Solid State Physics
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Lecture - 16
Crystal Structure (Contd.)

So, we are discussing Real Crystal Structure.

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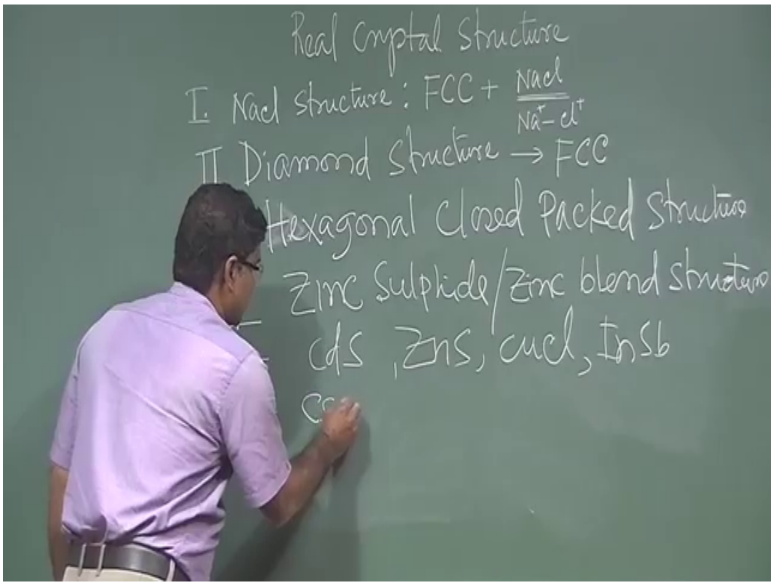

So, there are special structures: one we have discussed is the sodium chloride structure were basically is in FCC lattice, in FCC lattice the basis sodium chloride basis are attached. So, we have seen that sodium chloride. This two are attached with each lattice point and they are basically distance sodium and this chloride; chlorine that distance is half of the body diagonal.

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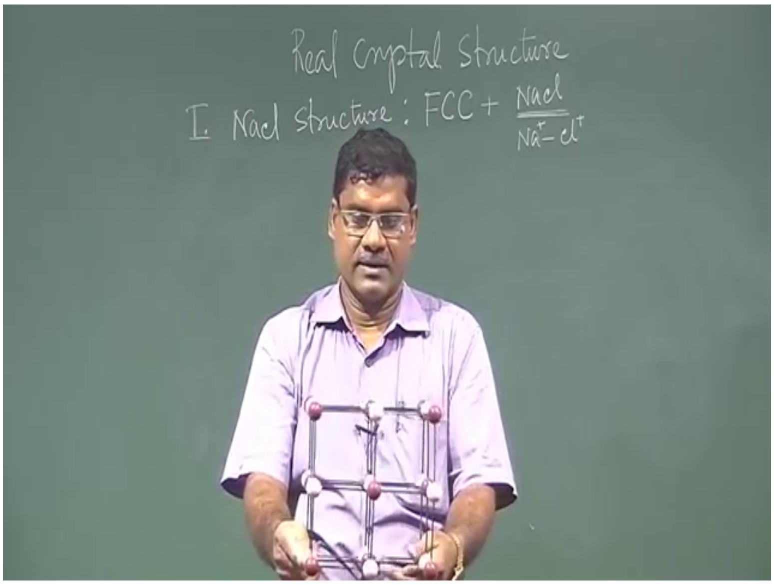

So, that here I explained. So, here I have explained that this; if I just consider the brown one and this position of sodium or chlorine, right; so sodium or chlorine.

So, you can see this then it is FCC, right. So, each 8 corner; 8 are there and then in each face; each face, right each face 6 faces. So, 6 part there, right. So, chlorine if we consider this the chlorine brown one then white one is white one is other one the sodium one. So, sodium is paste in such a way that as I told that that basis sodium chloride basis that distance between the basis and distance between the sodium of chlorine in that basis is half of the body diagonal; so for this sodium. So, this will be the chlorine. So, this sodium and this chlorine this is one basis, this sodium will have the chlorine, this one; right will have the chlorine this one. So, this is another basis similarly this 2 will have the basis, right.

