Solid State Physics
Prof. Amal Kumar Das
Department of Physics
Indian Institute of Technology, Kharagpur

Lecture - 14
Crystal Structure (Contd.)

So, you are discussing about the crystal symmetry. So, just I took the example of cubic crystal, and for that I was explaining what are the symmetry elements, and that element, I was showing in case of cubic crystal. So, what the time in, forget the translational symmetry. Let us concentrate on the other three symmetry rotational symmetry or symmetry of rotation.

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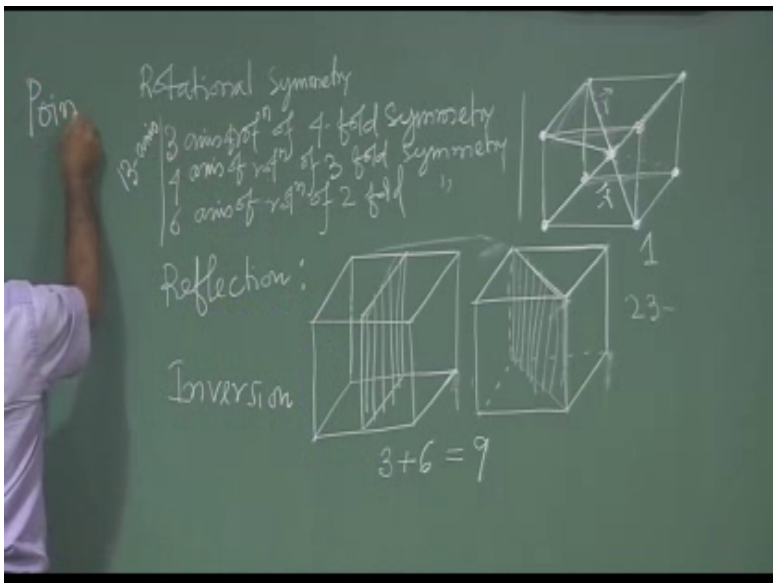

So, we found that different axis of rotation, there are many axis of rotation with respect to that axis, those axis. If you rotate the crystal, you will have the symmetry, but there are differences in, how many fold of symmetry for different axis. So, we have seen this, basically three axis of rotation, of four fold symmetry. So, this three axis passing through the centre of the face, this axis passing through the centre of the face, and they then, we have seen these 4 axis of rotation of three fold symmetry.

So, this is the body diagonal, these are the body diagonal right, and 6 axis of rotation, of two fold symmetry so that passing through the middle of the edge of the cube. So,

opposite edge passing through the, opposite edge, through the middle of this edge. So, 6 axis of this type, one can get from the cube that I have shown you.

So, total 13 rotational axis, having different fold of symmetry one can get for cubic system, cubic crystal noise and for reflection, I have reflection symmetry with respect to reflection from a middle plane of lattice points, if you get the exact, whatever the image, reflected image you will get, which exactly with coincide the other half of the crystal.

So, then we will tell that the crystal have reflection symmetry with respect to that plane. So, plane I have shown that if in case of reflection, probably once more I can just draw with respect to reflection. So, this one can choose the plane in the middle of the cube. So, this is the plane if I. So, you can have the image of this half, exactly it is, this other half.

So, it has the crystal, this cube crystal has same to with respect to this plane in the reflection plane mirror plane. So, this type of plane you can get 3 right. So, opposite face, to opposite face giving one plane other opposite to face, and this other two face. So, total 6 faces. So, three reflection plane one can get. Similarly, plane through the body, diagonal planes through the body diagonal. So, plane through the body diagonal, this is the plane through the body diagonal.

So, this is the plane. So, in this plane, this half will be. So, other half is just inject reflection of this half, with respect to this plane. So, other half, just if top face, if you consider, then exactly you can. So, it is this plane and. So, you will get this, and this point is self will be here; this point is self will be here. So, just connect them. So, that is the reflection symmetry of this cubic, is symmetry respect to respect, and as I told that, this type of planes from each opposite face you can get 2. So, this is 1 and another 2.

