Texture in Materials
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Module - 10
Texture in FCC, BCC and HCP materials
Lecture - 49
Texture in BCC Polycrystals - I

Good afternoon everyone and we are continuing with the module 10 which is Texture in Face Centered Cubic, Body Centered Cubic and Hexagonal Cubic Crystal Structure Materials ok. So, this is lecture number 49 and we will be starting with Texture in BCC Polycrystals. This is part 1.

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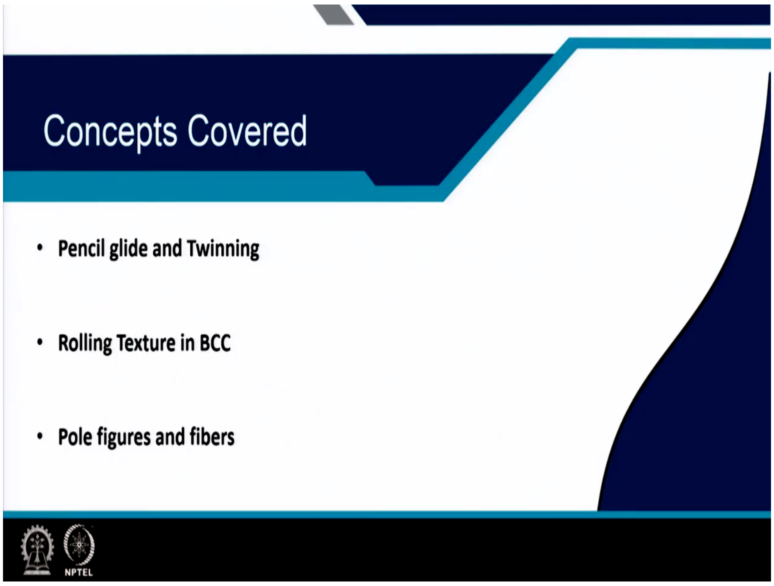

So, the concepts that will be covered in this lecture are Dislocation Pencil Glide and Deformation Twinning. You know we will just give you the basics of it and we will introduce to it and in this course, as you know that, we are hoping that these fundamental things, you already the students who are doing this course already know about it and therefore, it is just a revision for you.

So, secondly, Rolling Texture in Body Centered Cubic and we will show this texture in terms of pole figures and fibers so.

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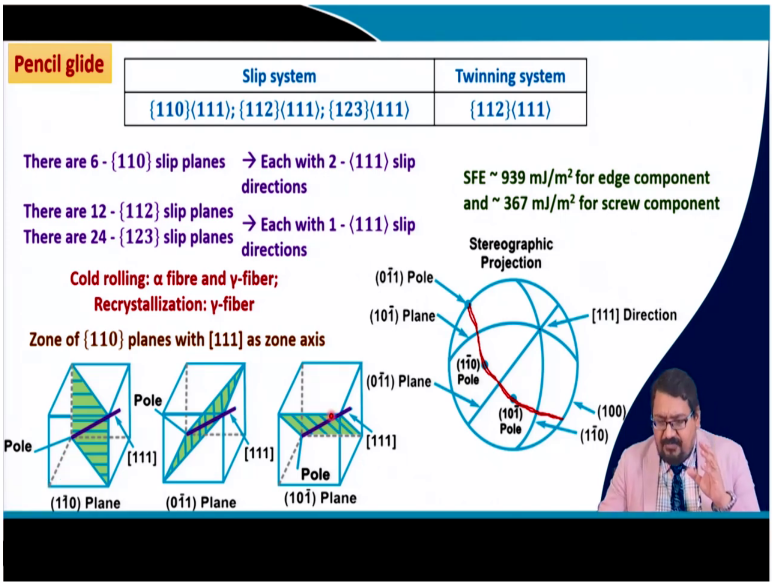

Pencil glide as discussed in previous lectures too, the Body Centered Cubic Material has no closest packed plane or closest packed direction. The most close packed plane in case of Body Centered Cubic Material is 110 plane and in this 110 plane, there are 111 direction which is the closed packed direction, not the very in the closest possible direction.

But, the closest direction in BCC. So, there are 6 you see, 110 slip planes and each 110 - 6 plane 110 slip plane have 2 - 111 slip directions right. So, on the other hand the there are 112 slip planes, 123 slip planes in which the Body Centered Cubic Material can slip along the 111 slip direction.