So, this say you will get 4 basis overall, if you see because there are many atoms, but we have counted that how many lattice point or per unit cells. So, that is 4 lattice point per unit cell. So, that we have; we can get the coordinate of each 4 basis, right. So, that is very important that we will see later on. So, this how basis are distributed if you consider the origin and then with respect to that what are the coordinates. So, that one can easily tell. So, this model is very helpful and drawing picture also one can nicely show the position of basis and their distribution in the crystal. So, now, I will go for another structure another structure.

So, crystal structure real crystal structure. So, basically this is diamond structure.

So, carbon in diamond form; how it has crystal structure? So, that basically in diamond like sodium structure sodium chloride structure sodium chloride have that structure, but this same structure followed by the other materials there, this as I showed this potassium chloride and then magnesium oxide silver bromide, right for sodium chloride structure similarly diagonal structure. So, here it is again; this is FCC structure; FCC lattice. Now in FCC lattice, earlier, we have shown this; how sodium chloride are distributed right or potassium chloride are distributed magnesium oxide are distributed.

So, in same FCC Bravais lattice. Now here; this we are telling another structure another name we have given this diamond structure that is the same Bravais lattice, right, but there must be distribution of basis will be different from that other one, right. So, basically this name has come as I told this depending on the distribution of the basis in that same structure, right. So, here we have to find out how the basis are distributed in the in the structure which is called diamond structure.

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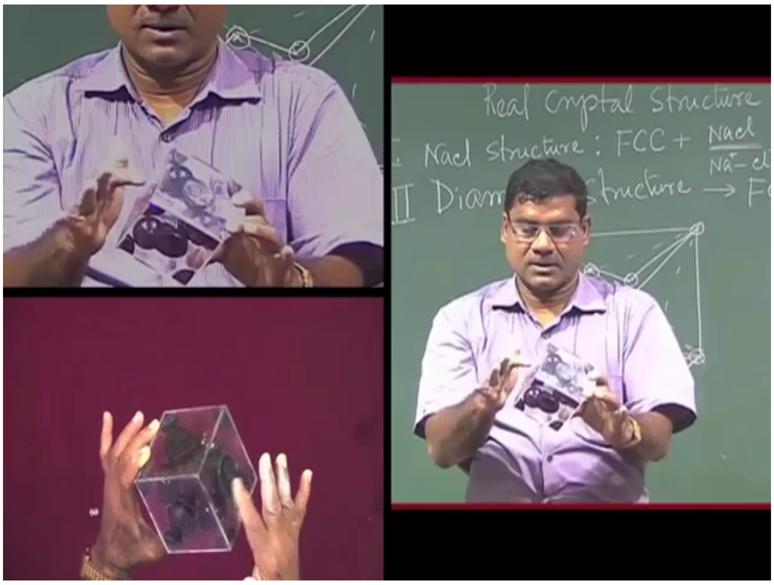

So, I will show you in model then it will be easier to easier to understand. So, basically if you see this one, right. So, FCC structure; so, for just one can FCC structure, right; so this diamond structure. So, first we need basically FCC structure, right. So, just let me draw also then it will be.

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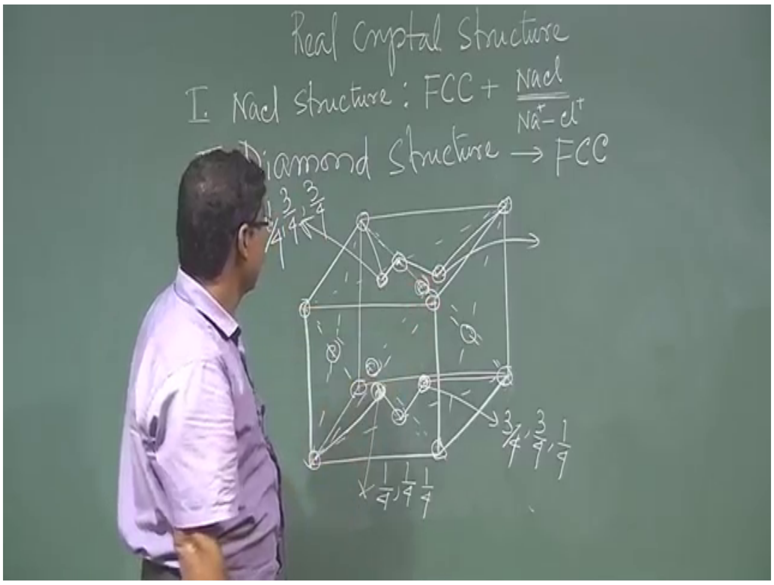

So, just if I draw the; so, FCC structure cubic. So, I will put carbon; say in each corner in each corner; in each corner, right and in each face middle of the face, I will put middle of the face; I will put middle of this face I will put and I have this face, I will put carbon. So, then I have I have this face. So, for this; so, I have to; I put here for this one, I will put here and for other face; this face, right. So, I will put here; so this FCC structure.