So, you will get 6 from each set of opposite face two. So, you will get 6 6 symmetry plane. So, total you will get 9 reflection symmetry in cube crystal. So, 9 symmetry planes in cube crystal. So, total. So, this all this rotational and this reflection this two together is giving basically 22 symmetry element, 22 symmetry element for cube crystal.

Here, I have just taking cube crystal. So, that is why this is the number for any other crystal; one has to find out and one can show that the net number of crystal symmetry element will be very lower than the cube, one cube has the maximum symmetry hexagonal have also maximum symmetry. So, then inversion, what is inversion, what is

inversion symmetry. Inversion symmetry basically, if you have a, let me draw here a cube, in case cube let us find out in case of a cube. So, in this cube. So, one has to find out a point with respect to that point, if you just with respect to that point, I think I have to, with respect to that point.

Yet just let me check I will take this way. So, this opposite corner, this one like it is or has to find out the symmetric point is this, and then if I take this and opposite is this one, basically, body diagonal body diagonal. So, and this will be opposite to this. No, this will be opposite to this. Oh sorry. So, this will be opposite to that is that corner of yes.

So, this will be opposite to this and this will be opposite to this yes. So, here what I have done, let me tell you I think I have yeah. So, is. So, this is a point, if I choose at the body center. Now, you have lattice point, if you just take a vector joining this lattice point, this lattice point with this point if this vector is r. So, in this crystal, if there is a lattice point, exactly at minus r.

Then we will tell this crystal have inversion symmetry with respect to this point. So, it is not only this point, only this two point, it has to generate from other point also, with respect to this one. So, that is why I have drawn this. So, this with respect to this is the, if this is the r, this is the r. So, exactly there is another point at minus r. So, for all point you can all 4 points. So, this point has familiar this. Similarly, this point you can show. So, exactly.

So, inverse symmetry is telling basically, if it tell just this crystal have inversion symmetry with respect to the body center. So, immediately if I take a point lattice point at this here. So, there must be another lattice point at this point here. So, that is tell you symmetry is telling, but here this, since cubic crystal we have been known, where the lattice points are there. So, it is easy, now easily we can see that yes when this point exist in cubic crystal this other went will must exist.

So, that is the so, already. So, this. So, this cubic crystal. So, this is the all, this is called inversion symmetry and this cubic crystal have only one point, one point of symmetry. So, if I add this one with this 9 plus 13. So, total 23 symmetry element for, and this all three, whatever I am discussing rotational reflection and inversion symmetry, this is with respect to point, this is with respect to plane, and this is with respect to line.

For all cases you can see this crystal is itself in space it is at a at own place, it is not going to the other place . So, it is in one place just rotating or I am generating, just seeing this symmetry with respect to inversion or. So, I am not. So, it is not covering the space. So, this three together, this three rotational reflection and inversion this symmetry together, and their combination they are called basically, point group symmetry of that crystal .

So, for crystal system. So, total this point group symmetry, total number of point group symmetry is basically, is 32; one can show that there are only 32 point group symmetry, and all crystals, what about the structure, either you or hexagonal or tetragonal, all crystals will show only these 32 types of group symmetry point, group symmetry and another symmetry is called space group symmetry, another symmetry is called space group symmetry .

So, with this symmetry, with this symmetry point group symmetry. So, if you add basically, translation symmetry, translation symmetry with point group symmetry