And this slip planes becomes active at say a different temperature or a warmer temperature or a high temperature or a different strain rate, that is higher strain rates. So, there are 12 you can see 112 slip planes, each having 1-111 slip direction. On the other hand there are 24 - 123 slip planes which have you know 1-111 slip direction.

So, if we calculate them then there are 6 into 2 12 110, 111 type slip system right. There are 12 112, 111 type slip systems right and there are 24 123, 111 type slip systems in it. So, totally there are 12 plus 12 plus 24 is 48 slip systems are present in an usual you know Body Centered Cubic Material and therefore, Body Centered Cubic Material usually deform by all these 3 slip systems under different conditions of temperature and strain rates.

On the other hand, there could be twinning that may occur in certain Body Centered Cubic Material and these are 112, 111 type twining. Now, if we look into the stacking fault energies of this Body Centered Cubic Material.

If we are looking into you know steel or iron which are having a ferritic microstructure ferrite, which is body centered at you know lower temperature, at ambient temperatures then the stacking fault energies of the edge component and the screw components are very high.

You see for the edge component it is about 939 milli joules per meter square, whereas, for the screw component it is 367 milli joules per meter square. So, most of the Body Centered Cubic Material represents a material of a type of a high stacking fault energy material and therefore, they deform mostly by you know slip activities which is called a Pencil Glide. Because the slip direction remains the same whereas, the you know slip planes keeps on changing because of the activity of the screw dislocation to cross slip from one plane to another in order to produce a mechanism which is known as a Pencil Glide right.

So, most of the time because of the presence of a large number of slip planes for a particular slip direction, a deformation does not produce certain component but rather it produces fibers during the deformation and the recovery recrystallization process.. So, if it is a cold rolling process and the texture is obtained mainly because of the cold rolling and there is very less activation of recrystallization processes, then both alpha fiber and gamma fibers seems to form.

Whereas, in case of rolling which is accompanied by dynamic recrystallization or if it is recrystallized later statistically then gamma fiber forms strongly and this is the main two fiber which are usually observed in case of Body Centered Cubic Material particularly in case of steels and ferrites, ferritic steels.

So, if we look into the crystal structure of Body Centered Cubic Material and we see the different planes that are activated. So, in order to look into this let us take the 111 as the zone axis. And let us look into these crystal structures and let us look into the stereographic sphere or you know circle to find out that how this slip systems can operate and how to get an idea that how pencil glide basically takes place. Now, if we look into the zones of the 110 planes for the 111 zone axis, you will see that let us say that this is a crystal structure this is a cubic crystal for the BCC and this is the 111. Definitely it will be the body diagonal of this crystal structure and we have also looked into this part earlier in you know in one of the previous lectures..

So, if you look, you see the 111 direction is in a 110 plane and this particular plane is you see 110 right. On the other hand, you will see that it also lies the same direction 111 also lies in another 110 plane and it also lies in another 110 plane. So, a single 111 direction can lie in 3-110 planes and therefore, the deformation can sustain in terms of a pencil glide along this 111 direction where the dislocation plane can shift from one 110 to another 110 among these three. So, if we look into the stereographic projection of this particular situation, we can see that if this is the 111 direction where my pointer is and this 111 direction is shown in terms of the 111 pole consists of you know the great circles of the 110s.

So, the first great circle comprising of this, is this one; the great circle comprising of this, is this one and another great circle which is this one for this plane. So, it consists of this three great circle which is passing through this pole. So, the 110 poles corresponding to each of these great circles. So, for this great circle this one, for this great circle this one and for this great circle it will be either here or here.

If they lie at 90 degrees away from this pole and therefore, if we look into it a little deeper, let me take the pen, then if we if we connect this and you will see that this will form the great circle comprising of this 111 direction. So, this great circle is at 90 degrees to this point right.