So, at each lattice point, I have put carbon atom, right. So, then, this is not sufficient for diamond structure or carbon structure in diamond form. So, there are some more atoms carbons are put in this FCC. So, they are put as a basis they are put as a basis additional basis point. So, how they are put, here let me tell and then I will show you in model. So, if you take this. So, from top if you take this diagonal. So, if this face it is; so this one diagonal this one diagonal. Basically you have to come down to towards the diagonal or one-fourth towards the diagonal if you come one-fourth. So, it is basically this way. So, this is down below then this is FCC one. So, if I go this way then again from here one-fourth down.

So, this 2 additional atom are placed. So, one-fourth below of this top one. So, one-fourth this along the diagonal we are going. So, other sides from bottom. So, I had taken these diagonal I have to take. So face diagonal basically I have to take the opposite another somewhat this one. So, other one other diagonal from here again if I go one-fourth up along the diagonal. So, this will be then this; the face atom. So, one-fourth say

I will go this side one-fourth I will go say this side then this there are one-fourth you say going up inside then this side. So, then this diamond structure you know. So, what we are seeing this FCC structure.

So, 4 lattice point per unit cell right 4 lattice point per unit cell. So, 4 carbon atom is there right additional 4 carbon atom, I have put one is this is another and 2 more here; what are the position just one-fourth of. So, if it is one-fourth. So, this actually as I told, this you have to along the diagonal body diagonal you have to you have to one-fourth. So, along the axis one-fourth then one-fourth and then one-fourth and this other one are to go here; so this half, then this three-fourth; one-fourth; one-fourth.

So, that will be the coordinate of this from this corner if; so, for this one; what will happen? one-fourth, three-fourth, three-fourth, right because this is coming from other diagonal side and this one will be this one will be three-fourth; three-fourth, then one-fourth, then three-fourth. So, this will be the coordinate of this one. So, whatever I described here. So, I will show you in model, I will show you in model. So, this the diamond structure you know. So, first confirm that FCC structure. So, 8 corner; 8 corner, right; 8 corner; 1, 2, 3, 4, 5, 6, 7, 8 corners; so, 8 atoms are there. So, here just one eighth is shown because one eighth you know this each corner point have one width one eighth contribution in this in this cube right. And this; see this 6 faces and each face is having one atom.

So, it is shown half because it is contributing half to this; so 1, 2, right, 3, 4, 5, 6, right. So, 6 surface, 6, 6 atoms are there; so this FCC. Now additional I told additional atom. So, if I take this way, right if I take this way. So, if this is corner if I take from this corner. So, along the face diagonal this along the face diagonal right along the face diagonal; so, I have 2 additional as I told this; it is this one what will be the coordinate. So, is the one-fourth and then one-fourth other side and then going half one-fourth right; so this one, this one, right. So, this one basically and then, then as I; as on this way and then this means this face one and then; that means, up and then again one-fourth up; so, this one; so, this atom, right; so, what will be the coordinate of this one?

So, this basically; if this is one-fourth, one-fourth, one-fourth; so, this coordinate of this one will be three-fourth, three-fourth and then up one-fourth, right. So, this 2 atoms coordinate one can fixed and this diagonal I have considered face diagonal. So, on top it will be just as I told this other one you have to consider. So, this one; so, this diagonal, if I consider the same way just go down one-fourth, then in middle up on the face, already, it is there, then from there, again you go one-fourth along the body diagonal. So, one-fourth; so, then this corner; so, what will be the coordinate of this 2 of this 2 additional? So, if I consider this one. So, this is basically I will along the x axis, I will go one-fourth, then along the y axis, I will go three-fourth right along the y axis, I will go three-fourth and then I have to go up three-fourth, then I can reach here, then I can reach here.

So, this coordinate will be one-fourth, three-fourth, three-fourth, right and other one. So, this one; so, along the x axis, I will go three-fourth and then along the b axis, I will go; I have to go one-fourth and then along the c axis I have to go three-fourth. So, this is a, another position of the additional atoms additional that is that is basically additional basis. So, from here also you can; I can see.