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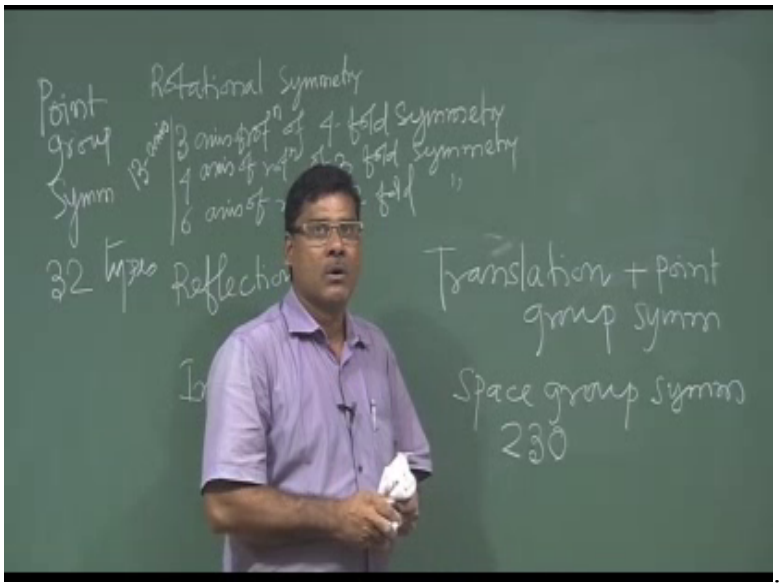

So, these will give symmetry in space. So, thats called basically space group symmetry. So, translation symmetry is with the point group symmetry.

So, point group symmetry. So, as I told this 32 types or 32 number with translation symmetry. So, if you combined, take combination of them, different combination of

them. So, one can show that, one can see that there are 230 space group symmetry is space group symmetry.

So, all crystals have maximum this number of, not this one crystal will have this. So, all crystals, whatever the space group symmetry will follows. So, it will be, it will be a out of this 230. We do not need more than 230 space group symmetry to find out the symmetry of all crystal system right, and basically, this Bravais lattice, it follows this, it shows this 230 types of space group symmetry.

So, this is the about the symmetry of crystal, and these the elementary preliminary concept of symmetry, and, but this is a very worst subject. So, in this. So, for undergraduate course is, we do not have scope to explain more about this crystal symmetry. So, that one we learn in higher class. So, I think whatever this, I have told you, so that is enough for undergraduate course. So, this next I would like to discuss about the unit cell. Already you know what is unit cell. So, this is the smallest, this is the, there is the pattern unit, that the unit repetition of which one can from the crystal.

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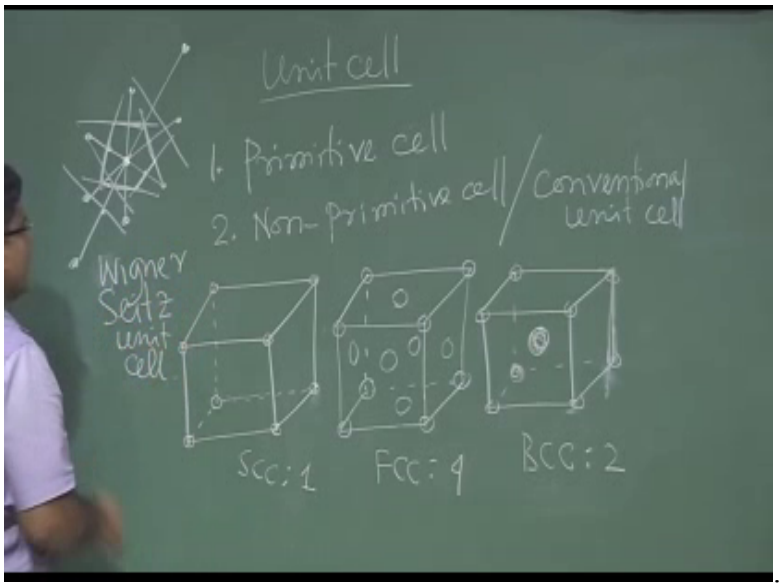

So, basically two types of unit cell that I have not discussed. So, unit cell. So, basically 2 types of unit cell; one is primitive unit cell, and another is non-primitive cell, non-primitive cell one is, another is primitive cell. So, very frequently we use this term in solid state physics. So, primitive cell and it is sometimes, it is called conventional unit cell, conventional unit cell.

So, primitive. So, let me take example of simple cube. So, it has three type of unit cell. So, it has this say this has simple cubic crystal. So; that means, it has 8 corner and in each corner, there is a lattice point. So, here we have, I am showing that this number of lattice point per unit cell is 1.

