Solid State Physics
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Lecture - 22
X-ray Diffraction from Crystal (Contd.)

So, we are discussing about the experimental method to determine the crystal structure.

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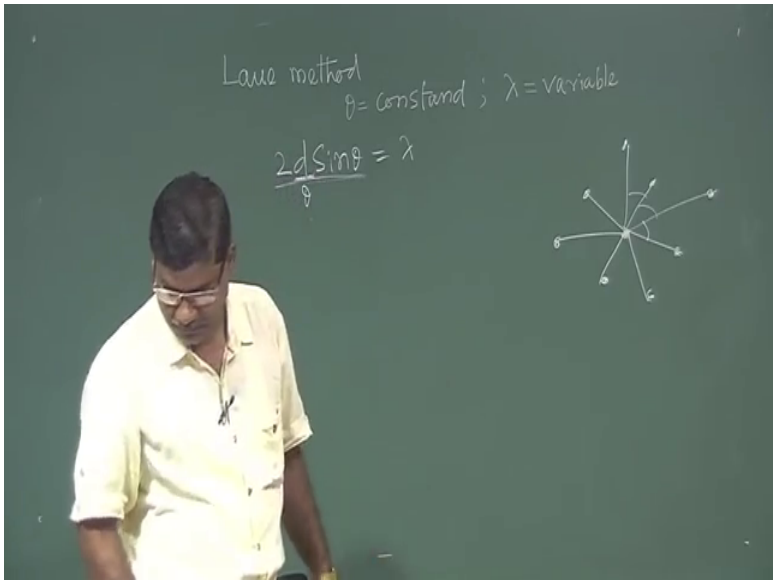

So, in last class, I have discussed about the Laue method. In this method, theta is constant and lambda is variable and we have seen that from crystal for a particular angle. So, diffracted rays are on a cone. For different plane, angle will be different and for each particular plane it will form cone. So, those are concentric cone and if I place the screen or x-ray plate, these points, diffracted points, will be on that x-ray plate, they will form spot on that plate. This spot, basically on a cone for a particular plane and it is not for a particular plane, its each point is for a particular plane. Now, that each point on a cone that is basically this different orientation of the planes.

So, each plane presents the, basically represents the planes of real crystal. So, Laue spot on a x-ray plate or on a screen, they are arranged orderly, basically following the crystal symmetry and each point is plane. So, in real crystal order of planes are there; they are oriented in different directions. That can be represented with points on a plane. These have some advantage, some particular advantage that we will discuss later on.

So, what we are seeing here, what we can know from this method Laue method and from this method we are basically getting Laue spot on photography or x-ray plate. So, what we will get? What information we will get from this experiment? I think I will just explain.

So, say this is a crystal and the x-ray is falling on. These are crystal surface; it is one of the plane, crystal plane. Now, x-ray is falling on it; it is falling perpendicularly on this surface, on this plane. Now, obviously, the reflected ray is backward and or it is forward direction. So, if I put x-ray plate here, I will get at the center say along the direction of the incident x-ray, I will get a spot on that photographic plate, I will get a spot on photographic plate.

Now, here condition is x-ray is falling; basically I think I should, x-ray is falling on this crystal; crystals don't have only this one plane, it has many plane. So, just it has many plane, this is one plane, this is another plane. If it is 1 0 0, so, that will be 0 1 0. So, this can be another plane; this is 1 1 0 plane. There are many planes. These planes are oriented in different direction. Planes can be oriented this way, this way, in different direction, in different orientation along this, in different orientation along this, different orientation along this. So, in all sorts of orientation of this crystal planes are there.

Now x-ray is falling on this, so, this is perpendicular to this surface. Now, this x-ray, that incident angle of this x-ray with different planes are different. But, it is for a particular plane it is constant, because we are not rotating the crystal. Crystal is fixed, this x-ray also direction is fixed, now with respect to this plane, other planes in this crystals have different angle, different orientation. So, with this x-ray direction, also this all planes are have particular angle. This angle, basically here, whatever with different planes, this angles are not varying, so they are same all the time in this geometry and we are not rotating the crystals. So, theta is constant, is same for all the time. It is same for this, for different planes.

So, in this condition, what happens from Bragg law? 2 d sin theta equal to lambda. For different d, theta are fixed; for particular d, theta is constant. This part for a particular plane, this part is constant. Now all sorts of lambda are there so, it is picking up that suitable lambda to satisfy this condition and then in that, along that direction we are getting the diffraction. So, we will get the diffraction spot.

Now, you see this, if this as I told this 1 1 0 planes. So, for this 1 1 0 planes whatever the lambda there, x-ray are falling and it has some angle. To satisfy this condition, with their suitable lambda, it will be diffracted, we will get reflection. We will get one spot here.