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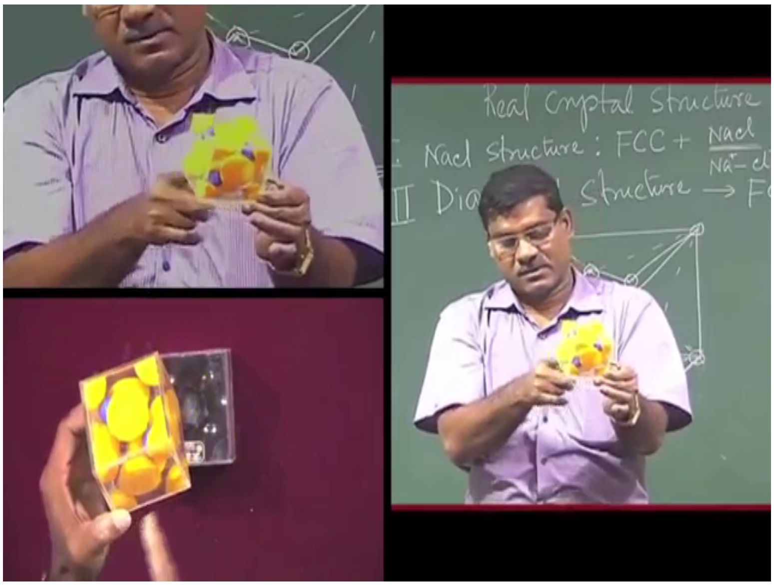

You can look; so, this yellow this basically its telling the position of the lattice point right. So, in each lattice point that is carbon are there carbon are there and additional 4 carbons this blue one blue 4 balls you can see it is there. So, again this you see from bottom surface bottom face; so, along this diagonal along this diagonal. So, one-fourth of both are in one-fourth of and axis wise, you can find out this a will be one-fourth b will be one-fourth and height is one-fourth for both height is one-fourth c ax c will be one-fourth right and for this one. So, this is x a and b will be three-fourth, three-fourth and height is one-fourth, right and this top one again just opposite diagonal face diagonal, right; so, here this just one-fourth below or three-fourth up.

So, what will be the position one-fourth three-fourth b and then your c along the c axis, three-fourth and this one. So, three-fourth along the a axis one-fourth along the b axis, right, one-fourth along the b axis and three-fourth along the c axis. So, you can locate the coordinate of this 4 additional basis. So, in FCC structure; now if basis are placed in this 4 additional basis are placed in this 4 position structure will be called diamond structure right. So, if this here this is whatever as I told this coordinate; this coordinate will be one-fourth one-fourth like in terms of a, b, c, but since it is cubic crystal

So, it is all a one-fourth of a one-fourth of a. So, this the along the a axis along the b axis and along c axis one-fourth one-fourth this position and this position will be I think at this it will be this position will be three-fourth right along the a axis, three-fourth along the b axis, you have to go three-fourth and then height is one-fourth right height is one-fourth right. So, similarly this one additional one this additional one will have will have this one-fourth one-fourth along the a axis, then I have to go three-fourth because it started from this corner. So, this three-fourth and this height is three-fourth.

So, for both this height is three-fourth; so, both height is three-fourth and position of this coordinate of this one will be; I will go three-fourth.

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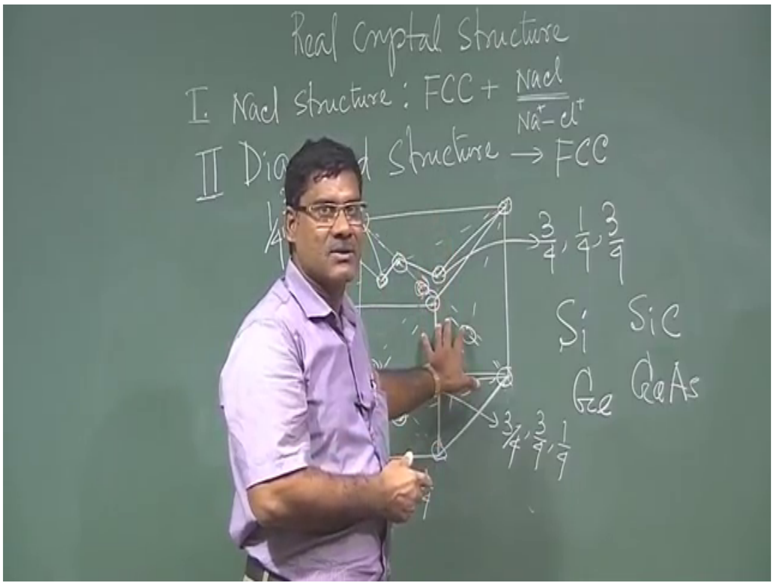