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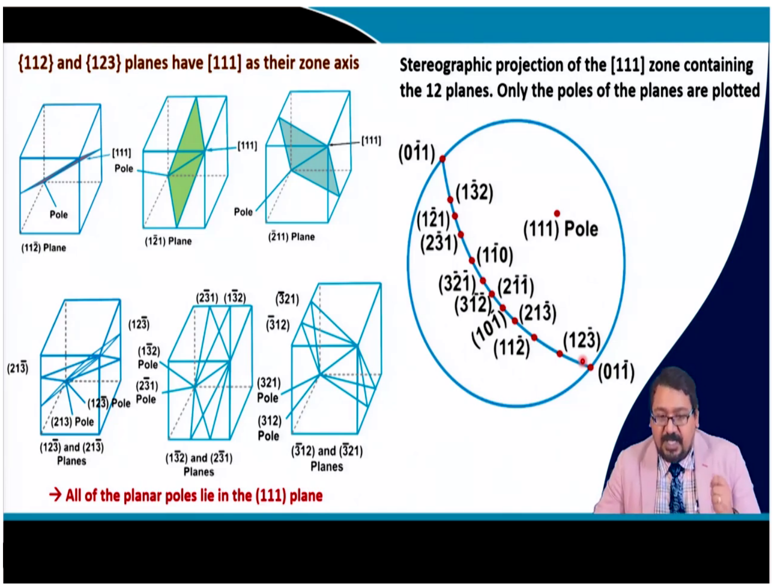

So, if we look further, we will see that not only the 111 planes passes through the you know this particular 111 the sorry the 110 planes passing through thus this 111 direction, but also there are 112 planes and 123 planes. So, we see that if we take the same 111 direction, you see for this three cube that are the unit cells for the BCC, it comprises of 112 bar, 12 bar1and 2 bar 11 type plane.

So, these three planes 112 types from which this 111 direction is passing through. On the other hand if we look here for the 123 type planes for this same 111 direction, 2-123 this one and this one right. On the other hand if you look this 111 direction, this 123 once again, this 123 and this 123, on the other hand for the same 111 this plane and this plane.

So, 6-123 planes are passing through the same 111 direction. So, if all the all of this planar poles are lying in this 111 direction or; that means, we can say it in opposite sense that if all this planes poles lie in this 111 plane. Then we can show that in a form of a stereographic projection of the 111 zone, which is here, containing all this you know 3 plus 6 and the 110 which is again 3-110 that is total 12 planes lying in the great circle comprising of the 111. So, you see the 110s, the 112s, the 123s are all present and there are 12 you know poles showing all these 12 planes in a great circle comprising of the 111 direction. So, in this is the way by which the Pencil Glide in case of the Body Centered Cubic Material takes place during plastic deformation.

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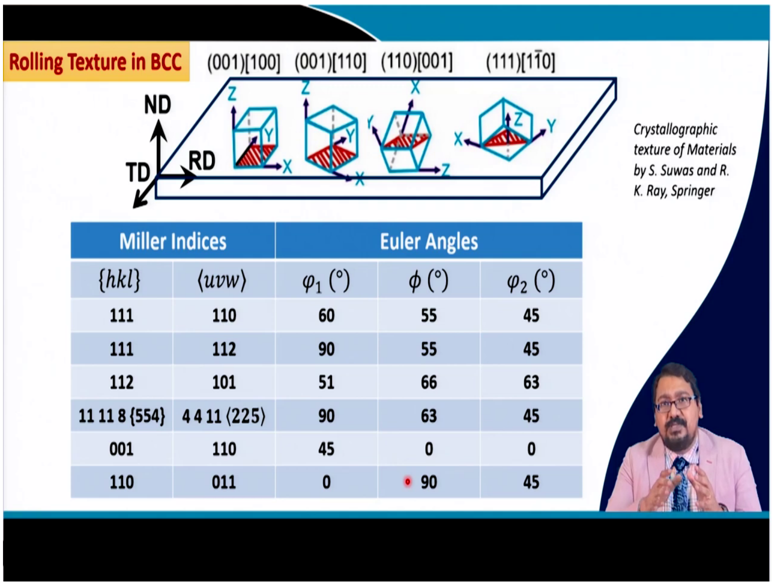

If we look into the rolling texture of these BCC polycrystalline materials, example is as I said ferrite that is the for the steels that is alpha ferrite, if this is the rolling, direction if this is the normal direction ND, ND is normal to the rolling plane.