Now, another planes are there, just this way you can think, this same plane, 1 1 0 plane, its family. For this plane, here this lambda is also constant, but different value, may be different value, for that suitable lambda will be taken and. So, this whatever here the orientation of the planes, following that orientation, we will get reflection. Here, this Laue spot, whatever we are getting, that exactly because here with respect to this planes or with respect to this incident x-ray, orientation of all planes are fixed and we are getting Laue spot, diffraction spot, for each plane. Orientation, whatever this here Laue spot we are getting, that will basically just, it will show the basically orientation of different plane in the crystal.

So, this Laue spot presents basically the orientation of the planes in the crystal. This here whatever in which place you will get the spot, so these are the, these basically exactly the orientation of those planes. From Laue method, whatever this Laue spot we are getting see, that spot together will show some symmetry. So, from that symmetry one can tell what is the crystal structure of the material, of the sample, we have taken.

So, basically here mainly this method is useful for knowing the symmetry of the crystal.

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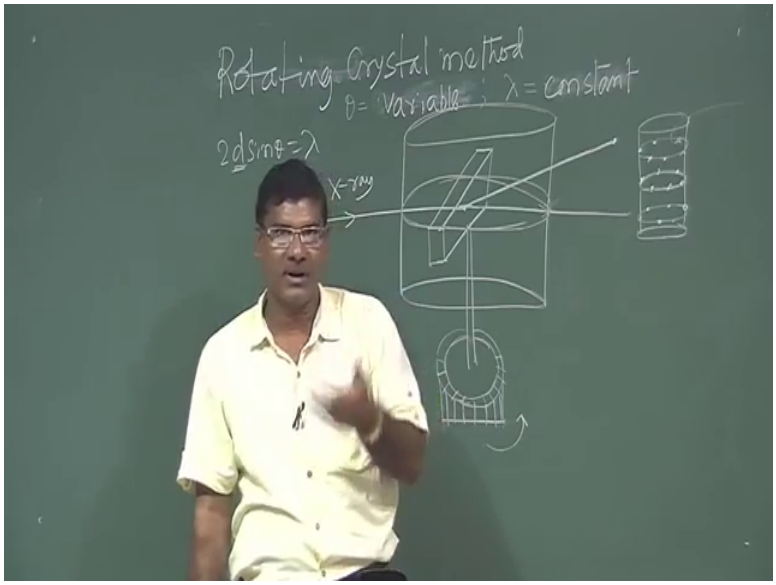

Next method is, rotating crystal method. So, everything based on this 2 d sin theta equal to lambda, Bragg law; but, the diffraction pattern we get, that depends on this method and method depends on the experimental geometry. In this case, in this method, theta is basically variable and lambda is constant, means monochromatic x-ray will be used.

So, what is the geometry? For this, I will not draw; I will explain using this just notebook. Here, this you have sample, let me, that sample is fixed on goniometer. It can rotate. It is not manually just rotating, but it is used just better we can tell is rotator; by some means it is rotating with some speed. This crystal, it is rotating with some speed it is rotating. So, all the time it is rotating. What does it mean? Now, this x-ray is falling on it; what is happening? This x-ray again it is making angle with the different planes. If you consider just one plane whatever the angle it is made, crystal is rotating, now angle is changing. Continuously this angle, whatever initially it is made with a crystal plane, now it is changing.

So, this theta is varying that's this. For all planes, theta is varying continuously. So, what will happen? Now, this it will be diffracted following this 2 d sin theta equal to lambda. With a particular planes having lattice spacing d, lambda is constant, for this plane. So, now, it will be reflected or diffracted this ray from this plane will be reflected at a particular angle; it is rotating so, angle is changing at a particular angle when it will satisfy this condition. So, we will get basically, one is like this, so this direct one and if angle is theta, it will be reflected with this. Angle between this 2 will be 2 theta, because if from this crystal surface this angle is theta, so angle between the incident and reflected one it will be 2 theta.

So, in this method; now imagine, for a particular plane, incident x-ray, it will be reflected depending on the angle. If it is say this is the crystal plate, if this is the angle and then it will be reflected in this direction or if it is incident, it will be reflected in this direction. Now, this plane is rotating, so this angle is changed. This angle is, incident angle is changed, but you will not get reflection for all this angle because it has to satisfy this condition.

