Texture in Materials
Prof. Somjeet Biswas
Department of Metallurgical and Materials Engineering
Indian Institute of Technology, Kharagpur

Module - 03
Texture representation
Lecture - 11
Inverse Pole Figures

Good day to everyone. This is lecture number 11 representing Texture using Inverse Pole Figure ok. So, let us start.

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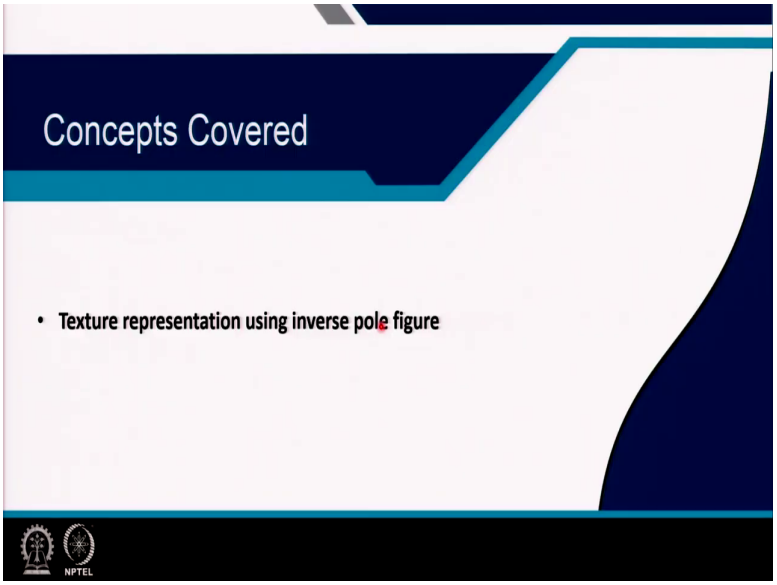

The concept that will be covered in this lecture is texture representation using the inverse pole figure.

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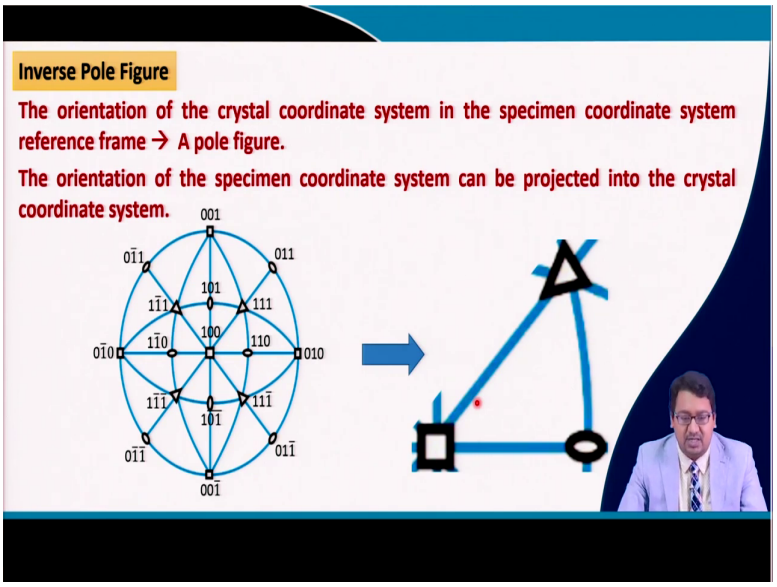

So, what is an inverse pole figure. In addition, you have an idea of this because of our previous lectures. So the orientation of the crystal coordinate system is usually shown in respect to the sample coordinate system right. This is known as the pole figure right. On the other hand, if we represent the orientation of the sample coordinate system in terms of the hkl crystal crystallographic pole and we represent that sample coordinate system with respect to the crystal coordinate system. So, representing the sample coordinate system in terms of some hkl pole with respect to the crystal coordinate system is known as showing texture in terms of inverse pole figure. Now, what is an inverse pole figure? The inverse pole figure comes because of the symmetry of the unit cell. For example of a cubic material, and if we look into the stereographic projection of the cubic material. What we will see, and this is the 100 standard stereographic projection because the 100 is at the center exactly.

