Texture in Materials
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Module - 04
Texture representation
Lecture - 10
Pole Figures (Contd.)

Good day to you this is continuation of Module 4 Texture representation and this is Lecture Number 10 and we will continue with understanding how we represent texture using the pole figure Pole Figures.

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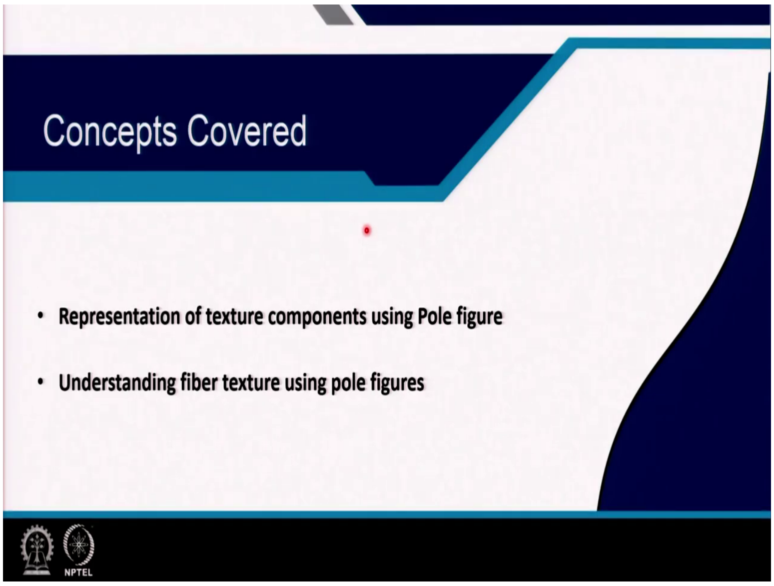

So, the concepts that will be covered in this course lecture are, representation of texture components using pole figure and understanding the fiber texture using the pole figure. So, we have already understood in very detail that how various texture components can be represented in the pole figure and we will take a look into it further.

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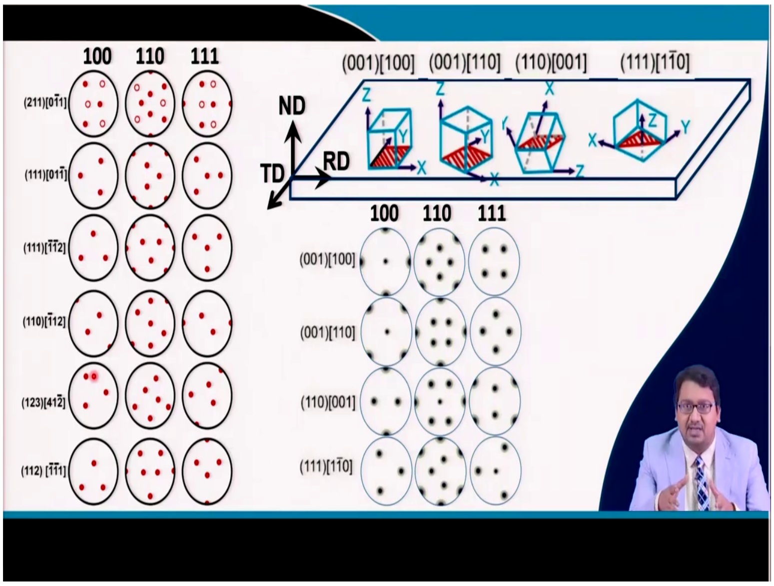

So, in the last lecture what we were observing is that in case there is a presence of a cube texture component like this; then you can see that the pole figures will look somewhat like that and we found out and observed how we can determine these pole figures. The 100 110 and 111 pole figures for the texture component 001 110. Similarly, we also observed that how the rotated cube component 001 110 can be observed in the pole figure, how the Goss component 110 001 can be observed in the pole figure right, and how the 111 110 component can be observed right. So, all these components could be easily determinable because the center of any one of these pole figures represents a HKL plane which can be represented using a standard stereographic projection like for example, in the case of the cube orientation we have at the center the 100. So, a standard 100 stereographic projection can be used to determine these pole figures.

On the other hand, in the case of the rotating cube, it is again 100, in the case of Goss, it is 110. So, we used the 110 stereographic projections, and then we can determine the 100 110 and 111 pole figures right. On the other hand in the case of 111 110, where 111 is along with ND we used the 111 pole figure because the 111 was at the center to determine these pole figures, so to determine the texture. But, that apart from these there could be other components that may form and there could be various other components that may develop right and here are the few examples of them and you can see that I have shown the 100 110 and the 111 pole figures with respect to various texture components having miller indices of the important planes and directions.

Say, for example, this one is the first one 211 01 bar 1 and here you can see that neither of these poles has intensity at the center because the ND or the rolling plane is basically 200. So, in order to determine the positions of the 100 110 111 with respect to the RD which is vertical, the TD which is horizontal in this direction for all these cases, and ND which is at the center, one must first determine the standard 211 stereographic projection right. So, that in this way we can obtain various texture components and you can see here the second one is 111 011 bar which basically we determine from the 111 stereographic projection. And then the third one is 111 112 bar which can again be determinable with the help of 111 stereographic projection; because one of the 111 poles is at the center that is it is at ND right.

