Electron Diffraction and Imaging
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Lecture – 03
Stereographic Projection -2

Welcome you all to this course on Electron Diffraction and Imaging. In the last class we gave some brief idea about how to construct different types of polar nets, and how to use it to get some information.

Let us just have a recap of what we have done so far. The first thing which we cover was what is the definition of stereo graphic projection, then the next aspect which we covered was what are the properties of the stereographic projection, the third is construction of polar and Wulff nets which can be used to measure an angular relationship in planes. The third is how to use this nets that what it is.

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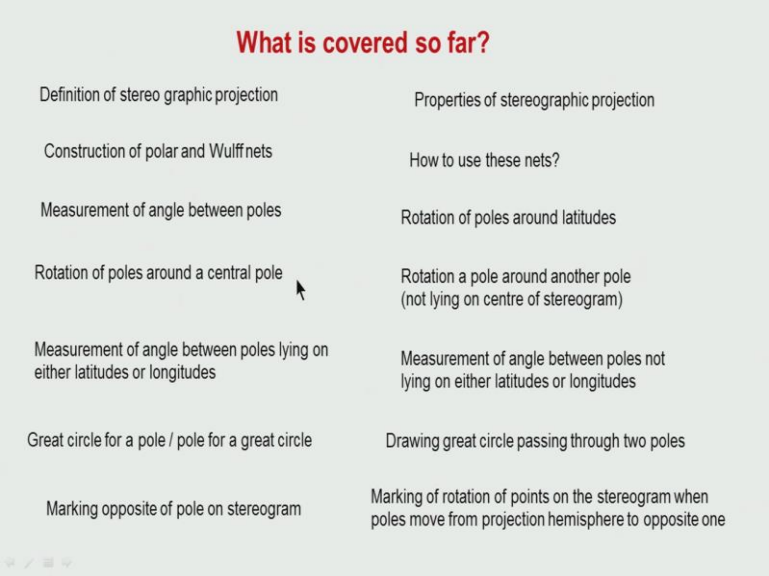

There what all things which we covered? One measurement of angle between poles, then rotation of poles around latitudes, how to measure the angle, then the next is rotation is poles around the central pole, how to do that and the rotation of a pole around another pole which is not lying on the centre of the stereogram then how to go about and do this rotation. Then measurement of angle between poles lying on either one is measurement of angle between poles which are lying on either latitude or longitude. Another is

measurement of angle between poles which are not lying on either latitudes or longitudes, then how to construct great circle for a pole, given a pole how to construct a great circles for it. Then suppose two poles are there how to draw a great circle which is passing through these poles. Then suppose pole is given how the opposite of the pole can be greater than stereogram.

Another is marking of rotation points on the stereogram in the poles. Poles move from one hemisphere to another hemisphere; that is suppose pole is being rotated in a stereogram its moving beyond the projection hemisphere into that other hemisphere in such cases how to represent the projection of the pole. These are all essentially the basic operations which are necessary to use the stereogram effectively. That is all which we have studied. This one has to give a lot of exercise, practice it, and that is the only way you can learn how to use that stereogram.

Though I am just telling in how it is should be done and less of time until you work out on some problems its difficult, because this is the stereogram is essentially suppose to be used get orientation relationship between planes and all these things this is essentially and something which has to be worked out for which unless you do a lot of problem involving the various aspects of how to use the stereogram one will not be able to understand it thoroughly.

Thus what I can give some assignments are later and as you take it course you can go through the do that assignment that we will be able to gain better understanding of how to use the stereogram.

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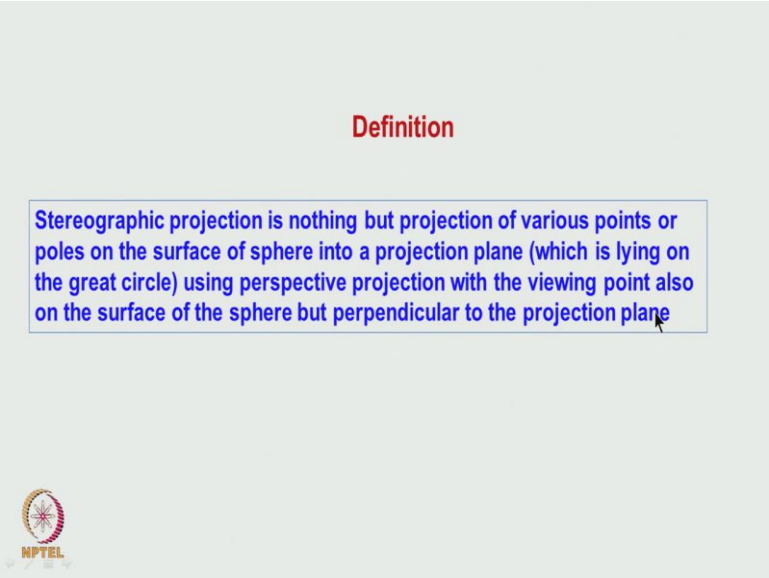

What is the basic definition of stereogram? I mention first the beginning the stereogram is nothing but a perspective projection, but its conditional one. The stereographic projection is nothing but projection of various points on poles on the surface of the sphere into a projection plane and the projection plane is lying on a great circle and using perspective projection but the viewing point also on the surface of the sphere, but perpendicular to the projection plane that is what essentially.

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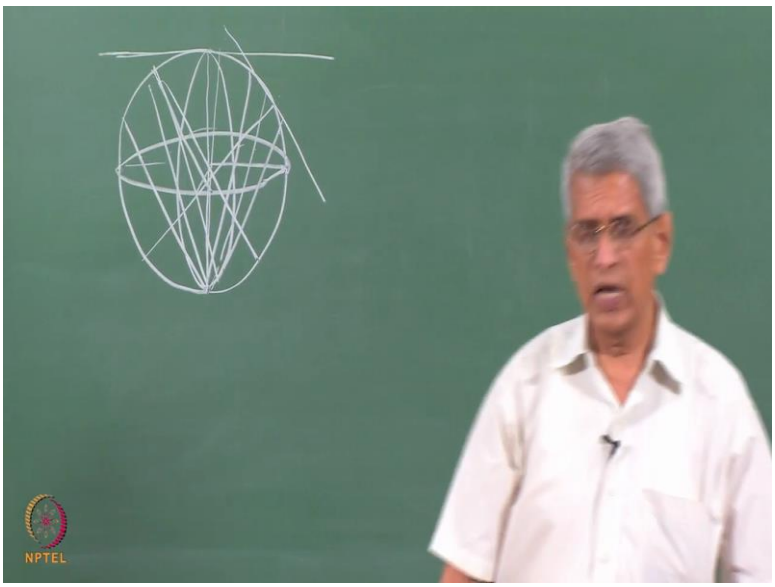

This is nothing but if this is sphere, if this is one of the projection plane then if we are giving from this direction all the points on this hemisphere they are projection they cut this equatorial plane this points are the once which show the angular relationship in three dimensions which is nothing but the angular relation three dimension which is projected on to a two dimension.

So, this projection is called as the stereographic projection. Instead of taking this plane we can take a plane which is just we can keep a sheet of paper here which is tangent to this axis of the north south axis through which we are, any excess for that matter suppose we have giving it in this direction then this will be kept here and then this plane perpendicular to it this is going to be the equatorial plane. So, you that this plane or this plane or it is can be this plane are the plane which comes here, but this projection is called as. So, what is will be in projected all the point which are there only on the surface of the sphere which is getting projected that one should understand.

This is the (Refer Time: 06:27) difference between the conventional perspective projection where it is very difficult to get in angular information, whereas in this particular projection the angular details are transferred on to the projection plane. Having on so far how to measure angles under different circumstances, let us look at how is stereogram can be constructive for a crystal.