Therefore, what we will see that this stereographic projection is made up of a number of triangles right. these triangles. The triangles with corners made up of 100, 110, and 111. So, we have a triangle like this, and a triangle like this, or triangle like this, another one like this, this one, this one. If you look at this quarter part of this stereographic projection, these are made of 1, 2, 3, 4, 5, 6, six triangles of corners 100, 110, 111, each one of them. So there are four quarters like this 1 2 3 4. Therefore, 6 into 4, so there are 24 triangles. And they are symmetrically made up of 100, 110, 111 right.

Therefore, if you look in the opposite direction there are 24 more. This is a kind of this is a kind of a sphere. Then in the front there are 24 triangles there it is made up of 24 triangles; and in the backside which is made up of another 24 triangles; so 48 triangles.

So, any one of these triangles can be used to represent the texture. We can take a single triangle. We know that this part of the triangle, this corner of the triangle represents a 11 100 axis, and this 110 pole, and this 1 111 pole. Therefore, we can represent the texture anywhere inside the triangle showing an important sample reference direction. This is the way how we use inverse pole figure to represent the texture.

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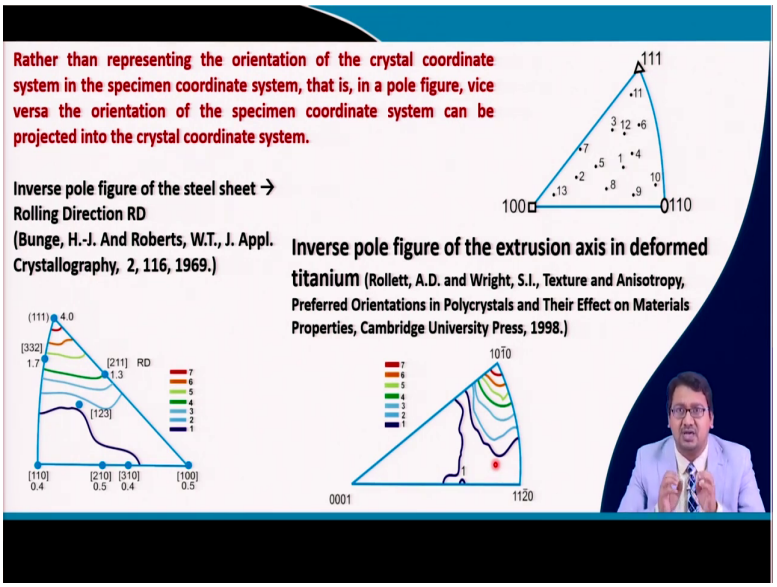

So, rather than representing the orientation of the crystal coordinate system in the specimen coordinate system, which is the pole figure, the vice versa is used the orientation of the specimen coordinate system can be projected into the crystal coordinate system. And say this is an example that we showed earlier in some earlier lecture also.

And say for example, we have say 12 or 13 number of crystals present in a polycrystalline material. These crystals in ideal conditions should be grains right. So, say for example, important direction is say a rolling direction. We are showing the rolling direction of each of these crystals separately. We can see that crystal number 1 or grain number 1 has an intensity point here. So, the RD is parallel to a certain hkl pole which is which has its intensity here like that 2 is here, and 3 is here, 4, 5, 6 like 13 is here, 11 is here, 10 is here.

So, we can see that each of these grains have a particular intensity of a crystallographic axis parallel to ah an important sample reference directions, and it could be the rolling direction or the normal direction or the transverse direction or x y z important reference direction of the sample right.

Using an inverse pole figure, one can obtain this important sample reference direction. So, if there are three important sample reference directions, we have to use three inverse pole figures to decipher the exact texture of that particular material. So, a very old paper in 1969 by Bunge and Roberts in Applied Crystallography showed the inverse pole figure for a rolled sheet. They showed that this is for a cubic crystal poly crystal, cubic poly crystal, and they showed the high intensity points here at 111 poles. And this intensity point reduces, and then they are various low intensity points present here. So, that there is a huge spread in the texture component. The component does not seem to be a single component, but it is spread from here 111 to 323 to 211 and 123, and thus forming a kind of a fiber right.

So, not the that the important sample reference direction that particular one say it is the rolling direction, does not have a single component along it right, single crystallographic pole around it. It has multiple pole along the rolling direction right. It can be shown using this inverse pole figure.