And this is the transverse direction which is normal to both ND and RD we can see that there are typical components that develops in the BCC material contains, you see 110 001, 001 100 right, 001 110, 110 011 not shown here, 111 11 bar 0.

So, few components that forms here has been shown in this figure and all the components that can develop during a rolling process of a BCC material polycrystalline material is shown in this you know table.

You see 111 110, 111 112, 112 101, 11 11 8, 4 4 11 right. One can say it is 554 225 or 001 110, 110 011 and they all form at different phi 1, phi, phi 2 in of the Euler space. Now, as we said earlier in case of the FCC material which is also true for this BCC material that when a load is applied when for a plastic deformation in a polycrystalline material. The applied load plus the load associated with grain boundary contiguity is actually provided to various positions in the you know in the billet or the of the material.

Now, the stress tensor at the grain boundaries or near to the grain boundaries will be different and it will be more affected by the grain boundary continuity. And as we go away from the grain boundary towards the center of the grain, the stress tensor will slightly slightly vary and at the center of the grain there will be less effect of the associated stress with respect to the grain boundary continuity.

So, the stress state at different positions of the microstructure not only differ, it also differs the stress sensor also differs in a single grain at different positions. Thus this leads to the increase in the spread of the component and thus it forms a kind of a fiber, instead of forming separate separate components during the deformation. In case of Body Centered Cubic Material apart from this as the deformation is associated with Pencil Glide.

So, the planes keeps on changing while the direction remains the same and there are presence of multiple 111 directions in the material. So, the formation of fibrous kind of texture is more prominent in case of Body Centered Cubic Material than even in the face centered cubic material.

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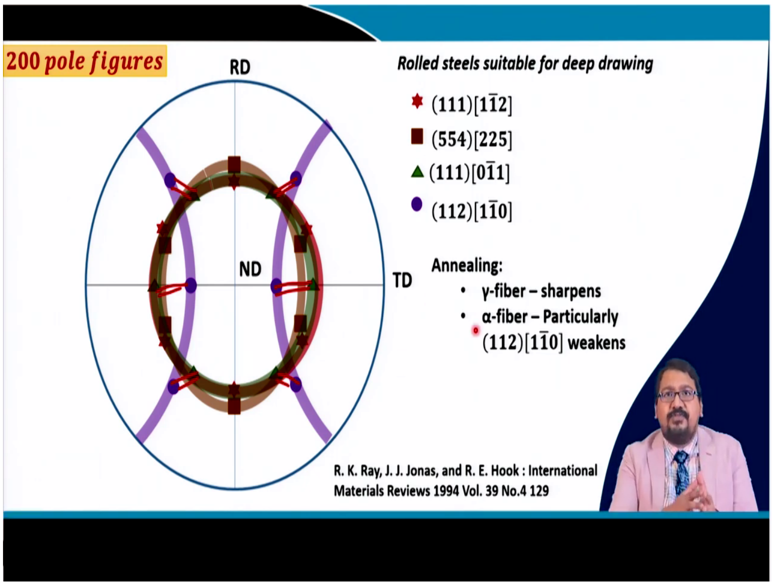

So, if we look into the you know rolling texture in case of this BCC material and we look in terms of the 200 pole figures, we can see that a rolled steel which is suitable for deep drawing has a lot of texture components and we have pointed out this by using different you know symbols.

And this is taken from the paper by Ray Jonas and Hook International Materials Review in 1994, we can see that there are formation of 111, 112 type texture components. On the other hand you can see the 554 type texture components also forms, these are brown squares and then 111 011 type texture components which is which are these components which forms. On the other hand 112 11 bar 0 these components violet round shaped components also develop at the same time during the you know the deformation.

And the deformation process also involves you know dynamic recrystallization or it can involve a later annealing process. So, if we look that the components that are forming are shown in terms of you know spots over the 002 or the 200 pole figures.

Now, as I said in the previous slide that these components will have a larger spread because of the pencil glide situation and also because of the difference in the Cauchy stress tensor at different areas of the microstructure and even within the grains.

So, this large spread will lead to the formation of a fiber kind of texture which will look like combination of this and so, a ND fiber will develop in the microstructure. This ND fiber are more likely is the gamma fiber and this gamma fiber will be more properly visible using a Euler space or a orientation density function. On the other hand you look that this kind of fibers will also develop and this is this is a TD fiber right.