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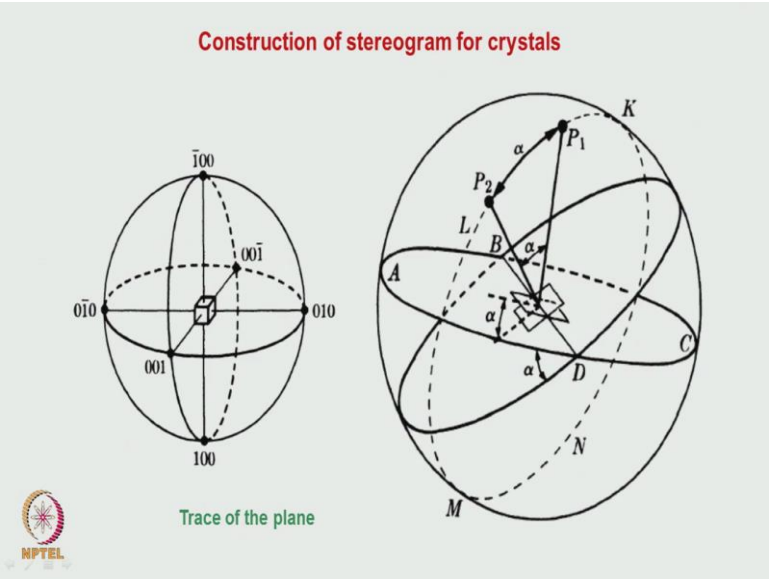

Here, if you see this is a sphere in which a cube of a crystal is kept we can assume this cube to be a may be a simple cubic structure and with that centre at the centre. All the plane normals are drawn from the various cube surfaces, they meet this, they cut the sphere on the some particular points these are all we call it has the poles corresponding to this those planes. And these points are nothing but essentially the plane normals which are cutting this surface on a particular point, this point as the pole corresponding in the plane.

And the plane which is passing through the centre this normal to this pole; if we extend this plane this plane is going to cut the surface of the sphere. The one on which it cuts always it will turns out to be a longitude or latitude and this is what as we discussed in the last class this we called it as the great circle. So, the great circle is nothing but the showing cut section of the plane there is on the sphere. And this is essentially what is being shown here, this is a small plane; the section which cutting and creating the longitude the great circle and the normal treat this is for the pole is.

Suppose you wanted to measure an angle between two planes in this particular case, this is what the angle between these two planes. That same is equivalent to angle between the plane normal also. So, by measuring the angle between the plane normal essentially what we get is that angle between the planes.

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Let us see how to construct the stereogram. In this particular case what has been done it there we showed one small cube. Here we are drawing plane normals corresponding to cube which has been kept at the centre. The plane normals are cutting the surface of the sphere at different points and generate various poles. What is essentially important is that for examples suppose we see that in these directions for this pole 001 bar. The great circle corresponding to it is this particular one. All the poles which are perpendicular to this pole all will be lying on these great circles. So, you can say that all the poles which are perpendicular to a specific pole lying on a great circle corresponding to that, so the great circle corresponding to various poles are also being shown in this the diagram they are marked here.

Now, what we can do it is that suppose we use this as the viewing direction, from this direction we are trying to view and look at all the poles which are lying on the northern hemisphere and what is the point at which they are making intersections on this equatorial plane.

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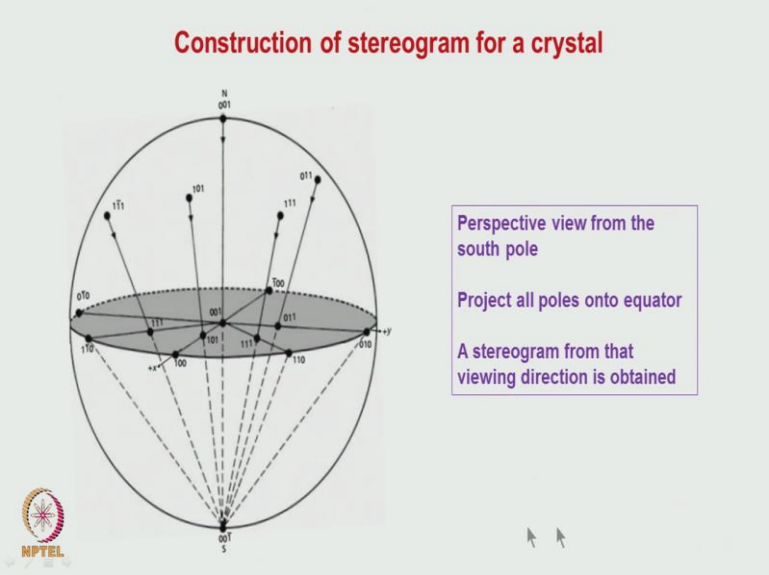

That is what is being shown in this stereogram, in this view graph. Here you can see that these are all the various poles. And all this poles also should as we have discussed in the last class the angular relationship between the various poles which are lying on the surface of the sphere that is being maintained here. And if you see this projection plane

that is; what is the stereographic projection; that is the projection plane which is shown here.

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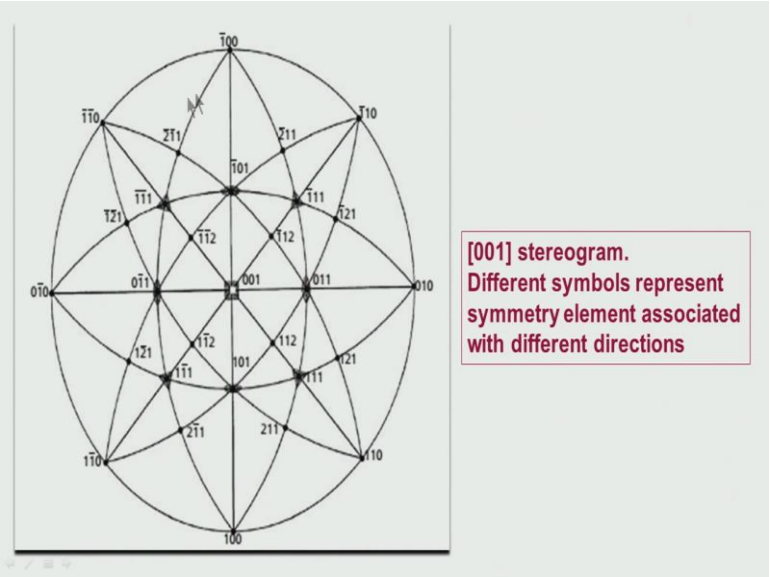

Now, if you look at this projection 001 is at the centre that shows the centre of that because that is the point through which the axis passes is through north south axis. And the 100 and 010 are 90 degree away from it they are going to lie on the primitive. As we can see here this is lying on the primitive of this circle; that is what essentially is being shown here. But we know also the all the poles which are 90 degree away from with they should lie on this great circle which is the primitive circle. Then how to choose this specific direction that the convention which we follow for in crystallographic that is being used that is from top to bottom it is the x and from left to right so y direction is z direction is in this perpendicular to the screen.

Then as per that stereogram which we have the previous slide the equatorial plane if we this is one this will be make an angle 90 degree with respective and 110 plane comes like this is how the various planes will be coming. And the great circles corresponding to other planes also they have trace also could be seen in this stereogram. So, this stereogram generally is referred to as 001 stereogram. And the here in addition cube that symbol which is being shown here, this symbol correspondence to it is a fourfold rotation which is associated with it. In this particular one if you look at it; it has that a

threefold rotation which is associated with it this along 110 directions. Along 110 directions two fold rotations is there.

So, all the symmetry elements also can be represented each of the point what have symmetry element is around this directions that also can be integrated on these a stereogram. So, we assume that it is essentially nothing but a cube which has been kept and the various poles which its making in this cutting on the surface of that sphere. And are the equator plane they make some poles corresponding to them. This is just give graph of that which we have seeing it.

