Solid State Physics

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Lecture - 15
Crystal Structure (Contd.)

So, today we will discuss real crystal system or real crystal structure.

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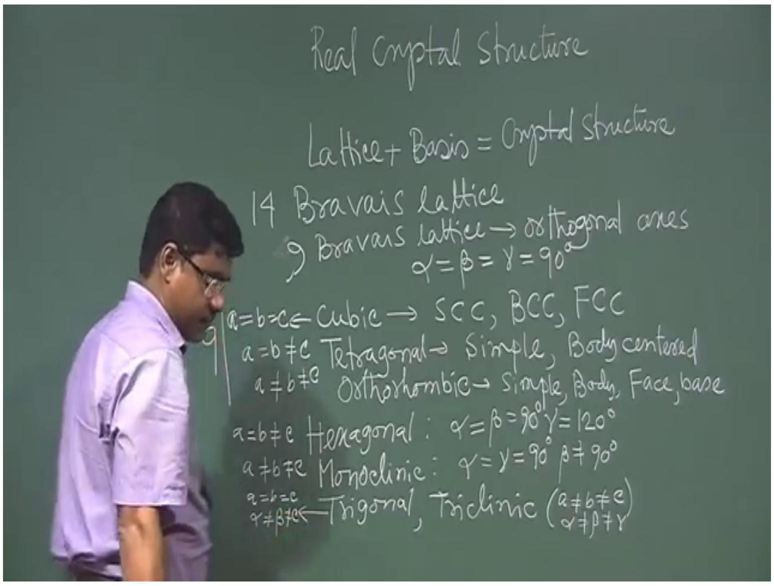

So, as I mentioned earlier that basically lattice plus basis that gives the real crystal structure. So, far we have mainly discuss about the lattice Bravais lattice of. As we have seen this there are 14 Bravais lattice .

So, out of this 14 Bravais lattice, 9 Bravais lattice have orthogonal axes, crystal axes a b c, where alpha equal to beta equal to gamma equal to 90 degree. So, basically this cubic crystal system, cubic crystal, cubic crystal system which has 3, simple cubic body centered cubic and face centered cubic right.

And then we have tetragonal, it has two type; one is simple tetragonal and another is body centered tetragonal. So, simple and body centered right. So, for cubic basically a equal to b equal to c, and for tetragonal a equal to b is not equal to c right. And another orthorhombic axes system, that orthorhombic crystal system having orthogonal axes, orthorhombic crystal system.

So, it has 4 Bravias lattice, let us simple, then body centered, then face centered and base centered. So, this for here, a is not equal to b is not equal to c. So, all angles are 90 degree, but there is a variation of this abc. So, total is basically 3 to 5 5 and 4 9, total 9 out of 14. Total 9 are having the orthogonal axes system, and other of this we have other crystal system, this say hexagonal.

So, in this case basically two angular ninety degree two angular ninety degree alpha beta equal to ninety degree, but gamma is not 90 degree, it is 120 degree right, and we have monoclinic. It has also two angular 90 degree, one angle is not 90 degree. So, this alpha equal to gamma equal to. Sorry, it is not 0, its 90 degree. So, its 90 degree, but beta is not equal to 90 degree.

So, it is not to, when 120 or say it can taken evolve value other than the 90 degree. So, in case of hexagonal; a equal to b is not equal to c right, and in case of monoclinic a is not equal to b is not equal to c . So, then we have two more us trigonal, we have two more this trigonal, this trigonal and trigonal, and triclinic right; trigonal and triclinic. So, in both cases. So, in case of trigonal, it is all angles are different, then I really, and they are a b c also different, but in case of that is what triclinic.

It is for triclinic a is not equal to b is not equal to c, and angle are different, alpha is not equal to beta is not equal to gamma, and for triclinic or it is called rhomboidal also. So, in this case a equal to b equal to c, but this all angular different, when they are not 90 degree. So, these are the. So, from they here 9 and from here one can get basically 5. So, this for this trigonal and triclinic is on the simple type. And in case of hexagonal also, it is only simple type, but monoclinic have simple and base center, this two are there simple and base center.

So, basically this is simple one, this is monoclinic simple and base centered to. So, 3 and this is simple 3 4, and this is simple 5. So, total 5 plus 9 is 14 Bravais lattice. So, just we have discus then and. So, for what we wish to find out. Now the real crystal structure of a material. So, as you have discuss that material will have crystal structures, taking one of the Bravais lattice out of 14. It will have one lattice, one type of lattice, and then adding basis in that material, one can find out the real crystal structure of that material.

So, same Bravais lattice, but adding different basis in that structures. In that lattice we can get real lattice structure of that material. So, let us take some materials, which are familiar to us. So, what are the materials generally we see frequently in our day to day life.