On the other hand, the another paper and this is a relatively new paper 1998, not new, very old paper by Rollett and Wright in Texture and Anisotropy, they showed the inverse pole figure of titanium and deformed titanium which is a hexagonal close packed material. And that the inverse pole figure shows three important sample poles or directions that is 001, and these are miller (Refer Time: 08:20) indices which we have learned in previous class says and 112 bar 0, 101 bar 0. So, one can observe that the texture intensity is very high along the 101 bar 0 might represent a very important sample reference direction, and then it reduces. Therefore, there is a very large spread right. So in this way that texture can be represented in terms of inverse pole figure.

in this case the reference system is not the important sample reference direction, but the reference systems are the important crystal reference directions. Thereby important sample reference directions are shown here right.

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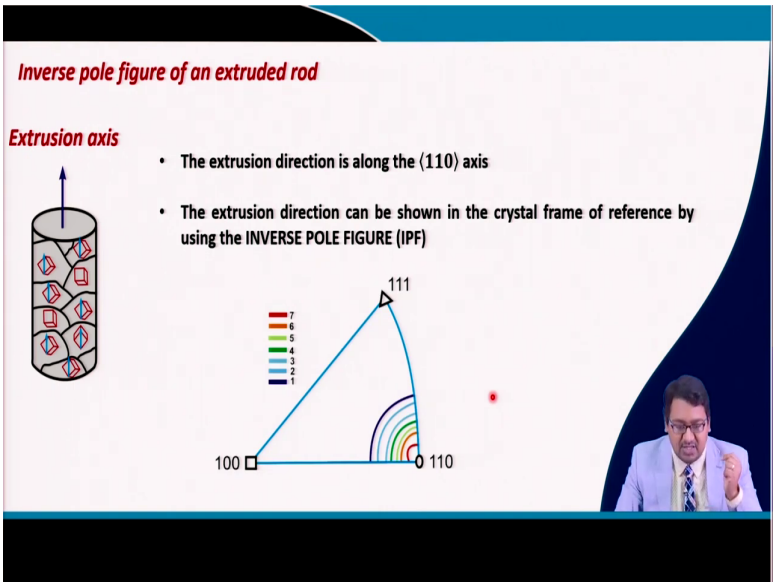

So, most of the time the inverse pole figure is usually shown for axial deformation. And why? Because in an axial deformation like an extrusion process or a drawing process, there is an important direction a single important direction which is the axial direction and that is here the extrusion axis, in some case it could be the drawing axis like that.

So, say for example, if we have a rod produced by an extrusion process, and it has a certain number of grains with a particular intensity of texture component say these components they are specially separate out, but they have certain intensity and so that it shows of as an intensity in the texture. Then that these are those crystals, which shows that the extrusion axis is parallel to 110. Therefore, these are 110 axis. So, if the extrusion direction is along the 110 axis, then we can show the extrusion direction in the crystal frame of reference using this inverse pole figure abbreviate as a abbreviated as IPF here right. So, the texture corresponding to the extrusion axis is shown as high intensity points spread from 7 to 1 in the 110 direction of the inverse pole figure.

So, this is how the inverse pole figure is used to represent the texture. Most of the time it is used to represent the texture of material, which has been axially deformed. So, axial texture usually shown by inverse pole figure to describe them right ok.

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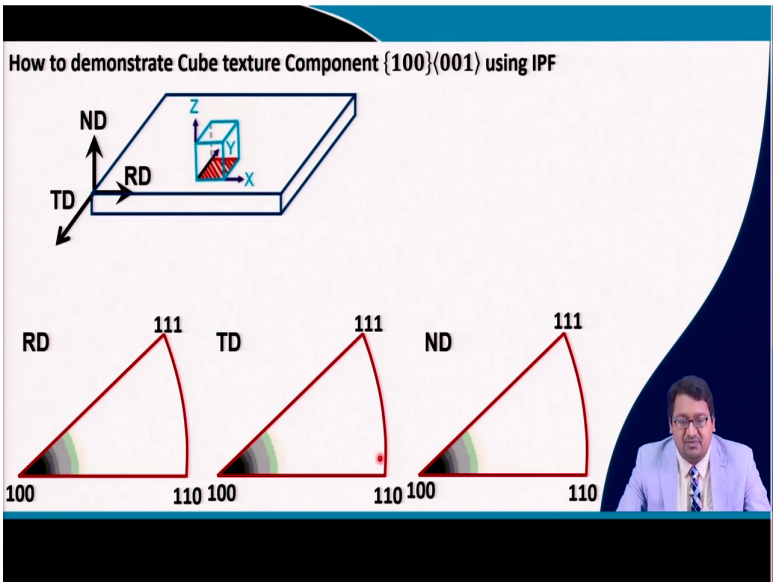