Suppose for you wanted to find out what is the angle between this, we know that from the centre to this from this is 90 degree from here to here that is. On the circle all the points are 90 degree away from that what the information which we know.

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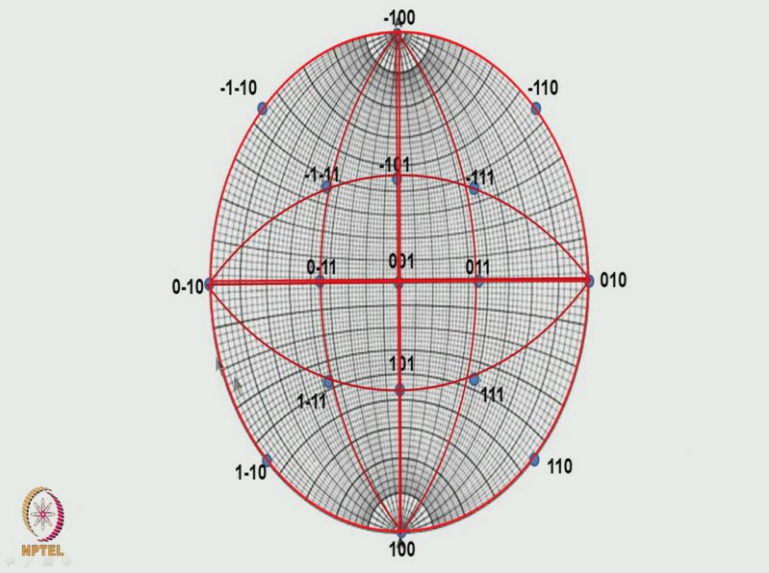

And now you wanted to measure the angle between this various planes. What we should do is, we should keep it on top a Wulff net that is what essentially which has been done; on the Wulff net which has been done.

Now, like we have to use what we have learn in the last class that is if wanted to measure an angle between two poles that poles should be either lying on latitude or on a longitude; here this are lying on a latitude. So, we can directly measure the angle which is 45 degree from 001 to 011. Similarly, from here to 101 this is 45 degree, then from

here to here you know that we can directly measure this along the circumstance this is another 45 degree and from 010 to 110 this is 45 degree. Suppose you wanted to measure with respect to this particular point then what we have to do it is that we rotate this stereo trace tracing sheet and bring this point to the then we can measure that will turn out to be 54 degree, because this is all this stereogram 001 standard its stereogram is for a cubic crystal. This is the way we can use the stereogram and the Wulff net to measure and find out angle between the planes. That is what we did some exercise in the last class.

But when we wanted to construct a stereogram this is not the method we can go about and construct the stereograms, because these with a nice part experiment that we have kept crystal at the middle of the cube and done this, because if you have to generate stereogram of like this we have to take some photograph and the go about and (Refer Time: 15:46) which not a practical way in which it can be done. Thus, another way in which we can compute the angles between the various planes in cubic system and generate a stereogram; that is what we will discuss it now.

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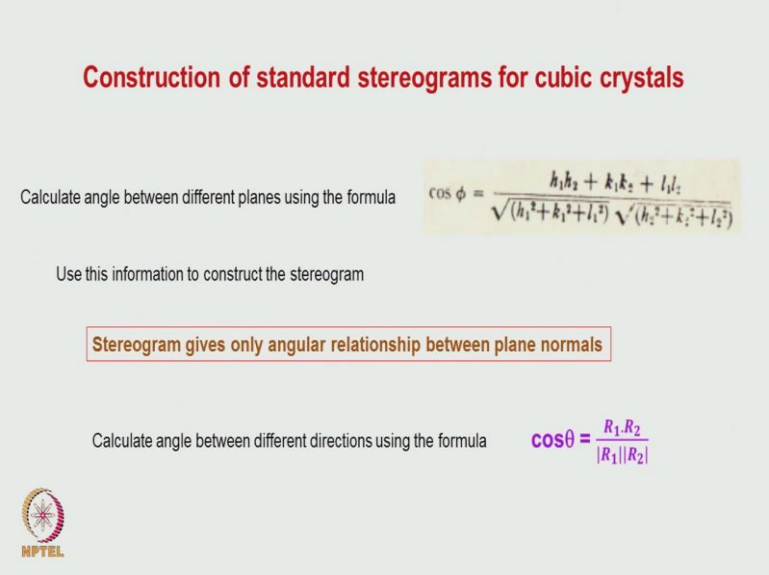

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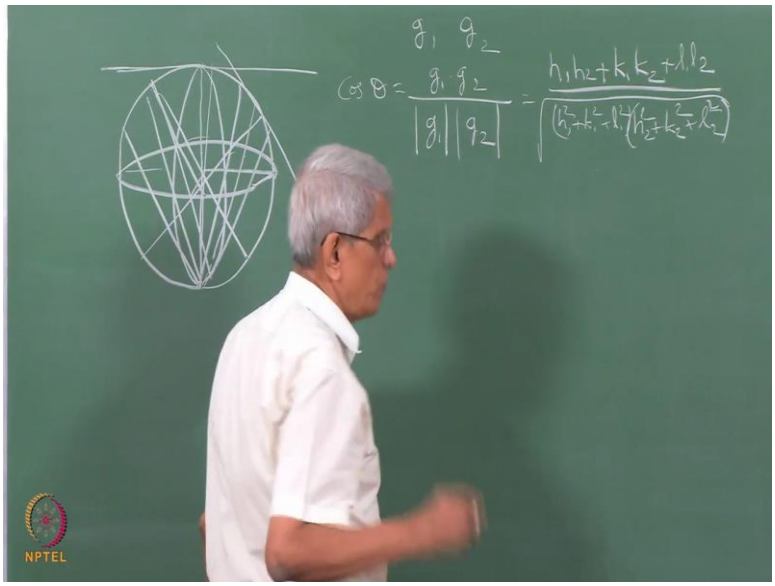

We know that the angle between various planes can be determined using this formula between two planes. This are related by vectors g 1 and g 2 the angle between them equals g 1 that g 2; g 1 and g 2 are in reciprocal space g 1 modulus of g 1 in to modulus of g 2. G 1 and g 2 are essentially in the same direction as the plane normals so the angle between them gives the angle between the planes this formula could be used. What will happen in the case for a single cubic system; this will becomes h 1 h 2 plus k 1 k 2 plus l 1 l 2 divided by root of h 1 square plus k 1 square plus l 1 square into h 2 square plus k 2 square plus l 2 square.

Using this formula angle between the various planes could be calculated. Same way angle between; because we know that this is true only for the case of cubic system because the lattice parameter does not figure in this case. And also that plane normals and the directions have the same indices for cubic system, whereas for a all other crystal structure (Refer Time: 17:41) this is the plane normals and the directions the crystals they do not have the same indices. And because of that if we have to find out the angle between the planes, the angle between the planes we have to use this formula cos theta equals that difference symbol orthorhombic case if we consider.

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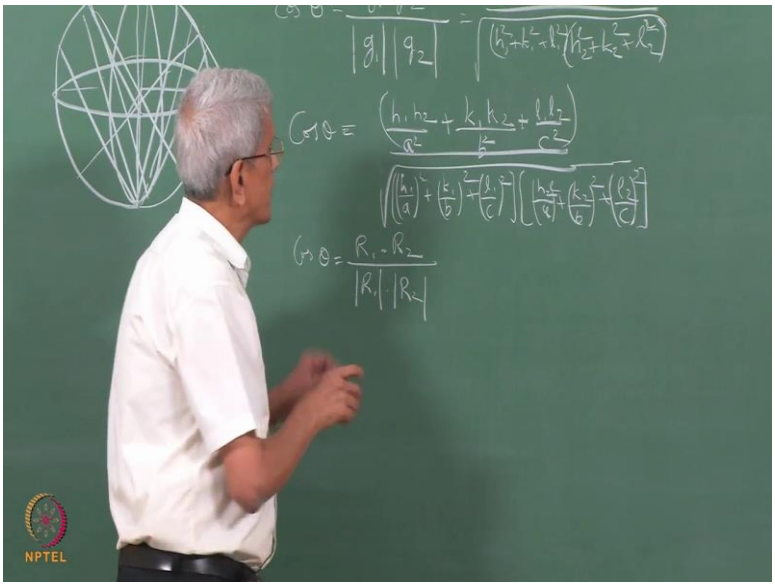

It will be h 1 h 2 by a square plus k 1 k 2 by b square plus l 1 l 2 by c square divided by root of h 1 by a the whole square plus k 1 by b the whole square plus l 1 by c the whole square l 2 h 2 by a of whole square plus k 2 by b the whole square plus l 2 by c the whole square. This is how it is turn out to be.