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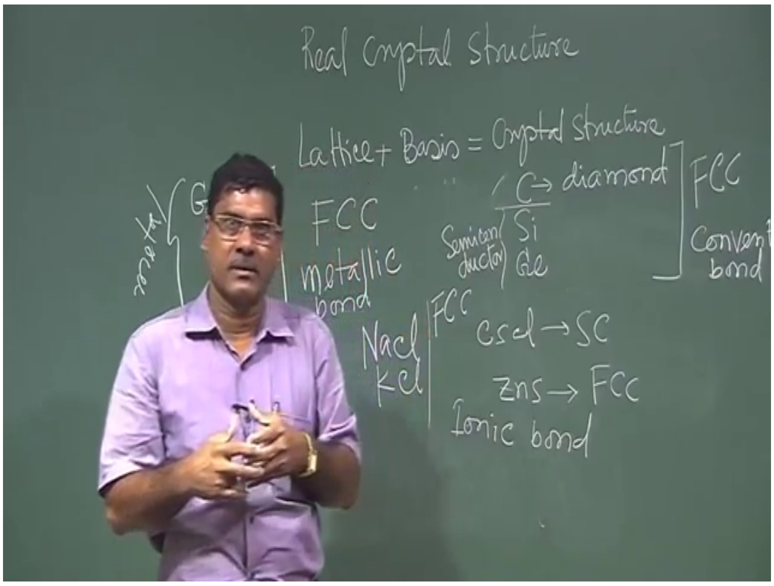

So, that is gold, silver, platinum right. So, this generally people use for ornament, and the other material say copper, aluminium etcetera. So, these are basically metal. These are metal, and all of them are having FCC structure, FCC lattice, Bravais lattice is FCC.

Now, in these FCC if you use just gold atom, then it will be called, we use copper, it will be copper. So, where we will put this atom, so if it is purely F C C, and this atom can be put at the corner of the unit cell, or at each lattice point directly you can put the gold atom. So, that is that will be FCC structure. Similarly if you use copper atom at each lattice point, so it will be copper material.

So, having the FCC structure. So, there are other materials, if I list them, say carbon, silicon, germanium right. So, these are the materials, generally you do not see, except carbon, carbon we will see. So, it has different form you know graphite, diamond different from. So, carbon diamond found. So, again all this material, as I told this is the basically metal and these are basically semi conductor.

So, carbon in diamond form is not semiconductor. So, rather than carbon. So, you can, that is silicon germanium, is basically semi conductor. So, again this all this three materials again, they are having the FCC structure, they are having the FCC structure.

So, it has Bravais lattice this FCC type right. So, but this is the metallic and this is the semiconductor, but they both are having the same FCC structure. So, what are the difference. So, here I told this atoms will seat at the lattice point.

But in this case, it is not the, it is slightly different. So, it is different that basis type is different as these are different atom, but main difference structure wise comes from the basically, how basis are arrange, how basis are arranged in the lattice. So, main structure is FCC. So, that is Bravais lattice that is there. Now that, all though all are having FCC; but for different material, it has different property, it has different property elliptical property, this magnetic property etcetera. So, they are they are different, although their structure are same .

So, this this because of the distribution of the basis in that FCC lattice so that decide the properties of this those material. So, let me tell some more material like sodium chloride, potassium chloride, then your cesium chloride, than zinc sulphate. So, there are here just we have seen this pure made of your atom, but here this combination of atom. So, they are having also, this store having this is again FCC structures.

These are having I think simple cubic, and these are having zinc sulphite, these are having FCC. So, so what we are seeing here that many materials are, most of the metals are having, here whatever I have exited, I having the FCC structure, but they are different material. So, they are different material it is not only for the different basis. It is also very important and it is this, main fact is that the basis, how basis are distributed in that structure in FCC structure, that is the important factor, which decide the properties of the crystal.

So, this structure, this is say this gold, silver this, here silicon, germanium. So, their having the same structure FCC structure, but as I told that BCC are distributed in the, in their structure in different ways, and how they, in same lattice were provide this atoms, these atoms are arrange in different way, their basis are arranged in this material, in these structure in different way. So, that is basically, because of the bonding; that is because of the bonding. So, in this case this metallic bonding is responsible for such type of, crystal metallic bonding metallic bonding, this will metallic bond, and for this type of material they should implied potential fluoride. So, this cesium chloride. So, here basically ionic type of bonding, ionic bonding, ionic bond ok and for this diamond silicon germanium.

So, here this convent bonding, this responsible convent bond is responsible for this type of structure. So, same FCC, but different structure, based on the distribution of the basis. So, that is because of the different bonding among this among in solids. So, I will discuss this different kind of bonding this three are the primary bonding, but there are two more bonding. So, I will discuss about this bonding, crystal bonding another class, but now what I want to continue that what about the structure of real crystal.

