**Solid State Physics**
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**Lecture – 21**
**X-ray Diffraction from Crystal (Contd.)**

So, we are discussing about the experimental arrangement in last class. There are basically 3 established methods, experimental method to study the crystal structure using x-ray diffraction. So, this for each method this is the, Bragg law is used. Based on this Bragg law, these experimental arrangements are done and I have described just mention the condition for each method. Now, I will describe in details.

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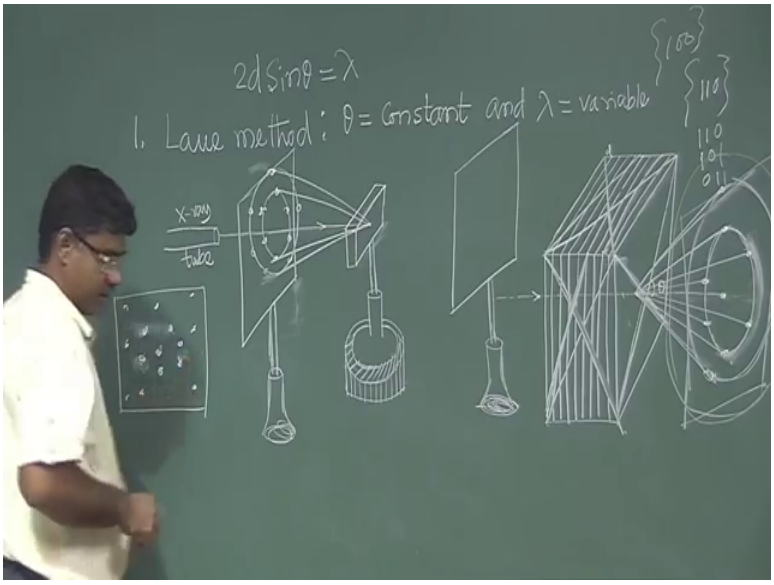


So, basically first one I was discussing that is Laue method; so, that is Laue method. In this Laue method, theta is constant and lambda is variable; d is there, so, you want to determine basically d. For each d and theta is constant, lambda is variable; means, suitable lambda will be selected to satisfy these Bragg condition. We need experimental arrangement for this configuration. Let me just sketch this experimental configuration. So, if I let me try, I think; yeah, so, this is a small piece of a single crystal, I have shown you this silicon single crystal. So, this small piece of this single crystal is just I have drawn here. It is put on a head of a goniometer. Goniometer means you can change the angle so it is called goniometer.

So, if I just, let me, this just I have a scaling on that; so, just here, scaling are there of angle, so, one can just rotate the crystal to fix at a particular position. Since, in this case this theta is constant, so here, incident x-ray are falling, so x-ray are coming. From x-ray source, x-ray are coming; say this is a x-ray tube, x-ray is coming, falling on that crystal and then it will be diffracted in all directions. So, that is why, satisfying this condition it will diffracted in all directions and then to, it is a diffracted, will get intensity for each direction of diffraction.

So, we have to now detect that position of those peak or what I should tell, high intensity. For that, different way people detect. Earlier days generally this x-ray film were used; I do not know whether you have seen or not this, but earlier days we used to for camera, for optical camera we used to use these this film, for photography film. So, similarly for x-ray also these films are there. But, nowadays now it is digital screen are available, so on screen one can detect the intensity, but we will discuss in terms of film which was earlier used to detect the intensity on a space. So, x-ray is from x-ray tube; x-ray are coming and falling on this sample.

So, this sample position we can fix, we can rotate and keep a particular position, then angle with this crystal surface that will be in same; so, that means, theta will remain constant. Whatever the planes are there, if I do not rotate the crystal, these planes are also fixed. Angle with different planes will be different, but they are fixed. So, we are not changing the angle between the planes and the incident x-ray. So, that is the geometry for fixing the theta constant, for fixing the theta at a particular value.