In this the general formula is still valid, but if you wanted to find out angle between the directions then the cos theta will turn out to be r 1 that r 2, where r 1 or r 2 directions it is the modulus of r 1 that modulus of r 2. In the case of tritogonal lattice a will be equal to b then this formula will change accordingly. But what is essentially important is that in the case of all are the lattices other than cubic lattice the angle between the planes depend upon the lattice parameter values that one should keep it mind. So, considering the case of a symbol cubic system using this formula we can find out angle between the various planes.

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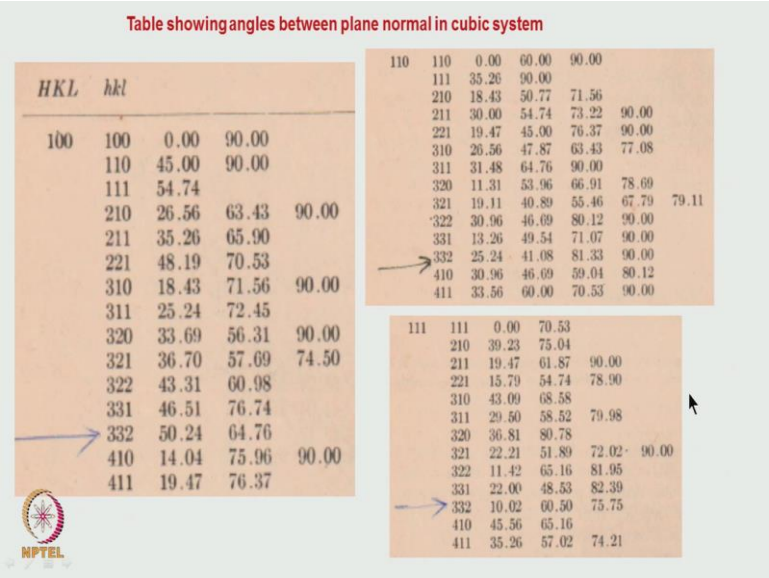

And these calculated values are given in this table. So, in this table if you look at it this is here instead of h 1 k 1 l 1 here it is used by h k l the capital and small letters are use to represent them. This is one plane 100 and another plane if it is 100 angle between them become 0 for this we know all this research.

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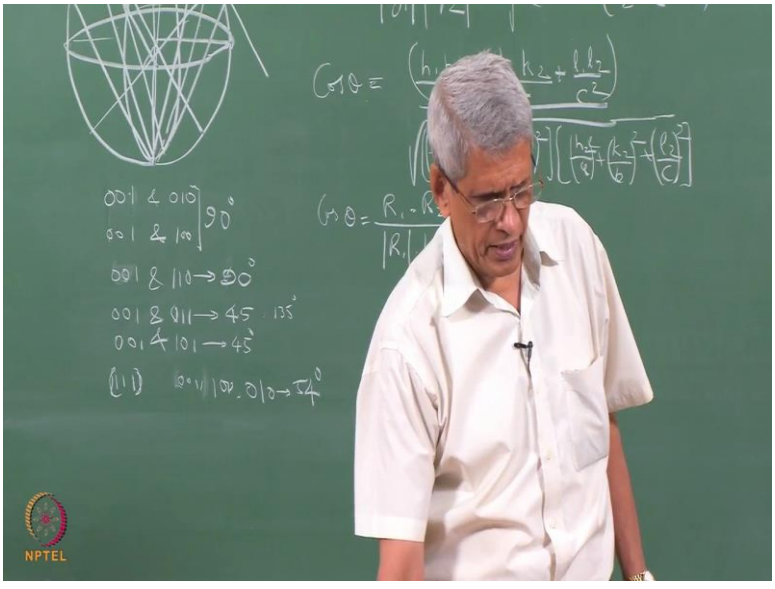

So, I will just write that between 100 and 010 or let us write between 001 and 010 or between 001 and 100 this angle is going to be 90 degree. And similarly between 001 and 110 the angle is going to be 90 degree, because this one can calculate and get it and just

writing in the between 001 and 011 this angle is 45, between 001 and 101 this angle is 45, if this turns out to be here 001 and 011 bar then this angle will turn out to be 135 degree. This angle we can correctly measure and tabulate it.

In fact, the information regarding these three with respect to 001 plane to other 100 one type of plane 110 type of plane and 111 type of plane is sufficient. Because with respect to 111 plane; there is 111 direction if you take it this will be with respect to 001 then 100 or 010 this makes an angle of 54 degree. Using this information we can construct the stereo that is stereogram for 001; that is what we will just study now.

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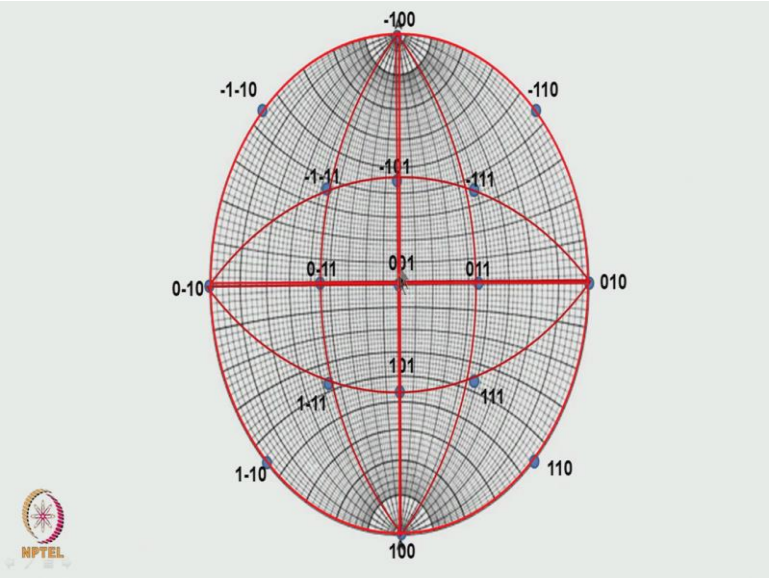

What has essentially been done is that since we are drawing stereogram is 001 the 001 will come at the centre of the stereographic projection. So, what we have done is taken the Wulff net on top of it we have kept a stereogram, drawn the primitive circle, and then mark this two axis x and y, mark this point at 001. By convention 100 direction as to come here down and the 010 direction has to come in that y direction.

Now, the angle between 001 and 100 is 90 degree. So, in this direction it should be 90 degree away so the pole will come here that, so we can mark this pole. And 010 pole will come here and we can make out that from here to here along this circle if you go this is 90 degree it makes. And then 110 plane essentially if we look at it that makes an angle 45 degrees with respect to 100 and also 45 degrees with respect to 110; that means that that has to come in between these two at angle of 45 degree. And we know that from 001

110 is 90 degree; that means, that is 110 has to lie on this of primitive circle. So, we can mark this point.