Similarly, this one 110 parallel to ND at the center, and thereby in this case too it is easily determinable using the 110 standard stereographic projection. Now in the case of 123 412, you can see that these kinds of poles are obtained for 100 110 and 111 in case of 112 111 such kinds of poles obtained for these pole figures. But that it is not very easy to determine the 123 standard stereographic projection or 112 standard stereographic projection to determine these pole figures. Therefore, we basically have developed mathematical calculations and there is software that is used to identify these poles and the position of these poles can be used to determine the RD UVW and the ND HKL that is the miller indices of that particular texture which has formed experimentally right. So, that another issue regarding this is that when a particular process say solidification process or phase transformation or a process which is kind of a plastic deformation says it is rolling or forging or extrusion or a wire drawing process or even a deep drawing process.

The process involves not only deformation, but it also involves recovery and recrystallization processes, the strain rate of the process is involved and the temperature and everything impacts the deformation behavior, the strain hardening behavior of the material, and thereby the microstructure its morphology and definitely various kinds of the mechanism when involved then it evolves various texture components simultaneously. Thus, the pole figure not only looks like having component points or poles, but it may look like having a fibrous or containing a lot of fibers which becomes difficult to determine using miller indices because then multiple miller indices may be required to identify the texture type right.

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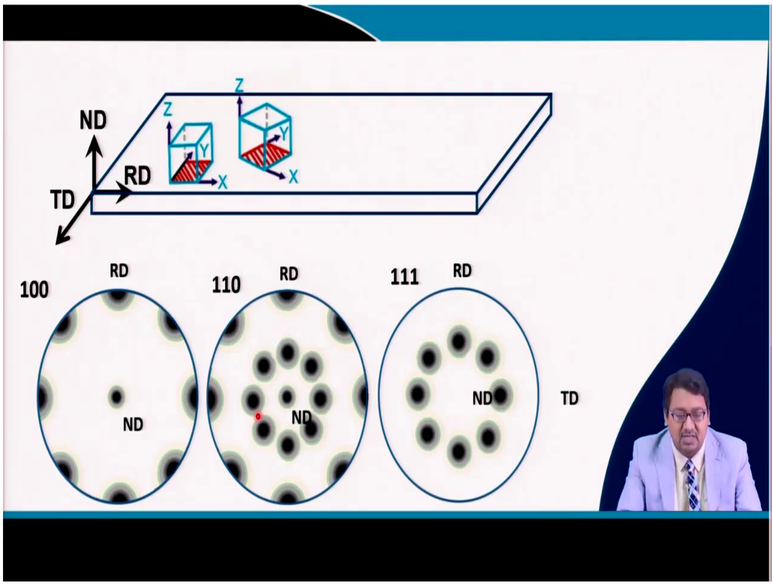

So, let us go ahead say, for example, we have this cubic unit cell present this orientation that is the cube component present in the rolled material and thereby we will have this kind of texture and we have shown this in the earlier lecture that we can have this 100 pole figure positions like this, 110 positions like this and 111 positions like this. Now, simultaneously if the rotated cube is present in the material now the components related to the rotated cube may also evolve right, and thereby the texture now will look something like this in case of and then you can see that if the spread of these components is higher then it will not look like different components rather it will look like a fiber right.

So, you can see that fiber texture may evolve and there could be other components too, but say we it is, but it is very difficult to show three or four components together. So, I am showing only two components together in this case cube and the rotating cube.

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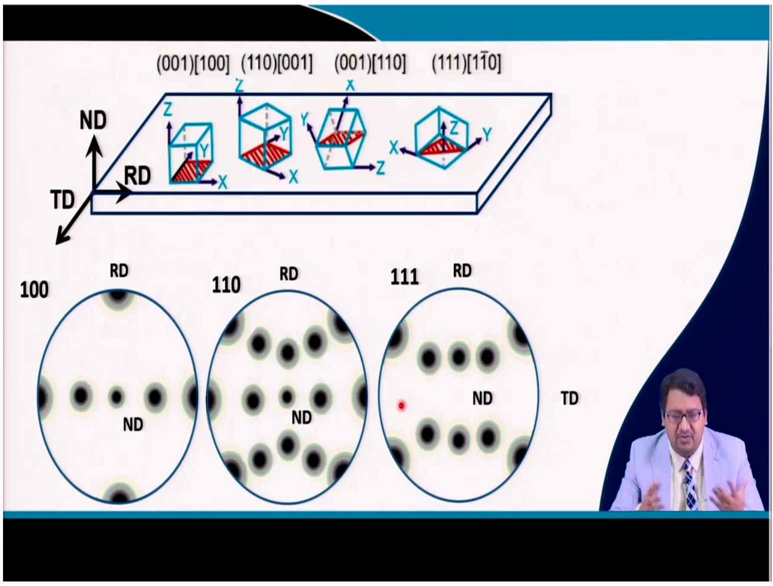

And now I will show the cube and the Goss texture together and it can happen that the cube and the Goss texture may form together and it can happen that the rotated cube is also present. But I am just showing these two together and then you can see that we can observe the formation of fibrous texture and then if the components intensity spread is higher then one may not be able to determine the component itself, but it will look like a continuous fiber right and this can happen for the 100 110 and the 111 pole figure.