So, now let us let me give few examples that can lead you to understand more in detail about the inverse pole figure. Now, let us say we use a rolled sample and the roll sample has three important sample reference directions that is RD and NTD. We use the same cube texture component which is 100, 001. Now, if you as I said and we have seen about this texture cube texture component a lot in the previous lecture too, and then those we have RD parallel to the x, y and z of the cubic unit cell which is the 100 axes. If we draw the inverse pole figure, we draw the RD inverse pole figure, TD inverse pole figure and the ND inverse pole figure to represent the texture as a pole in using three inverse pole figure. So, what would be it? So, in the RD inverse pole figure, if the inverse pole figure is made out of 100, 110, 111 all the time. Therefore, RD is parallel to 100. St will be showing high intensity here. The TD is parallel to Y which is another 100, 0 0 010, so it will be showing intensity points here. In addition, the ND is parallel to 001, which will also lead to form a high intensity point here. So using three inverse pole figures, we can represent the texture for a particular cube component here.

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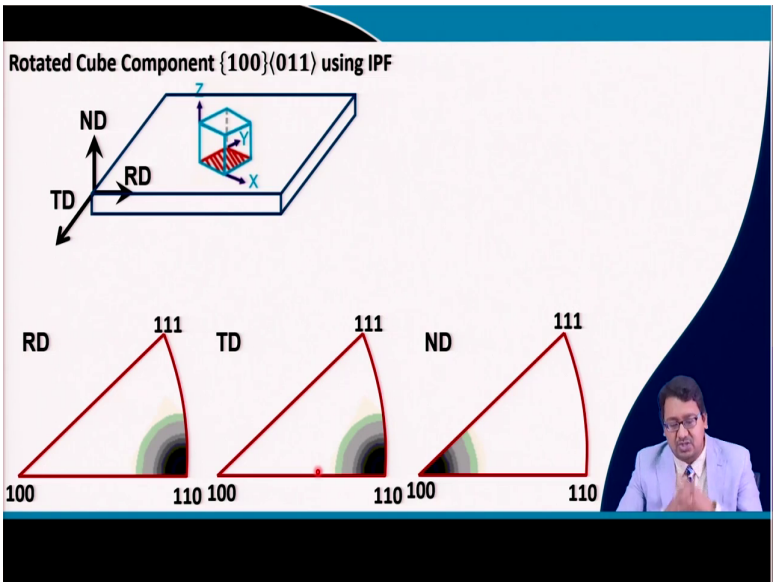

So, rather than using a cube component if it is a rotated cube, now it is 100, 011 the same examples that we showed for the pole figures. ND is parallel to 001. If we look into the ND inverse pole figure, we see that high intensity is coming along 100, so in the 100 pole family right. On the other hand, if we look in the RD, and it is it is in between x and y. So, if x is 100 and y is 010, so the RD is parallel to 110. Therefore, the intensity of RD will come in the RD inverse pole figure at 110. On the other hand, TD which is perpendicular to both RD and ND forms along another 110 which is perpendicular to RD 110 right. It forms at another 110. Therefore, the TD inverse pole figure will also show an intensity point at 110 right.

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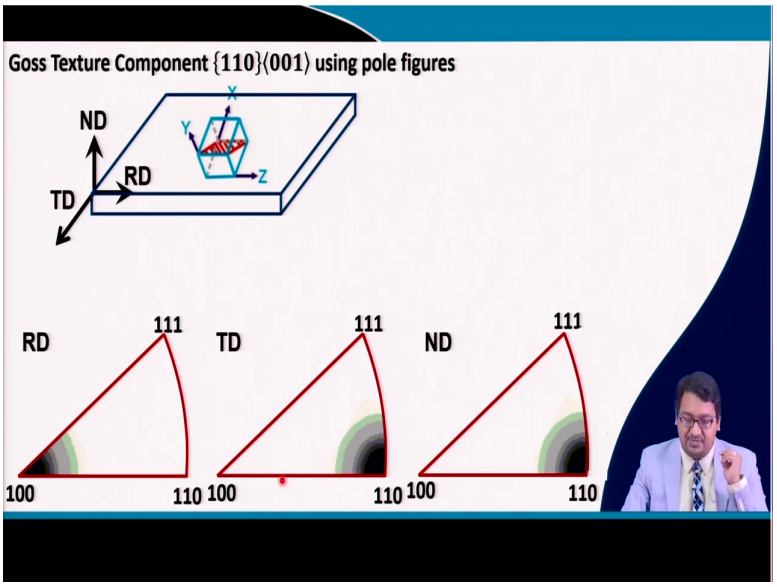