So now, we have essentially got this point and we know that 011 is makes an angle 45 degree with respect to 001 as well as 010. And that should lie on this equatorial line. And that also we can make out that if 100 is a pole the great circle corresponding to it which is 90 degree away from it that is this line. And we know that 010 makes an angle of 90 degree with respect to 100, so it should be lying on this line.

Since it is lying on a latitude and equatorial plane line we can directly measure 45 degrees from here and mark it. Similarly, 01 bar 1 we can mark it. Then, if a mark 011 we can draw a great circle corresponding to it like the way we learned in the last class, we can draw a great circle corresponding to this particular one we can draw another great circle. Similarly 1001 will come in between this at 45 or 1 bar 01 will come between 001 and 1 bar 00 in of 45.

So, we can draw great circle corresponding it and we know from the angular relationship that corresponding to 011 all the poles which make an angle of are 90 degree will be lying on this longitudes. Then if you know the angle between these planes since their lying on the longitude we can mark those points, this way we can mark all the points correspondently. And another like if that for example, 1 bar 1 bar 1 if you take it 90 degree from in the way from these that is essentially the great circle corresponding to this one will be the one which is passing through all these this is the way it will be passing through the great circle. And the great circle corresponding to 11 bar 0 will also be is the line which is passing through this.

These two intersect at 112 that is because 112 is 90 degree away from 11 bar 0 and it is also 90 degree away from 1 bar 1 bar 1 and the great circle corresponding to both of them intersect at this point. So, that intersection point should correspond to 112 pole. Or we can just do that if you take this 1101 and this is 011 and this is the intersection point. If you take a vector addition of this will turn out to be 112. And the 001 and 111 if you take the vector addition of it this point will turn out. So, this point which is lying on these two lines that has an intersection will have this in vector addition. There are many various ways in which we can read, but like this we can mark more poles. And this way we can construct stereogram for 001. This is how the stereograms are constructed ok.

But taking the general method of that considering the general method of putting a cube at the center of this sphere it is the nicest way in which we can visualize it and understand how a stereogram is develop.

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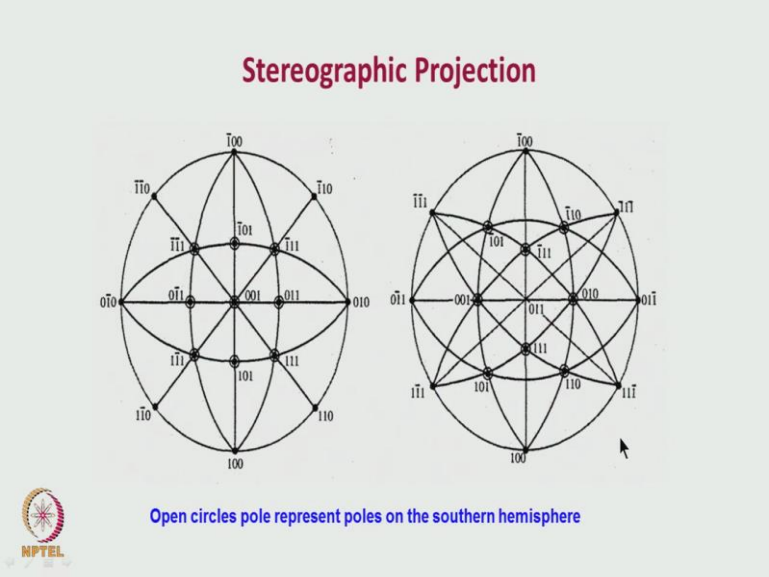

In this particular projection what I am showing it essentially is the 001 projection is being shown. And here if you see the two circle which you can see the once which are field circles they are corresponding to the poles which are lying on the top hemisphere. If you wanted to project the poles which are lying on the bottom hemisphere then what we have to do it is that all those poles will be marked with a open circle. That is what essentially it is being shown here.

As I mentioned earlier we can instead of taking this as the plane I can take this plane and looking this direction and then also create a stereogram corresponding to this pole 11 bar 1; that is what is being. Suppose I wanted to create a stereogram corresponding to 011; one is visualizing it that way or the other way which we can do it is once the stereogram has been done. If you remember is a there how to rotation of poles that we learnt in the last class. So, if you want that this two come to the center 011 and 001 makes an angle of 45 degrees so this has to be rotated along this equator on your line by 45 degrees it will come to the center.

When this comes to the center all other points also will be rotated by the same with the all the poles will be rotated, because the when we rotate that entire sphere is being

rotated. So, this will be rotated by 45 this will be also be rotated all of them will be rotated by 45. And essentially this moves on the equatorial plane, here what it will hope in this will be all moving on the latitude corresponding to them as we learn in the last class.

When we do that, now we can see that 011 has come to the center, 001 which was there has moved 45 degrees has comes to this point, 011 bar which was there has moved from here and reach this point. Similarly, 1 bar 11 was their moved on this latitude and reached here and 1 bar 10 which was there has moved and come and which was below this plane that has now come on to that surface and here the 011 bar was their behind this that has come on to the (Refer Time: 30:49) the 0. So, this is what the new stereogram for 011.

This way also we can draw a stereogram corresponding to various that there is suppose a what 111 to come what I should do it essentially 54 degrees I should move it here, then the 001 will move in this direction and reach here.

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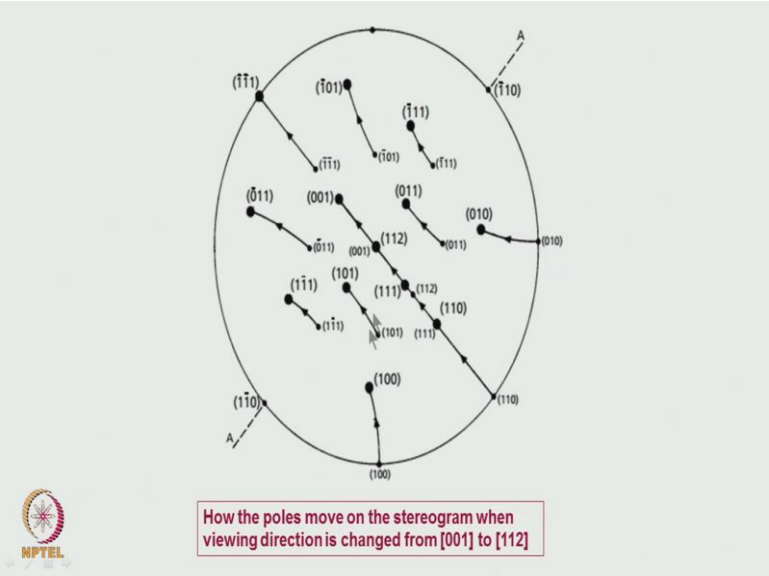

This is what is shown as an example, like what I mentioned that you have to. See this is for the case of 112 the pole is being brought to the center, this about 36 degree when this is being rotated, in the same direction on this equatorial plane 001 is rotate then it reaches here all others because the rotation axis now is around this 11 bar 0 in this axis then if we rotate around this axis this is going to be the equatorial plane.

And these are all the latitudes. So, 001 which was their initially it has moved and come here to this position, this is the new position. Now we can see that all the ones which are written the lattices which a larger fond they are all correspond to the new position of the poles; that is this is for 112, so on if its come to a center. These are all the position in which the poles will be lying. But what is essentially being shown is what was their original position and how they have moved, that is what is being shown here. This is the way in the previous view graph from 001 we have reach 011.