Now, important fibers here in case of BCC are the gamma fiber, which you know, sharpens during the static annealing or if the deformation is carried out at a warmer condition or a hot condition that is rolled under hot condition. So, that dynamic recovery along with dynamic recrystallization takes place. Now, the alpha fiber which consists of the fiber between you see the 111 110 and 112 110s that is the fiber if I say fiber which could be between these. You see these, these ok and in other positions too they we can because the 112 110 type components, they get weakened during the process of annealing.

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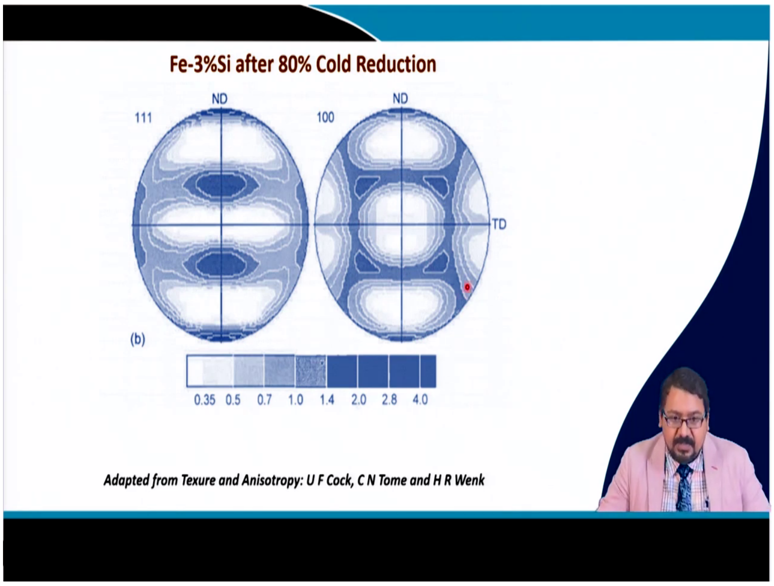

Now, if we look into few example and this is an example taken from the book of Cock, and Tome and Wenk of Texture and Anisotropy and this is an example of Fe 3 Si. You know electrical steel after 80 percent of cold reduction, we can see the formation of all these texture components in terms of fiber if you look into the 100 or 200 pole figure. And the fibers that I have typically shown using a schematic in the previous slide can be observed in terms of these fibers here without any distinction.

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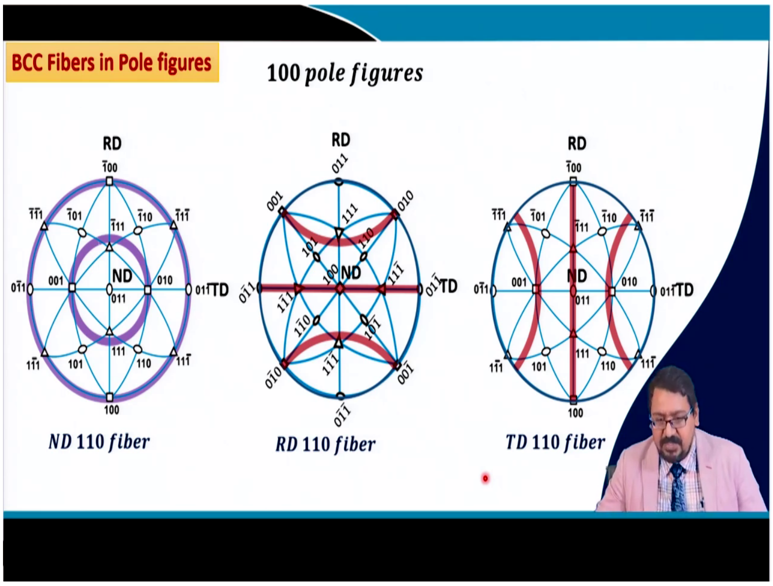

Now, if we look into the various BCC fibers that forms during the process of you know some kind of plastic deformation, this is 100 pole figure and in which we are trying to show the 110 type you know fiber texture.