So, this FCC structures, and this atoms are just sitting at the lattice point that is fine. Apart from that, there are very famous and convenient structure, generally we call them in different name.

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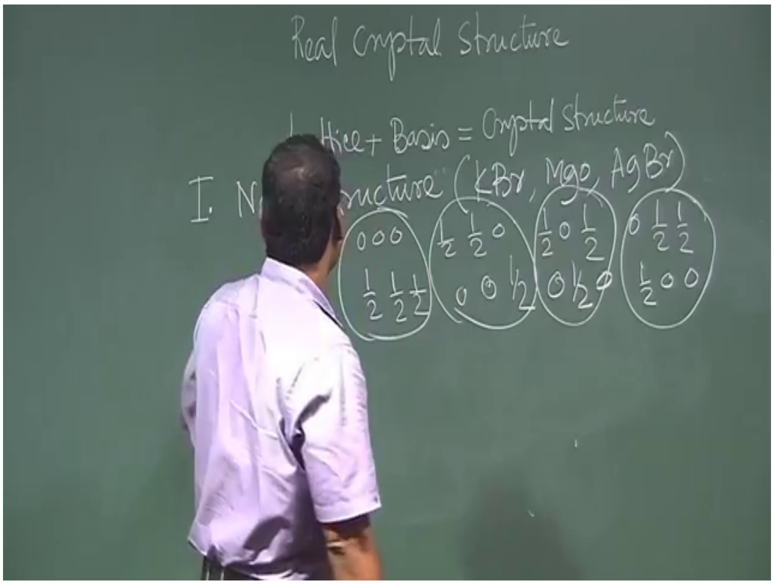

So, that I will discuss. So, one is this called sodium chloride structure. So, this is the special name. It does not mean that it is only for sodium chloride, but in sodium chloride structure, the way the basis are distributed, they are some other materials, they are some other materials, they follow the same structure they follow the same, distribution of the basis. So, the materials which are following the same distribution of the basis of this, as this sodium chloride.

So, the, we call them this sodium chloride structures. So, that material follows the sodium chloride structure. So, basically potassium bromide, potassium bromide, magnesium oxide magnesium oxide, and this silver bromide. So, they are also having the same structure of sodium chloride. So, that is why when we tell this potassium magnesium oxide follows the sodium chloride structure. So, now, this is not for only sodium chloride, but this is now a common structure of some material. So, this is the sodium chloride structure. So, I can write, but I can show in model .

I think. So, this is the sodium chloride structure, here you can see that.

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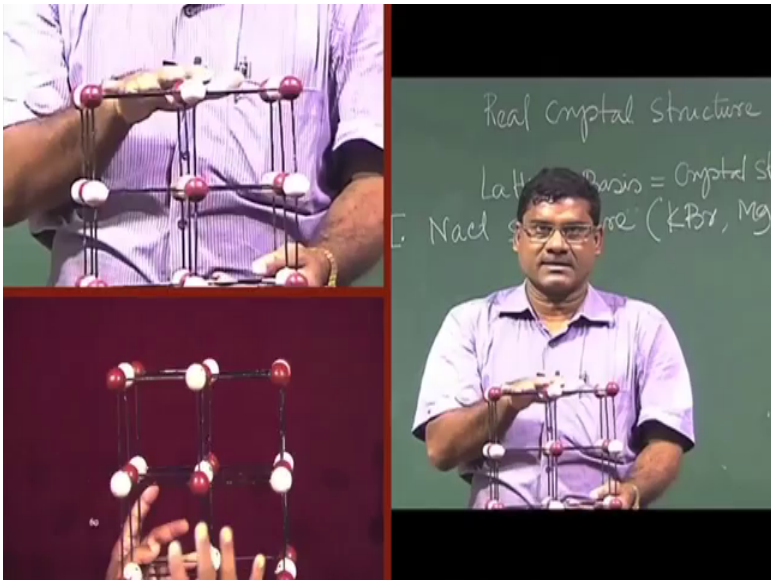

This is the cubic structure FCC structure FCC lattice, as I told that, mention that sodium chloride is having FCC Bravais lattice. So, FCC Bravais lattice means, it is the cubic structure. So, this is the cubic structure, as a whole this is the cubic structure right and. So, how many corners are there; 8 corners are there right, and in each face, 6 faces are there, in each face. So, lattice point will be there. So, whatever brown color we are seeing, that if you just look at the brown color, then that is the I can see this is the FCC lattice right. Now sodium chloride. Now basis sodium chloride right. So, we have to put in this lattice, we have to put sodium as well as chlorine right.