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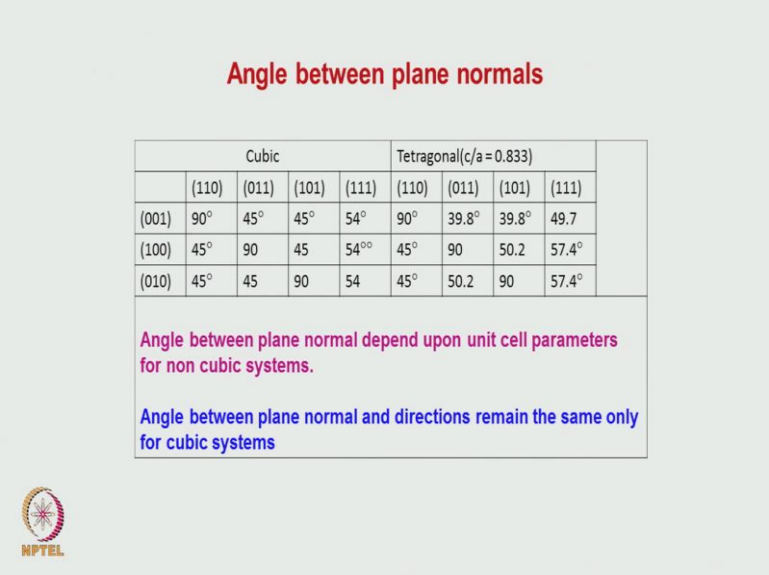

So, far we have considered we learned how to construct a stereogram 001, 011, 112 like this for any pole one can construct a stereogram that is for a cubic system. Normally stereogram are cubic systems are available in books are one can buy them also in a standard size and they can be use with the analysis.

Suppose, the sample which we are examine in a microscope is a non cubic system; the example which you have taken is suppose the second phase particle is a tetragonal one and the CBI ratio turns out to be 0.833. Then what is going to happen is that angular relationship we have to calculate using the value of a b and c. So, for each crystal depending upon the lattices parameter angle between the planes will change. This table illustrates that between 001 and 110 it is essentially 90 degree for cubic and the all other planes it is 45 degree. Here if you see for a this particular case between 110 and 001 they are (Refer Time: 33:51) which will be their it will be 90 degree, but with respect to 011

instead of 45 now it is the 39.8, 100 also 39.8, but with respect to 111 it become 49.7, with respect to 100 also we can calculated

Now, you see that between 100 and the 110 this is 45 degrees. There is with respect to 100 and 011 its 90 degree, but then be 100 and the 101 it is 50.2 degree. Now we can make out that the angles are different though the indices of the plane normal if we consider are the planes they remain that same.

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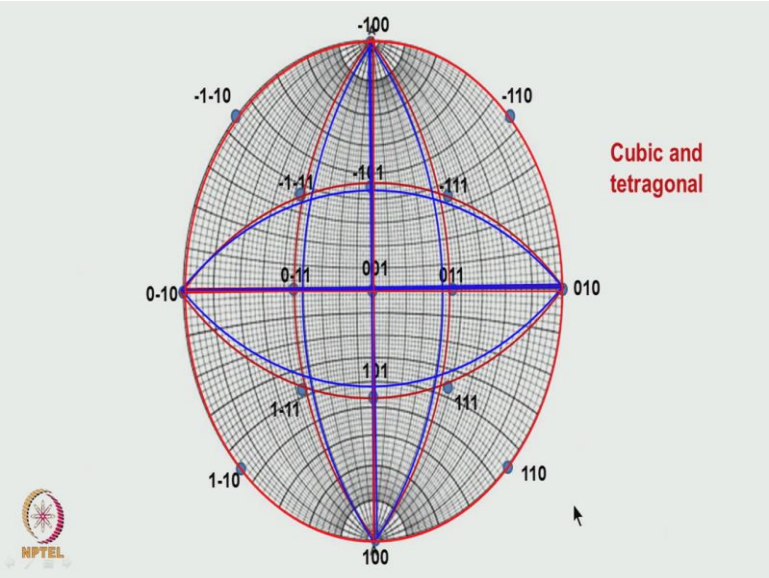

So, once we have a table like this like we constructed the stereogram using this information we can construct a stereogram for this tetragonal crystal also. That is what is essentially shown here, here what is going to happen between 001 and 100 it makes an angle which is essentially of around 39, there is from 001 and 101 its 39. So, since it is lying on a longitude we can directly mark it, between 100 and 101 its 50, so this is the point which it will come.

Similarly, it is 100 and 110 was 45 degree, 001 and the 110 is also 45 degree. Then between 001 and 011 if we consider this again 39, between 010 and the 011 it is going to be this point these blue lines the intersection represent corresponding to the tetragonal one. And for comparison I have keep the stereogram corresponding the cubic system also here. And now we can make out that this is the point which corresponds to 111 planes. And in fact, if you look in to the crystal structure along 111 direction now the threefold symmetry is last.

So, this way now when we know that the pole corresponding to 100 is their now we can draw the corresponding to this particular pole the great circles which we can draw 90 degree corresponding to that. But what we will find is that what is going to be the angle between this and this one has to be quite careful about it, but in the diffraction pattern from this particular point 90 degree if we draw here great circle those are all the ones on which all the diffraction point will be coming. But essentially what is important is that this particular pole is a plane normal, but the direction in the crystal if consider 101 direction in a crystal will be appearing at some other point. That is what is shown in the next view graph.

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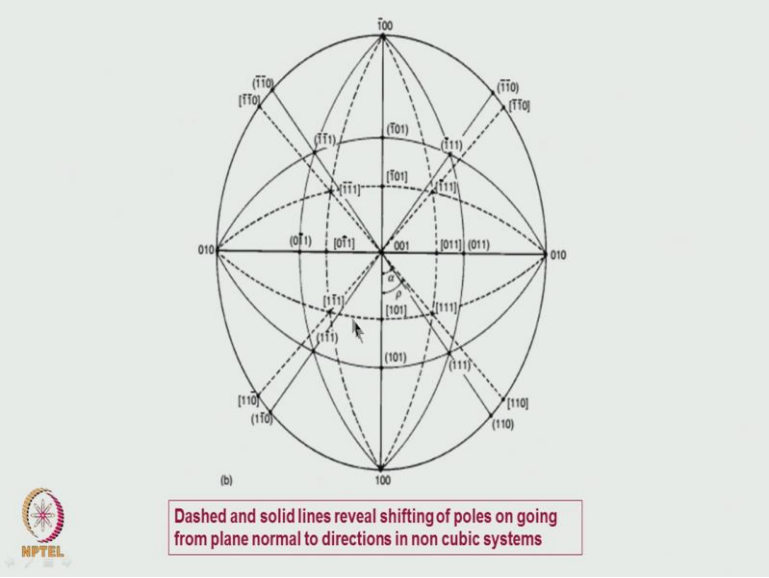

So, essentially one has to be careful because a compare to a cubic system one can just visualize the complexities which are creeping in, because here if you see it for the planes this is the great circle corresponding to them for non cubic system. And for the directions we can see the this is how because the indices remains that same, but you find that the poles corresponding to plane and the poles corresponding to a directions they are not that same. This fact has to be kept in mind when we wanted to use stereogram for analyzing the diffraction pattern.

These aspects one could not going to all the class because this has to be one which has to be worked out in a tutorial class there one as to work it out for one self. This you will

understand when you deal with the work on a system which contains second phase particles are systems which are crystal structures which are non cubic.