Now, to detect this intensity, this photographic plate is used. So, this photographic plate, just if I put like this, this is the photography one plate. So, this plate is hold with some arrangement this so, hold on a stand. Similarly, one more photographic plate is used, say it is put here. It is hold on a holder, this basically base. 2 photographic plate is put; one is in forward direction and another is backward direction. So, basically this one is called photography plate in forward direction and here whatever spot, we will see that is basically due to forward reflection and on the other hand, this side, we will see also the intensity variation or diffraction this side also. So, that is called back reflection.

So, that crystal basically x-ray when falls, it will diffract in all direction. If you put this plate in any position, you will see the intensity variation; you will see the high intensity in different place that is because of the diffraction in all directions. But, in these 2 position we are putting the film and that is this arrangement, is done this way and that is why it is a one method. If I put this photographic plate in other place, that may be different method. So, this is not Laue method. In Laue method, this way; this is the configuration of the experimental set up. Now, in this configuration what is happening that we will see, we will get some diffraction peak recorded by this photographic plate, x-ray plate and from that different intensity of Bragg diffraction one can find out the structure of the crystal. So, that is the aim.

Now, think that, here x-ray is falling; now this is a single crystal, it has many crystal planes. So, one plane, it is a set of parallel planes having a particular lattice constant that is known, that we know. Now, that plane, apart from that plane, there are many other planes in different orientation. In this crystal there are many sets of plane, in different direction, they have different orientation. So, that is what we have seen.

So, what will happen; let me draw a crystal. I have to draw in proper fashion. I think I have to draw more sharply, what I want to show I think I have to draw this way. So, this is the crystal, if I just draw in bigger way. So, this basically this one I have drawn in magnified way. We have this x-ray falls on this crystal, I think this is the middle point may be, this is the direction. Now, what will happen? This angle, there is a set of parallel planes, if I just consider one set of parallel planes; if I consider this is a, this all are equi-spaced parallel plane, drawing is not proper, but one can understand. So, this a set of parallel planes, now x-ray is falling, it will make a angle with this set of parallel planes. So, that angle is theta. It will make angle; angle is theta. Now if this rays, central one, if it is perpendicular to this set of planes and looks it is perpendicular on this sets of parallel planes. So, what will happen? This incident angle is 90 degree, grazing incident, this is grazing incidence, it is along the normal of this planes.

So, it has a particular d spacing; d is here, for that d, this angle is fixed because I am not rotating the crystal. It is a fixed position so it will make angle with this set of parallel planes, that is theta and that is constant. Now, this incident angle is 90 degree; grazing incidence angle is 90 degree; so it is along the normal. So, what will happen, it will just go, also it can back scattered. So, on this photography plate what we will see? There is a diffraction peak in this direction and that is, high intensity along this direction and it will be on this photography plate.

So, there we will see this one spot; say it is a white spot or black spot whatever depend on the photographic plate and this will give one spot here. Now, this is one set of parallel planes I have considered, but there are many sets of parallel planes. Let me consider another set of parallel planes. Let us see this plane. So, this plane, it can be the, which plane, 1 1 0 plane, if these are the 1 0 0 plane or 0 1 0 plane or 0 0 1 plane, these will be the 1 1 0 plane; that is there. So, this plane will. So, there is a many parallel planes 1 0 0 plane means there is a set of parallel planes; now these set of parallel planes will form a angle with this incident x-ray.

So, let us tell that this angle is theta; grazing incidence angle with this plane is theta. Angle is theta, then that means, the reflection will be also at angle theta. There will be from here, there will be from this sets of plane, since it is angle with this sets of plane is angle theta. So, reflected one also will be angle theta, either it can be this side or other side, depend on the inclination of this plane. So, let us tell that, this will be one diffraction direction, see reflected light one diffraction direction.