I have to go three-fourth, then I have to go one-fourth along the b axis, along the b axis one-fourth, right one-fourth and then height is three-fourth. So, one can look at fixed the position of the additional 4 basis in FCC lattice, then this is diagonal structure. So, it is the common name; now because not only diamond follows this one this structure other materials follow like silicon germanium, right. So, these are the materials other many materials is follow the of this silicon carbide silicon carbide gallium arsenide gallium arsenide. So, these are material follows the diamond structure. So, since other materials following there are many materials follows this structure distribution of basis like this.

So, that is why these are common structure for other materials we refer this structure. So, that is the basically diamond structure. So, this material have very this structure is we use it very frequently because these are semi conductor material and this whole electronics industry whole electronics industry based on semi conductor you know computer mobile whatever the electronics instruments they are using all things are made from this material.

So, I will discuss more when we will study the semi conducting properties of material. So, we will discuss more about this. So, there are few more structure very interesting structure let me discuss. So, next one; I would like to this third one.

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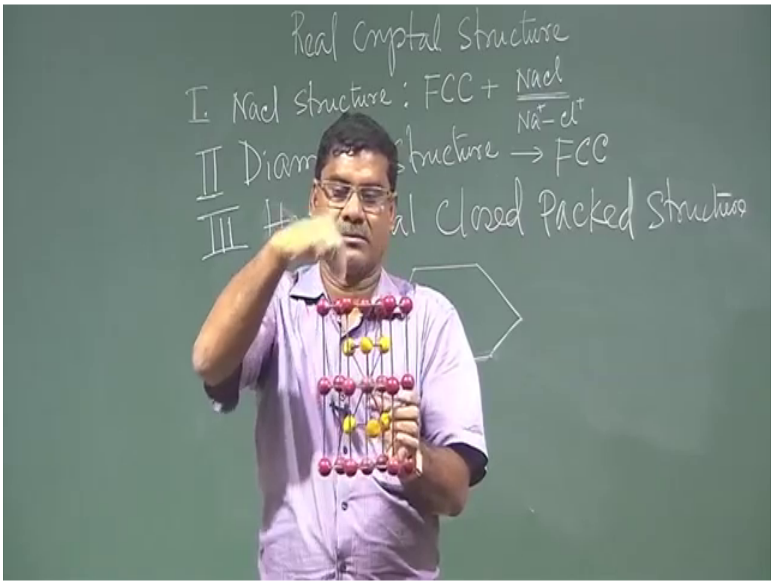

I can see this hexagonal closed packed structure hexagon closed packed structure. So, this also common name many materials follows this structure; so hexagonal. So, hexagonal you know this 6; 6 faces are there 1, 2, 3, 4, 5, 6. So, in hexagonal closed packed structure, I think, I will not draw it will be easy to show you from this picture model.

So, this is the hexagonal closed packed structure you know. So, this is what 2 layers are there basically 2. So, the hexagonal is having is a hexagonal structure is having this hexagon right hexagon, right. So, if you just. So, that will be the hexagon structure right. So, additional I think this also it is this also it is there and additional in between this there is a 3 more there is 3 more are there yellow color, then we will tell it is that is its closed packed hexagonal closed packed if this 3 are not there. So, still it is hexagonal, right, but when these additional atoms are there.

So, then it is hexagonal structure, right. So, hexagon and this if additional 3 atoms is inside is there. So, then it is hexagonal closed packed structure right. So, this is all hexagon closed packed so this that another side; so, this one way one can continue, right. So, here interesting thing is that that each how many then in hexagonal structure how many lattice point per unit cell per unit cell. So, this the basically one unit cell right one unit cell. So, all are lattice point here I have not put any basis its lattice point. So, here this 120 degree, this angle is 120 degree; you know. So, I can accommodate.