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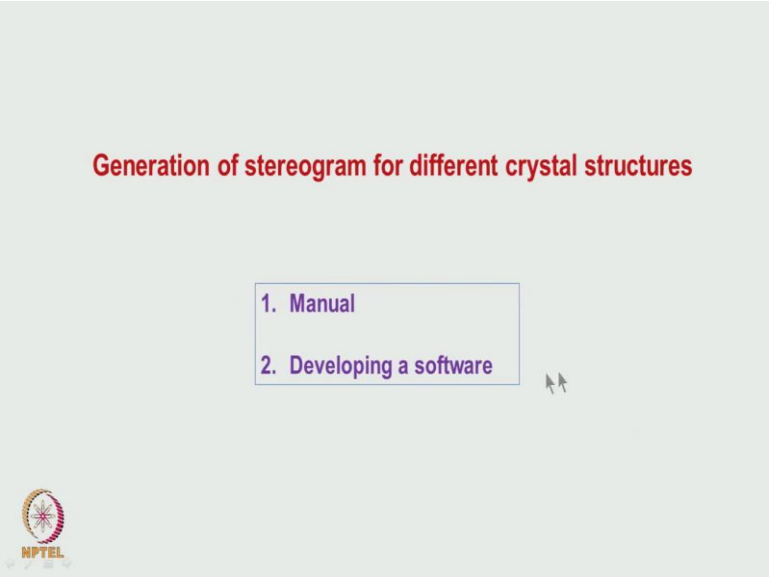

So far whatever we have talked about is how to generate a stereogram by doing calculation manually how it can be generated. But the same thing can be done by writing some core and software can be developed which can do that. And this is available in the open source softwares are free softwares are download softwares are available which can be used. And you just mentioned that instructions they will try how to do this rotation and all these analysis which has to be done everything will be which can be done.

But that you look like a black box, unless you understand what it does for which are trying to develop a manual that is develop stereograms manually and using them that way you gain in a experience then the confidence in your analysis will increase considerable.

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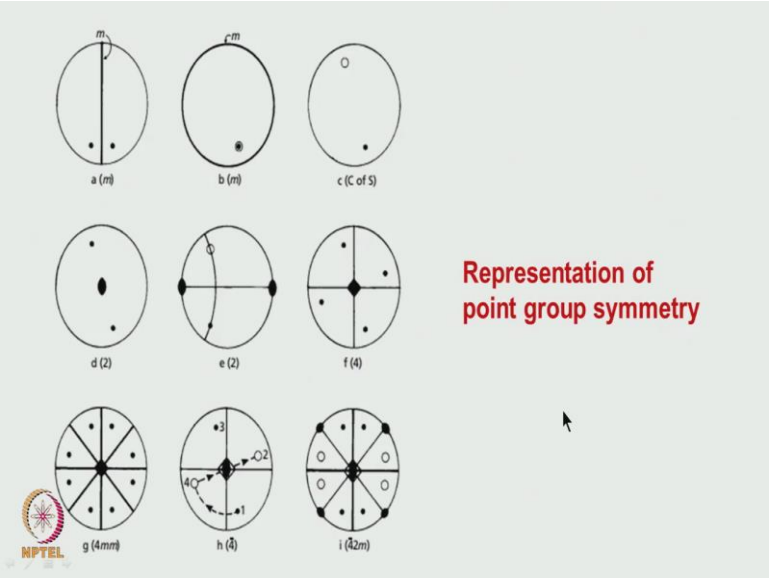

Now, what I will do it is how the stereogram is used in the representation of point group symmetry. These you may it have seen when you have studied cryptographic how point groups are represented.

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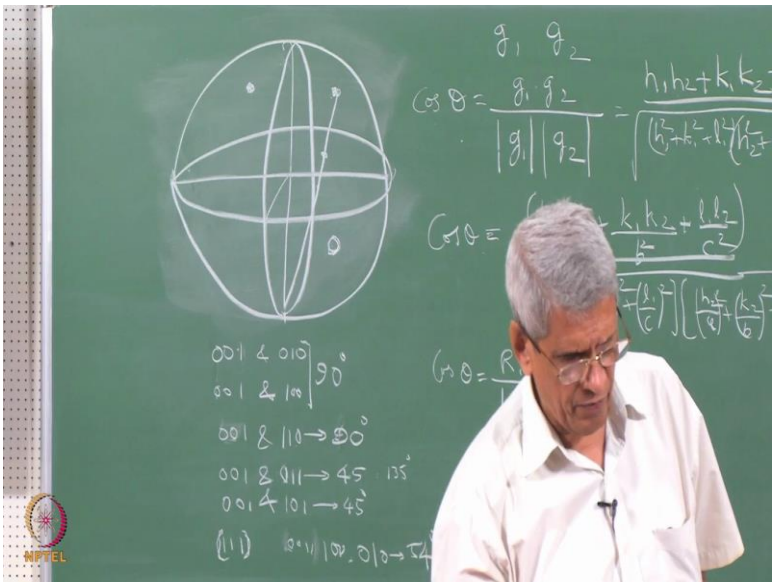

Essentially, we will again consider a sphere so that the visualization becomes much easy. Suppose we have a pole here and this plane is the mirror plane. So, if this mirror plane is their this pole will be reflected and it will be coming here correct if this is the viewing direction in which we are giving it then what will happen is that on the viewing plane

this mirror plane will come and this two will appear. That is exactly what is it being shown here. That is, this is the primitive circle and this is a pole and the mirror plane is passing through this axis x axis and then this gets reflected and it comes.

Suppose, you assume that this is the mirror plane equatorial plane then this point will be reflected and it will be coming somewhere here at the bottom one, but we know that the pole which is going to be there on the bottom one will not be represented on the stereogram generally. So, how we represent it as we learned in the last class; that is represented by viewing it from here and then using an open circle. So, if we do that this will be just super imposed on top of that and that is precisely what is being shown in this particular case. And this thick line essentially indicates that on this primitive a circle is where the mirror plane is also are there.

And another important factor which is known that is if we consider for this one this is the viewing direction. So, essentially when it cuts this surface the cut section in the equatorial plane has to live within the primitive that is also is what is being represented and shown here. Because you can see that all the poles which are being marked here they are all within this circle. And suppose an inversion is taking place across a point. This is what also be learned that that is across the center point you invert it and show it within open circle, that is how it is representation. In fact, what were we have learned in the previous class that is being use in the point group for presentation.

Suppose, it is a rotation around this one twofold rotation if there then what it will happen. So, this point if it is rotated by 180 degree. The same hemisphere it will rotate and come to some other point; and that is essentially what is. But it should be moving along particular latitude, when we rotated. That is what essentially is being shown. This projections are if we look at it this essentially on a like a polar projection. So, it is being moved from here and the same latitudes are concentric circle is moved from here to here this is for two where the twofold rotation axis is lying on this axis. Then when we do an 180 degree what is their going to be on the top hemisphere will go the bottom, then it will be shown within open circle.

Similarly, a fourfold rotation if we consider. So, it will be all on the top circle this what it will be rotate. Similarly various other a symmetry operations are see. And this is how the various point group symmetries are represented on a stereography projection.

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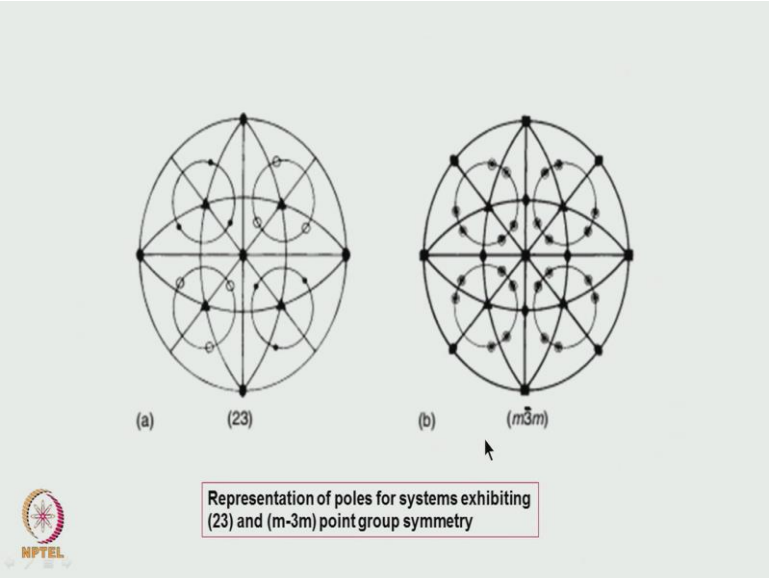

In fact, here if we look at it this particular point for a cubic system when it is two three are here if we see it 111 has data threefold symmetry. This are all the points which are three points which are going to lie, and they are make an angle which is equip distant from this one that is the locals of circle which has to be drawn on this. And we learnt the last class how to draw the locals of a circle.