So, this now if I consider 1 0 0 plane, not 1 0 0 plane, that is 1 1 0 plane; so, this also another plane 1 0 1 plane, whatever this is family. As I mentioned if you write 1 1 0 plane, it represents 1 1 0 plane, it represents 1 0 1 plane, it represent 0 1 1, 1 bar 1 0 etcetera, these are planes from a family and they are this all planes are basically equivalent, their orientation are different. There is symmetry and number density, on this plane; lattice point densities on these planes are same.

So, here not only these 2 planes, how many this type of planes we will get? We will get this planes also 1 0 0 plane, 1 1 0 plane all of this family; these also, so, these also. So, same plane, here you will get basically in different orientation equivalent plane they are in 6 orientations basically. You will get in 6 orientation and angle that theta, here is angle is theta, if you are getting this from this plane from other plane with the same angle, it will from the same angle. This theta is there; that theta, same theta will be what will happen? So, from these 2 I can see one you will get this and another you will get this with the same angle theta and this one this plane and this plane, if you see this inclination is this, here this is the x-ray, with this it will have some angle and normally is this direction you know of this plane.

So it will follow basically this, or the; it will form a cone with this angle. All this 6 planes, it will be diffracted with this angle theta and it will be all this diffracted plane will be on the, so all diffracted are other, same way you will get, yeah, I am trying to draw 6; so, 6 plane for you will get 6 spot. You will get basically, if I draw this say, you will get 6 spot. So, it will form a cone basically with angle theta, whatever the angle it will make with this one of the plane, with this. So, this is the axis of this cone, the direction of the incident x-ray and taking this one as a axis of this cone it, with angle theta or 2 theta it depends, so it will form a cone.

On the surface of the cone basically, this diffracted rays will be there and if you put here your photographic plate, x-ray plate, on this you will get this type of. So, from another sets of planes, with different angle say with this angle, it can be; one can draw say this is another sets of plane if you consider, where this angle will be different definitely. So, for those planes if they have symmetry like these planes 1 1 0 plane, I have shown if that type of symmetry is there, all of them will have a on another cone. So, for all planes you will get cones; concentric cone and each cone basically will have these are called Laue spot; wherever the maximum intensity, that is called Laue spot. So, we will get Laue spot and this Laue spot here on this, it is convenient for me to tell about this symmetry 1 1 0 plane.

So, you will have these 6 points on this. Similarly for other planes, if depending on their symmetry you will get the number of points on this. So, this is why you will get basically many concentric cones and family of these planes will be on same cones, but for different family. So, like 1 0 0; this is one family of planes, this is a another family of planes etcetera, you will get this. And back scattered one if you think, this other side, you will get basically this opposite side also you will get same cone. So, on that you will get spot.

So, in Laue method on the x-ray plate, what you will get? We will get, this is the x-ray plate, we will get point. Here, this 6 point you will get I think it will be yeah. So, 6 points you will get what as I showed you this, it will show this symmetry and this symmetry is basically, whatever in spot you will get symmetry and this symmetry will basically telling about the symmetry of the crystal 1 1 0 plane.

Similarly, for other planes you will get. So, this way you will get spot that is called Laue spot and this Laue spot whatever you are getting, from there you can determine the crystal structure. But this method is mainly used for to find out the symmetry of the crystal and looking at the pattern one can basically find out the symmetry of the crystal. It is not drawn properly right thing is. So, this way one can find out you know. This way one can find out the symmetry.

So, to study, to know the symmetry of the crystals, one use this method and find out what are the symmetry of this crystal; even what are the surface. You see whatever the, because if we cut a crystal and you can cut the crystal such a way that its surface is parallel to a crystal plane. It can be 1 0 0 planes or it can be 1 1 1 plane; so, if you have a crystal and what is the surface plane, that to find out that, one also use this method.

So, these are the experimental arrangement and the purpose of this experiment. So, more details I cannot tell here in this course, because there are many things to analyze really one has to have knowledge and from experience it comes, but these are the basic things of this method. So, in next class we will discuss the other method. So, I will stop here.

Thank you. Thank you for your attention.