So, 3 more hexagon attached with this. So, each corner will have 6 hexagon will have 6 hexagon right each corner this will have attached with 6 hexagon. So, how many hexagons are there; how many points are there on each face: 1 2, 3, 4, 5, 6 at each corner. So, each one is sharing with 6. So, from this 6, I will get one lattice point from this 6, I will get one lattice point. So, 2 and then you see this; this one is sharing with 2 hexagon, right, this one is shared by 2 hexagon, this is one hexagon, this is one hexagon. So, for each cell its contribution is half; so, from here and here; this from top and bottom surface. So, this 2 are there.

So, I will get one; so, one plus this each of how many I am getting; so, from each one sixth. So, from this 6, I will gave; I will get one, right from this 6, I will get one. So, 2 and from this 2 I will get one. So, 3 and then you have 3 more inside it is not sharing with any other unit cell. So, this 3 you know. So, this 3; so, 3 plus 3; so, number of unit cell per unit hexagonal closed packed structure is 6. So, it is really closed packed why reason is that this you have seen this in case of FCC, it is 4 lattice point per unit cell in case of BCC, you have seen 2 for simple cube it is one now for this closed packed it, it is 6 although that way I cannot say, but it has more lattice point per unit cell, but this volume also higher.

So, you if one can calculate, and then one can show this for hexagonal closed pack structure in this packing fraction is again for this case, it is 74 percent. So, this is same as the FCC. So, FCC structure also very closed packed and this hexagonal structure also very closed packed. So, this hexagonal structure this the very common structure for many material. So, this way the atoms are attached. So, I am not drawing this one; I think I could explain from this figure, right.

So, I think just I will mention 2 more structure common structure this is I think third one I can fourth one-fourth one is basically is also very common structure for many material zinc; zinc, zinc sulphide; zinc sulphide or it is called zinc blend structure zinc blend structure zinc blend structure.

So, this structure; this is the same structure as this diamond is having means it is FCC structure. So, in FCC structure whatever we have seen in FCC structure whatever we have seen this in case of diamond.

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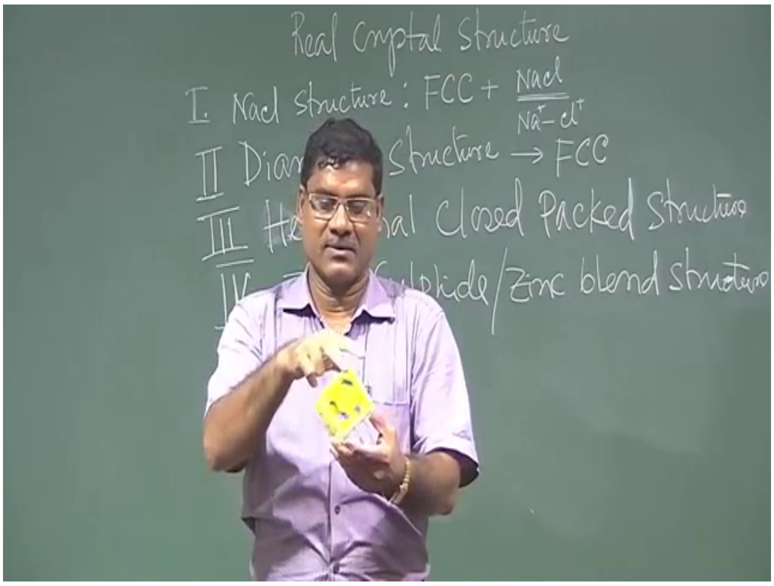

So, FCC yellow position of the yellow ball this FCC position of the ball is FCC right. So, all 8 corner and this all 6 faces are having the right. So, now, if in case of diamond in case of diamond structure; so, inside this 4 additional atom was this of this same material this same carbon or silicon or germanium. So, in case of zinc blend. So, if corner this FCC this lattice point if you put there this zinc and then this sulphide will be this just blue balls additional this 4 atoms. So, it will be that blue balls. So, if it is not same material, it is different material

So, then we can we tell it is a zinc blend structure. So, it is basically structure as diamond is having. So, is just a different name? So, there are different materials which follow this structure.

I can tell this zinc sulphide that is there zinc sulphide and then copper chloride indium antimonide copper chloride indium antimonide indium antimonide. So, cadmium sulfide cadmium sulfide cadmium sulfide; so, these are these are having these zinc sulphide structure or zinc blend structure.