So, how it is that I explain. So, I have one, this one you see this cube 8 corners. So, each corner has the lattice point. Now, you can see here; that is it is 1 8 portion of the lattice point for this cube. So, that is why from each corner, because this is one. So, next, from next half it will come one eighth. So, other side it will come one eighth. So, this 4 will give half, and this on top, it will give again half. So, it will be, it will move on. So, this is the just one unit cell for cube. So, here one can say.

In case of say F C C, I think on this plane one, and in this plane, in this plane one. So, we will have this, you will have I think you know this one. So, this type of. So, this type of. So, on each face right. So, it will share with the two. So, half per, from face half per cube per unit cell. So, you have 6 faces. So, 3 and 8 corner. So, again 1. So, total is 4 unit cell for this, total is four lattice point for unit cell this for F C C.

And similarly, for b c c you have a middle, apart from this 8 corner for, from this 8 corner unless it. So, lets the, this type of, I think this in middle one. So, this one and this from 8 corner one eighth. So, this in case of 2, in this case, it is 2. So, it is 1, this 4, lattice point per unit cell, and this is 2 lattice point for unit cell. So, this is the. So, what is primitive cell, and what is non primitive cell. So, this primitive cell is defined as the smallest volume of a, of smallest volume of unit cell, which will have one lattice point per unit cell.

Then it is called the primitive cell, if unit cell contains more than one unit cell one lattice point per unit, that unit cell. So, then it will be called non primitive unit cell. So, primitive unit cell, find non primitive unit cell is called conventional unit cell, and non primitive unit cell conventional unit cell, generally used very frequently, reason is that, it is not that it is FCC, it is not that one cannot find out the primitive cell from this case, one can construct the primitive cell from FCC from b c c. So, we do not need to use this unit cell FCC unit cell or b c c unit cell. Only one can use the primitive cell also one can find out for any crystal, one can find out the primitive cell.

But we prefer this Bravais lattice prefer this Bravais lattice, because of symmetry if you for this lattice if you find out the primitive cell this primitive cell will have different angle axis and lattice constant quite different from these cubic cell. So, you will lose symmetry of the crystal lose symmetry of the crystal and that is why it is very important to choose the unit cell even if it is conventional unit cell, but that is preferable for having higher symmetry. So, that is why with it is.

So, choosing the conventional unit cell non primitive cell it is related with the symmetry crystal symmetry when there some unit cell will have more symmetry that will be more convenient to study the crystal structure the property of the of the solids. So, that is why because of symmetry one use conventional unit cell. So, so if you have any one can construct there is a method one can construct unit cell primitive unit cell from any lattice. So, what one has to do taking one lattice. So, just connect other just connect other whatever the lattice points are there just cannot connect them just connect them.

So, in the lattice in three dimensional lattices, whatever the lattice point surrounding of this point are there. So, this is just connect. Now, just take the normal bisect of each line normal bisect of each line. So, one can see this I think is this no this I think this. So, this bisect basically, this covered a volume covered a volume in three dimensional volume covered a volume and which will be the smallest volume and we will have a only one lattice point for the unit cell that unit cell this is the one lattice point and then this unit cell is basically primitive unit cell and it has special (Refer Time: 32:19) with who discovered this process.

So, Wigner Seitz unit cell primitive unit cell. So, this way one can construct the primitive unit cell whatever the lattice factor. So, this about the unit cell of whether it is primitive type or non-primitive type; so, non- primitive type is called conventional unit cell which basically used because of symmetry. So, in case of cube this s c c simple cube is non is primitive cell whereas, the FCC and BCC are conventional unit cell, but this these are preferable, because of symmetry, but from this lattice one can construct the primitive unit cell on that is the that is the primitive unit cell, but it has less symmetry. So, that is why if we do not prefer this non primitive cell for this rather you prefer this conventional cell FCC and BCC. So, I will stop here.

Thank you very much for your kind attention.