Now, let us talk about the Goss structure component 110 001 type texture component using the inverse pole figure right. In this case, ND is parallel to towards this direction, which is 110 right 110, and RD is along z, which is 001. The RD inverse pole figure will show intensity at 001, whereas the ND inverse pole figure will show intensity at 110 right. Now, where what will be the intensity point along the TD. That in this case the TD is parallel to another 110. In addition, one can find out this by using a cross product between the RD 001 and the ND 110 to obtain that TD is also along another 110, and therefore, the TD inverse pole figure shows the position 110.

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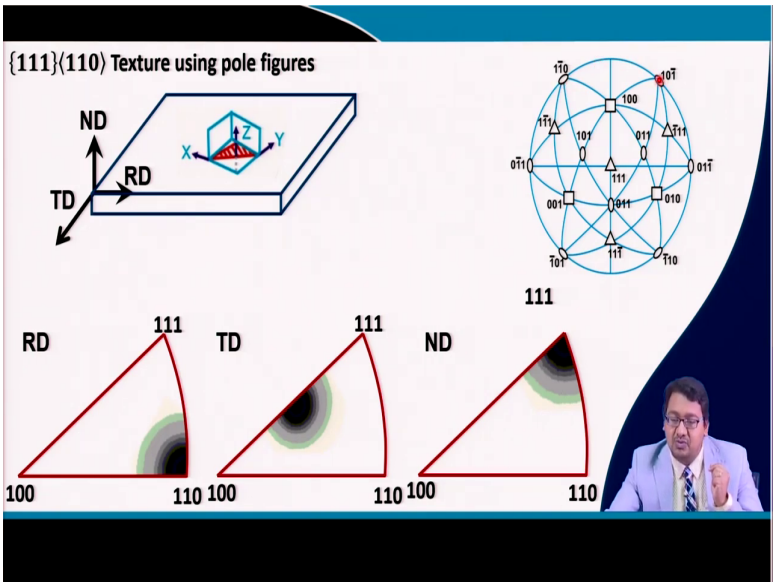

So, let us use the 111, 110 texture using the inverse pole figure. And this is the same example. ND inverse pole figure shows us its intensity along 111. On the other hand, the RD inverse pole figure shows its intensity at 110. In addition, where will be the intensity of TD? Now that if we make a cross product of 111 and 110, you will find that, the intensity of TD comes at along 112. Therefore, 112 will be in the equal angular division between 111 and 100. It will come somewhere in between and if you add 100 plus 111 somewhere here it will be 112. We can obtain this using the stereographic projection of 111. You can see that if 111 at the center. You can see if 011 is at 90 degrees to 111 here then at exactly ninety degrees to both that is here this is 112 poles or positions. This one can find out by adding these two 11 bar 0 and 101 bar poles. If you add them, it forms 21 bar 1 bar here. Thereby the TD pole that is shown by the inverse pole figure has the intensity point here, which is 112.

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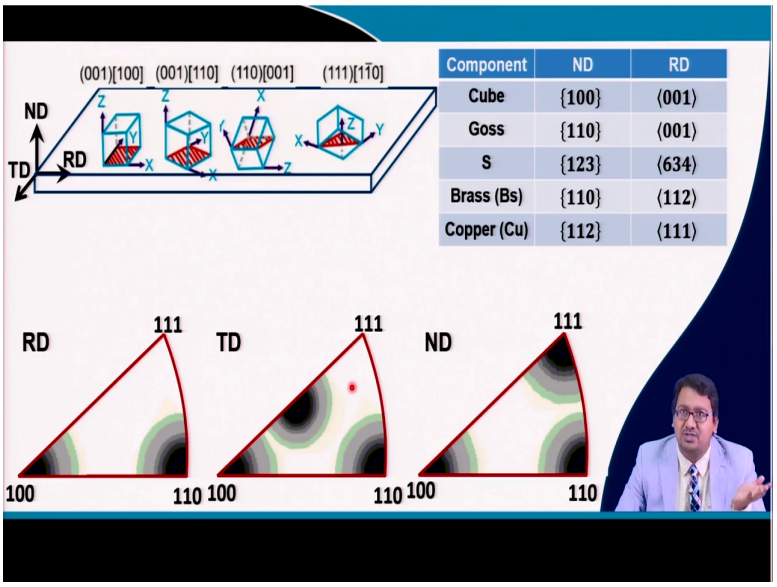