So, all these things has been done essentially to effectively gives stereogram to represent different planes and directions in the crystal. And if it is m three bar m then what is going to happen is that every point they will be a reflection. So now, we can see that around this local circle corresponding that we have every point there is a reflection it is getting reflected along this particular planes.

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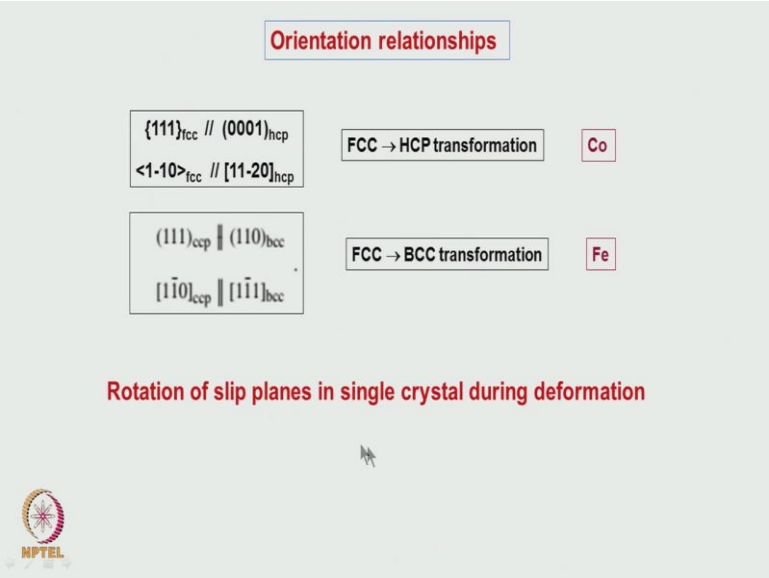

So, in short you can make out that the basic things which we are learned how to use stereogram all those technique are being employed to represent point group symmetry on stereographic projection. Another one which I mention though is said that I will not go into a detail, but I just wanted to mentioned this that orientation relationship that we can use the stereographic projections standard projection which are there to analyze and index the crystal structure. And if the fraction pattern contains the fraction reciprocal lattice information from both the matrix as well as the second phase particles by analyzing them using stereographic projection we can get information about the orientation relationship.

This is one which is has to be actually worked out on a specific system and the beyond the scope of this lecture this you will be learning when you are looking to sample in the microscope and you phase the situation where this sort of analysis has to be done. Another aspect in which stereographic projection is being use or another area is with we deform a single crystal of a sample. The crystal is oriented along a particular direction. We know that when we deform a single crystal for example, if you take a cubic crystal or a FCC crystals we note that there are twelve slip systems are there with respective a projection which we are chosen for deformation. We can find out what is going to be the smith factory on way each of the slip systems. And whichever slip system has got the largest smith factory that is the one which is going to be activated.

If the direction of loading is along some specific direction then more than one slip system can have the same smith factory then both the slip system could be activated. But what is essentially important is that suppose it is along a random direction one slip system is activated how the slip systems change during deformation. All this information we can get it from looking at the stereographic projection.

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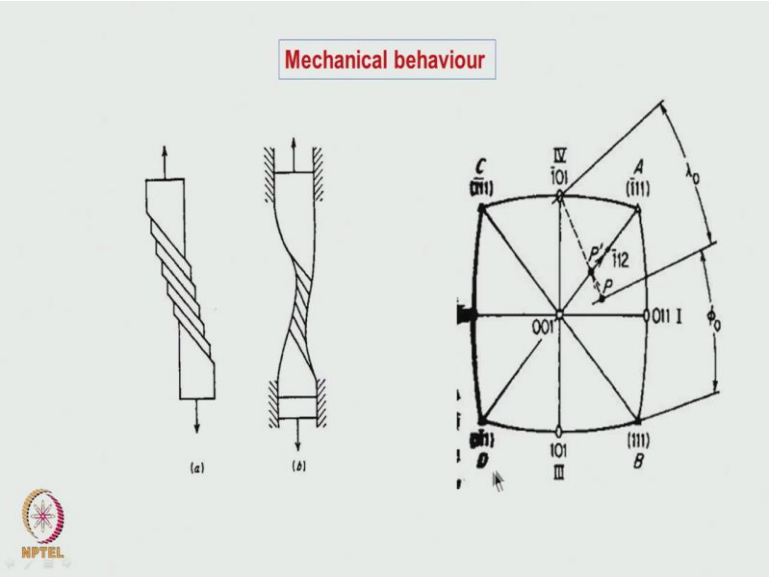

This is just one example which I had given in the mechanical metallurgy course will be studying all this aspect. In a single crystal we assume that only single slip system is activator so this is the way it will be deforming, if it is not being helped rigidly. If it is being rigidly then what is going to happen is that since it cannot translate the rotation of the slip system has to take place. So, that is what essentially is being shown on the stereogram. This is p is the loading direction and for which the 111 is the slip plane and the 1 bar 01 is the direction of which the slip occurs which has got the maximum smith factor, these is the one which gets activated.

But the as the sample is being held rigidly there is a rotation which takes place because of which it will try to move and reach this point. When it reaches this points the smith factory for the slip on 111 plane as well as 1 bar 1 bar 1 plane both of them are equal. So, both the slip system will be activated then essentially what happens if the direction of the loading gradually changes and reach which has here at the that is the point that which the sample fraction local.

But what is essentially important is that looking at the stereographic projection. On using the stereographic projection we can tell which slip system is activated first, what all other slip systems will be activated during deformation; all these information we can obtain. This is beyond the scope of a going to detail beyond this one scope of this lecture so, but I had just mentioned it so that you will remember in situation where you find when you are you are working with single crystals you can use stereogram to get information about which type of slip system will be a active when we deform a sample.

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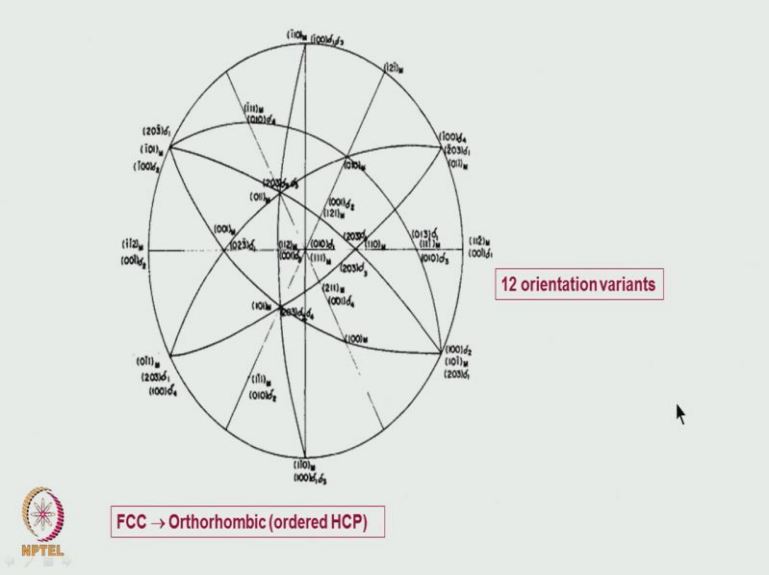

What I will do it is that I had given brief and overview of a stereographic projection basic construction of stereogram and the how to use it to measure angles are between planes and directions and how to rotate the crystal. All those basic operation I have taught and then how to generate a stereograph or cubic system as well as from non cubic system. The next aspect is how to use it that part of it you will learn it when you operate microscope look at microscope and analyze your result.

I will stop here now.