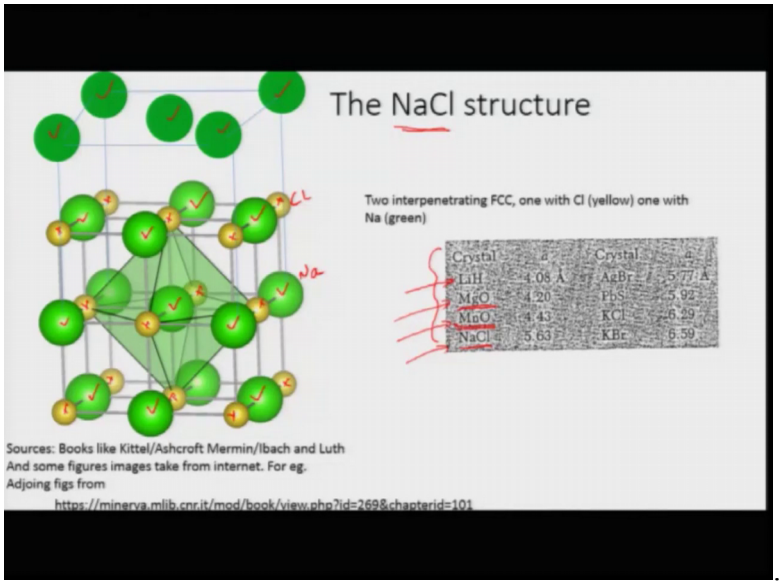

Another structure which is commonly seen in a variety of compounds is the sodium chloride structure. If you recall the diamond structure was two FCC lattices which are displaced along a body diagonal and the second lattice is actually kept at one-fourth along the body diagonal distance. The sodium chloride structure is also FCC structures, but they are interpenetrating they are not along body diagonals and they are this sort of a structure, where the green atoms is the sodium atoms and the yellow atoms are chlorine atoms.

If you look at the distribution of the chlorine atoms, you can certainly make out FCC structure. If you look at the distribution of this chlorine atoms, this certainly looks like FCC structure. They are sitting at the corners and on the faces of a cube. So, this is your FCC structure and if you look at the distribution of the sodium atoms which are these

green atoms ok, the sodium atoms which are the green atoms these also set on FCC structure where if I draw the next set of atoms for example, these are the next set of atoms or the lattice points, then you can see this green atoms are actually setting. They also form FCC structure. The green atoms if you forget about the yellow atoms and only look at the green atoms, then these are also FCC.

So, you have chlorine atoms and you have sodium atoms which form a lattice by interpenetrating with each other on one of the lattices sodium atom sit on the second lattice chlorine atom sit and this sort of a sodium chloride like structure is displayed by variety of materials. For example, NGO is a popular material used in research and condensed matter physics, MNO is also a popular material which is studied potassium chloride solids and potassium bromide solids.

Of course, NaCl is from where the original structure is defined and derived lithium hydride. So, all of these materials actually have a structure which is exactly like this sodium chloride is just to define this type of a structure two FCC lattices which are interpenetrating with each other in this way.

But with two different atoms on the two different FCC lattices just like you had the zinc blend structure here, you have the sodium chloride structure which has two interpenetrating lattices interpenetrating in a particular way.

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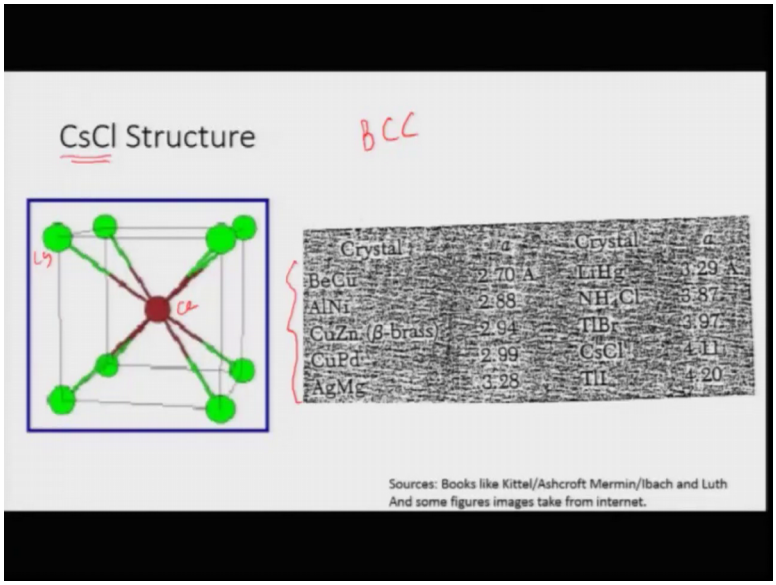

The caesium chloride structure is another type of a structure where you have atoms which are sitting on the corner of a cube. Its very much like a body centred structure, but you have atoms which are sitting on the corners of a cube and another different atom which is sitting at the centre of the cube ok. So, for example chlorine could be sitting in the centre and caesium is on the corners of the cube, there is one atom per unit cell. So, you have one caesium atom and one chlorine atom per unit cell and again there are a variety of materials which can form this sort of a caesium chloride structure.

So, you can have BCC structures where all the atoms are exactly identical or you can have BCC structure in compounds, you can have BCC structure by one atom is sitting on the corners and another type of atom or another element is sitting at the body centred position and this gives you your caesium chloride structure. So, these are some of the important structures which I have defined to you namely your cubic structure, simple cubic structure, BCC structure, FCC structure, the diamond structure, the zinc blend structure, your sodium chloride structure, caesium chloride, hexagonal Bravais lattice and the hexagonal close packed structure.

These are some of the structures which are displaced by a variety of elements or compounds and they can fall into one of these crystalline types or the lattice types.