So, how to put them, now, if you just consider that each lattice point, in each lattice point if you put the chlorine. So, brown color chlorine, then we can add sodium, this what about the white color you are seeing, white ball so, that you can take as a sodium position. So, here also we can see that sodium, just it is between two chlorine one sodium, between two chlorine one sodium. So, here this, here basically one can also tell that, this if you just considered the white one, then then you can see that, this also can be treated as a FCC. So, here what you are seeing. Here just brown one if I see, just 5 brown, and then middle 4 brown and then again 5 brown.

So, if you just look at the white one. So, this is here 5 white then 4 white, then again if you consider the next one, say again 5 white will come. So, say as if 2 FCC lattice are interested, are basically what is called inter positioning in this same structures, just shifting one from the other by half, just shifting one from the other by half. So, that way, this is the sodium chloride structure. So, in sodium chloride structure, we have the FCC and at latest point if I considered the chlorine or sodium, anyone we can consider, and then others one; either sodium or chlorine it will be placed following this another FCC. So, as it does just two or placed just shifting by half of the lattice. So, that way, this is the one can realize the sodium chloride structure, and other materials also have the similar structure, in case of potassium bromide, sodium will be replaced by potassium, bromide will be replaced by or chlorine will be replaced by magnesium oxide.

In case of magnesium, magnesium can sit at sodium place, and oxygen can sit at the chlorine place. So, we will get the magnesium. So, basically for all this material, the distribution of basis, is placed in such a way, this for all of them, there they will have the same position. So, one can in peaceful find out the coordinate, basis coordinate where this basis are placed. So, form the structure itself I can tell. So, in FCC lattice how many lattice point per unit cell. Basically 4 lattice point per unit cell right, so from 8 corner. So, contribution it is one eighth right.

So, 1, and from 6 faces are there. So, from each phase this contribution is half right, is shared with two cube, so half. So, from 6 you will get 3 3 plus 1 that is basically 4. So, 4 lattice point per unit cell. So, in principle there should be 4 sodium chloride, because in basis is attached to with each lattice point in same way, so that is the condition for real crystal structure, arbitrarily we cannot put. So, in that case you should have 4 sodium chloride per unit cell. So, in principle there are 4 sodium chloride. So, here if I just I can take this, this is in middle if I take this is the sodium. So, this sodium, I can take this origin.

So, this coordinate of this one will be 0 0 0 right. So, then 4 sodium. So, this another. So, if you consider this. So, I need 4 right. So, choosing the axis here. So, if I go this next sodium I will get half half 0, then I can get this one half 0 half, then I can get this one for that this 0 half half. So, this 4 coordinate for the sodium and. So, you can see here there are 4 chlorine also, attached with this each sodium. So, this coordinate of this one will be half 0 0, this one 0 0 half. This one half half half, and other one will be basically 0 half 0. So, what are the coordinates I got, for this four basis, for sodium ion basically, ionic pistol, chlorine ion. So, as I told this middle one, if I take 0 0 0, and then other 0 0 zero. So, then other one I can see from here half half half 0.

Then from this structure I am seeing as I already describe you half, then I can see half 0 half, then I can see 0 half half 0 half half right. So, corresponding, say here interesting things is that the basis. So, whether I will take basis, whether I will take basis of this one this, or other one. So, actually basis is just the distance between the, this sodium and chlorine as a, basis is just basically half of the body diagonal. So, this will be the for this, this will be the chlorine. For this, this will be the chlorine ok

So, for this, this will be the chlorine, for this, this will be the chlorine. So, if 0 0 0 for this, this sodium. So, chlorine as I told this just half diagonally, its body diagonal is half distance. So, body diagonal it is half distance right. So, what will be the coordinate of this one. So, this coordinate is 1 1 1 right. So, this coordinate is 1 1 1,coordinate is 1 1 1. So, this 2 is basically forming one basis, this two is, one is forming in basis, and then if you take this one. So, this is half 0 half, half 0 half right.

So, basis is. So, corresponding chlorine will be this one. So, this is the again this half of the body diagonal. So, this, what is the coordinate of this one. This 0 0 sorry 0 half zero. So, for half 0 half, I am getting 0 half 0 right. So, where half was there in that case as it is coming 0. So, this basically half 0 half. So, 0 half 0 right. So, just all will follow this way. So, just blindly I can write this way, and you can find out this coordinate the way I showed you. So, these are the 4 basis, sodium chloride basis in that structure, sodium chloride structure.

So, and as you know this we have to address the basis to each lattice point in same way. So, distance between the sodium and chlorine it cannot be different for this different 4 basis right. So, here whatever the distance between the sodium chloride in all cases you can see, this is the, it is the distance of the basis is just half of the body diagonal of this cubic. So, this is the sodium chloride structure. So, we will discuss some other structure in next class, interesting structure. So, I will stop here.

Thank you.