So, they are having these 2 different atoms. So, this just because of that this it is given different name from this diamond structure, but basically is it diamond structure. So, I think these are the most important structure and another is they are these caesium chloride structure, caesium chloride structure this some material follows this structure caesium chloride.

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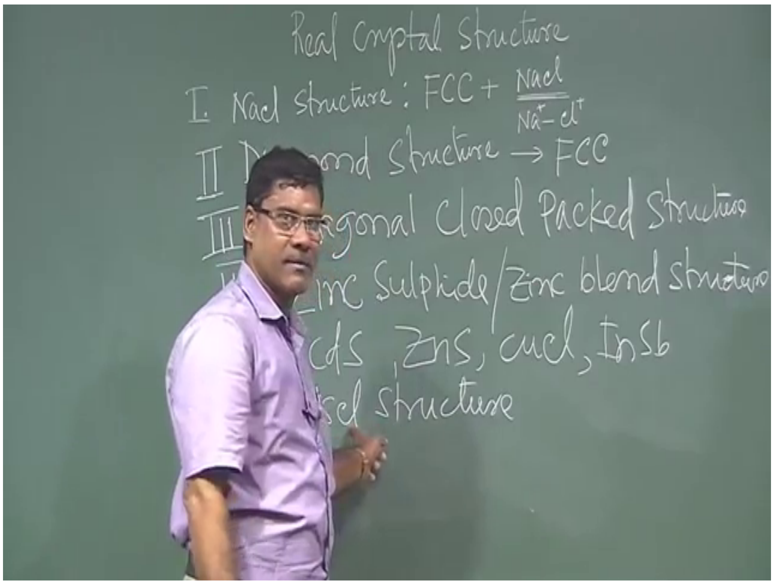

It is basically simple cubic structure simple cubic structure. So, all 8 corner will have the caesium and in middle, it will be the chlorine one in middle, it will be the chlorine one I think I have a; I think this I can tell see caesium chloride structure, right.

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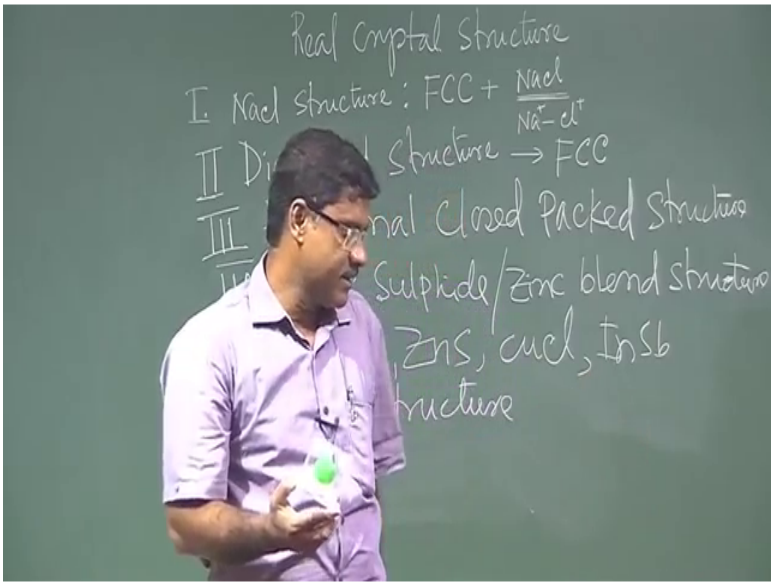

So, this caesium chloride structure I can tell. So, here you can see this 8 corner are having 8 atoms and in middle different atoms. So, if they are caesium middle one is rhodium. So, its lattice point per unit cell is one simple cubic that is why it is simple cubic, but additional that is basis; so caesium 8 corner one and this to form the caesium chloride.

So, basis is caesium chloride. So, that is chlorine is thus at the middle. So, it is not body centered it is not body centered its simple cubic and basis is just one caesium chloride. So, then this structure is called caesium chloride structure and there are many material follows this structure.

So, I think, we will discuss later on when we will discuss properties of different materials. So, these are the very common name of real crystal structure; where the distributions of basis are different although this Bravais lattice is same. So, I will stop here we will continue in next class some this crystal. As I told this crystal bindings or crystal bonds different kinds, so that we will discuss in next class.

Thank you very much.