So, if it is an ND fiber and the ND fiber the and this is the 100 pole figure, the 110 fibers will form something like this, one fiber will form here and another fiber will form here. If you look how this fiber starts to develop and as we have seen few examples of fiber in earlier lectures, but here also I am giving a small glimpse of it for you to understand. So, we will put say for example, if this is the 110 type fiber, then the center where the ND is should be 110. So, if we are using 110 stereographic projection, we may be able to evaluate it and we see that these are the 100 positions of the poles. So, the poles 100 are here. So, another 100 poles are here. So, if it is a fiber then this 100 is present all over through the circumference. If it is a full fiber and if it is axisymmetric.

On the other hand, this 100 will also be present throughout. So, under an asymmetric fiber, a full fiber the texture will look fibrous like this and these are the 110 fiber texture or 110 type fiber along the ND right. And supposedly this could be along phi 1 there by and therefore, the one at the center is the gamma fiber and even this is the gamma fiber because this comes because of the symmetry. Now, if we look, there could be other 110 fibers and let us say 110 parallel to RD and; that means, after phi 1 rotation equal to 0 degree, the rotation of phi along RD. So, this fiber is the phi fiber that is 110 fiber parallel to RD and in order to decipher this, we have to put a stereographic projection same as the previous one and if we put let us put the 100 stereographic projection here and then rotate the stereographic projection by 45 degree.

So, that the RD becomes 110 that is how we can get the 11, 100 poles for the 110 fiber texture and therefore, if we extend this 001 or 010, we can get this fiber and from this we can get this fiber, from these two we can get this fiber. Similarly, this can be done using this 100 stereographic projection 2 and then we would have to rotate the stereographic projection by 011 then also 110 RD fiber could form at a slightly different position not at a slightly different position at the same position.

Now, on the other hand in case of this the TD fiber can also develop like this, if we take in order to decipher this we have to take a stereographic projection. Which is 100 stereographic projection or 001 stereographic projection and rotate it in such a way that this is the 110 type pole along the TD and therefore, the fiber that is obtained with extending the 100 poles are the TD fiber right. So, in this way full fiber is shown in this these three full fibers comprising of the ND, RD TD 110 type fiber can form and these fiber may be full or partial in nature depending upon the deformation. Deformation mechanism, materials and other situations like you know thermally activated deformation or higher strain rate or lower strain rate and this fiber may change according to the situation of deformation.

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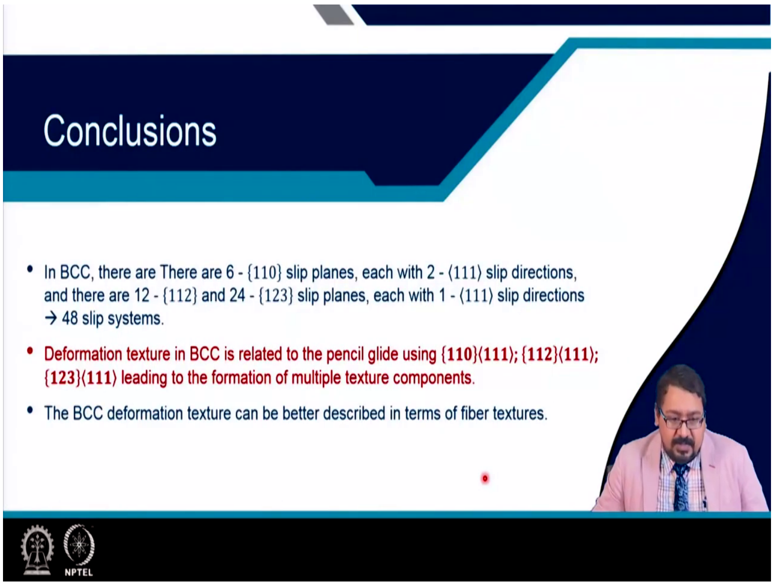

So, we can conclude in this lecture that in case of Body Centered Cubic Material there are you know 6-110 slip plane, each one will have 2-111 slip direction and there are 12-112 slip planes and 24-123 slip planes each having 1-111 slip direction. So, there are total 48 slip systems.

So, deformation texture in BCC is related to the pencil glide 110, 111, 112, 111 and 123, 111 leading to the formation of multiple texture components. So, the deformation texture is better described in terms of fiber texture rather than describing them in terms of you know components.

So, thank you for this class.