Now, let us go ahead. As we observed in the pole figure right, more than one components may present in the material leading to formation of texture fiber rather than texture components. So, say for example, we have used two different not all the four, but two different cubic unit cell. We have shown them in the inverse pole figure. If you look at the ND, if you look at the ND, we have intensity points at 100. So, it, so it is, it can be cube texture, it can be rotated cube too, it has intensity points at 110. So, it can be Goss texture. It has intensity point at 111. Therefore, it could be 111, 111 one sorry 111 11 bar 0 right.

Now, let us look into the RD. If we look into the RD, we see that RD is parallel to 100. Thereby it can represent this cube component. The RD is also parallel to 110. So, it can represent the rotated cube component. RD as parallel to one 100 represents the Goss texture 2. And RD represent this texture.

So, if all the four texture are present, then the inverse pole figure for RD, TD and ND may look something like this. In addition, thereby when this texture component will have a rather large spread then they will not look as separate component, but they will look as fibers. Like this hypothetical example, we may have cube Goss, S, brass and copper components of these miller indices present all over at the same time in case of face centered cubic material as we have seen earlier, and thereby leading to formation of fiber texture which could be easily represented not only in pole by using pole figure, but by also using inverse pole figure. So, based upon the utility and the usefulness, sometimes we use miller indices, sometimes we use

pole figure, and sometimes we use inverse pole figure to represent the texture, texture components, or texture fibers right.

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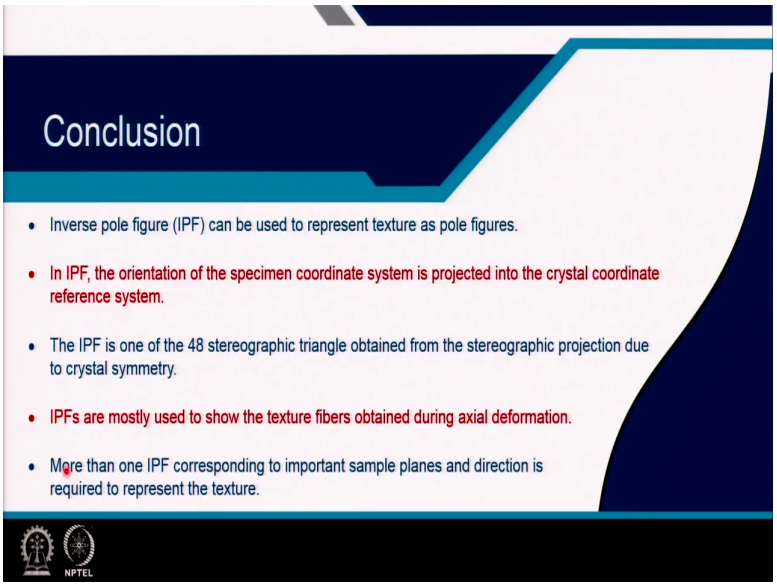

So, it can be concluded that inverse pole figures that is IPF in abbreviation can be used to represent texture as we represent texture using pole figure. In inverse pole figure, the orientation of the specimen coordinate system is projected into the crystal coordinate system reference frame right.

The IPF is one of the 48 stereographics triangle obtained from the stereographic projection due to crystal symmetry. And this I am talking about the cubic crystals only. The number of stereographic triangle present in case of orthogonal orthonormal or triclinic or hexagonal system will or may be different.

The IPFs are mostly used to show texture fiber obtained during axial deformation. So, IPF maps sorry IPF - Inverse Pole Figures are mostly used to show the texture fibers which is obtained during extrusion, drawing, or any other axial deformation like compilation open dye forging kind of situation. More than one IPF corresponding to important sample reference planes and direction is required to represent the texture.

So, you need if there are three IPF, then you need RD IPF, TD IPF and ND my IPF to represent the texture.

Thank you.