So, if you see this diffraction spot, now, what will be the pattern of the diffraction spot that will depend on how you are placing the photographic plate or x-ray plate. In this case, that is important how you are fixing the photographic plate. So, that is very

important because depending on that what will be the shape of this diffracted pattern that we will see in this case. Here, in this method, this plate x-ray plate is placed cylindrically. So, basically it is; keeping this at the axis of a cylinder, photographic plate is placed in cylindrical form; this is our sample is at the center. So, now, imagine that this crystals are having some planes, which is parallel to a common line, so, that means, in case of 1 1 0 plane, this is the direction; 1 0 0 plane, this will be the direction; 0 1 0 plane, it will be that direction.

So, there are some planes, immediately I can see 1 1 0, 0 1 0, 1 0 0, not 0 0 1. These planes are parallel to a common line; say if this is the line, all this planes are parallel to this line. So, perpendicular to these planes, to all this planes, it will be perpendicular to this line also to this axis we can tell this axis, because all planes are parallel to this, normal to this parallel planes this all this planes, will be normal to this axis also. So if it is the axis and all planes are parallel to this axis, then normal to all this planes will be on a horizontal plane. Normal to this horizontal plane, it will be in different direction, but it will be on a horizontal plane.

So, this is called basically zone; this called zone of planes and this axis is called zone axis. I have one figure, I will show you, it is like this.

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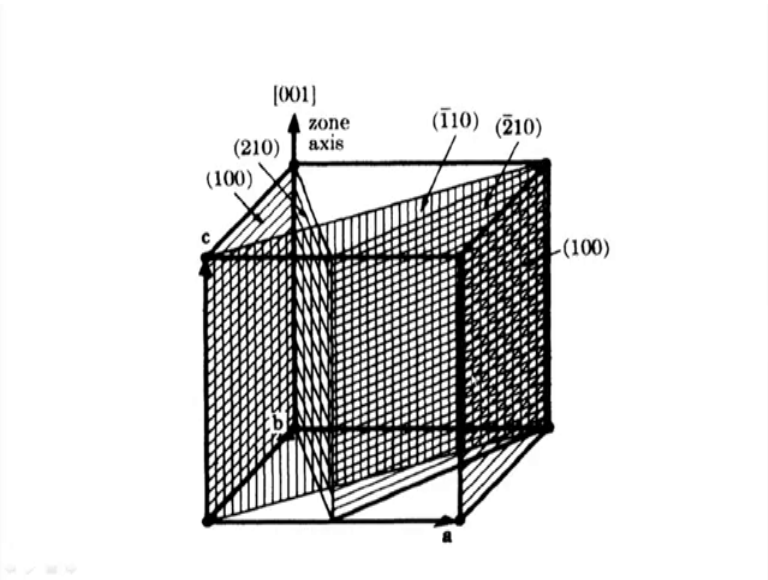

So, all this planes are here 1 0 0 planes, you see 1 bar 1 0 planes 2 bar 1 0 planes all this planes are parallel to this axis. So, this all planes are called zone planes. It forms a zone,

this planes form a zone and this is called zone axis and if you draw normal to each planes, normal will have in different direction, but they will have, they are coplanar. So, all normals are a coplanar. Diffraction, whatever we are getting, that is basically normal to the planes, it has importance. So, from this all sorts of these planes in a zone, they will planes in a zone.

So, diffraction from this all this planes basically, will be in the perpendicular direction of those planes and you will get spot. For all this planes on a, they will be coplanar, it will be on a same plane. Here, basically what we will get for these planes in a zone? You will get on a, if I draw here, you will get all spots on this circle. So, if I draw here, it will be on a circle, this horizontal circle, these are spot on this circle. This will represent different planes of that zone. If you take another axis, now this axis is a, this it is normal to the x-ray. Another axis if you consider this way, this is another axis, you will again this is will be zone axis for different set of planes, now, it is not normal. So, x-ray is not normal to this axis, it has some angle.

So, reflected one whatever you will get, it will be just with some this angle, it is up; again on up, you will get another circle, spot on that circle will represent the planes of this zone, having different zone axis. You will have circle, here having spots on this. Similarly, you will have, this from this method we will get this type of diffraction pattern and which will tell you immediately about the planes in different zones and these are, it is representing the crystal planes in which way they are oriented and they are following some symmetry. Here, in terms of zone axis, we have symmetry of this pattern.

From this method, it is we are getting different arrangement of the diffracted spot. In cylindrical form it will get this type of things, immediately we will identify. This is a planes from a zone, whose axis is perpendicular to the incident x-ray and this will have different orientation; zone axis will be have different orientation. So, from these experiments people can find out the crystal structure and here we have to remember this; in all cases to find out the crystal structure from the diffraction experiment, the symmetry plays a role. So, we will not discuss the analysis part in detail for this, but I will teach you that's next method, powder method.

So, that we will discuss in details, because this very commonly used in all research laboratory even in teaching laboratory. I will discuss in next class.

Thank you for your kind attention.