In this way four or five different types of poles may present in the material and that will make the pole figures look so clumsy and it will be very difficult to determine right so, but that is the; that is how it is and then using miller indices will be much difficult. So, we basically use and we basically understand the pole figure better this way to show the texture fibers right.

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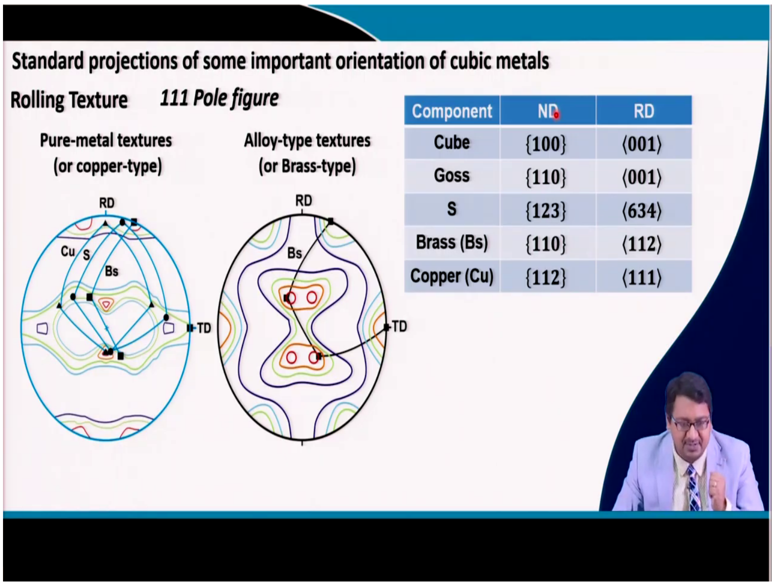

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So, that here I am giving you two examples of pole figures right the one pole figure is the pole figure of material and both of them are basically pole figures for the cubic metal. that if we look at one of them it has a texture component or texture fiber-forming here and another texture fiber-forming something here and here. So, there is an obvious difference between these two these two pole figures are 111 pole figures coming from two metals one having a high stacking fault energy, another having a low stacking fault energy. So, two face-centered cubic materials one having a high stacking fault energy central aluminum has a stacking fault energy of 200 milli Joules per meter square and so it is considered having a very high stacking fault energy.

On the other hand alloys such as single-phase brass 70 30 brass has a stacking fault energy it is a single-phase as a stacking fault energy of nearly 20 milli Joules per meter square and therefore, they are known as low stacking fault energy materials. On the other hand, if you have copper pure copper the pure copper has a stacking fault energy of 16 milli Joules per meter square and therefore, is considered to be a medium stacking fault energy. Now, when either aluminum or copper which is in the range of high stacking fault energy or medium when it is rolled the 111 pole figures having ND at the center RD at the top, and TD here looks something like this one right. On the other hand, if low stacking fault face entered cubic material like brass is rolled and then the texture evolves looks something like this.

Now, that both the texture that are forming are not only the formation of components but there is a high spread and it is like fiber with high intensity, low intensity, high-intensity points forming a fiber. Now that the difference in the formation of this texture component depends upon the mechanism which the material has worked during the same experiment which is rolling right. In case of high stacking fault energy materials during the rolling process the while the slipping is taking place and when this is a face-centered cubic material the deformation takes place by the one in the 111 planes in the 110 direction because the 111 plane is the closest pack plane and the 110 direction is the closest pack direction.

in a face-centered cubic material, there are 4 111 planes and there each of them has 3 111 directions and therefore, there are 12 independent 4 into 3 12 111 110 slip systems that can be used during the deformation. Now, when we talk about high stacking fault energy face-centered cubic material like aluminum or medium stacking fault energy material copper then in such cases the, when the 111 dislocation is deforming it form partials of 2 112 and the separation of this partial, is not very high when the stacking fault is very high. So, while the deformation is taking place we will come to this point later that for a polycrystalline material to deform 5 independent slip systems are required because there are 5 strain components that are needed to be satisfied in 3-dimensional space. So, when a particular 11 plane is deforming along a 110 direction.

Then what happens is that that after some point this they form partials of 112 and then after some point when it tries to move into another 111 planes, then the partial come together and then the screw dislocation basically cross slips to another plane and then what happens that the edge dislocations also climb and this leads to the process of dynamic recovery along with the deformation. On the other hand, when the stacking fault energy of the material is low and that is in the second case like what happens is that such kind of the partials are far apart and the cross slipping of the screw dislocation is prohibited and thereby because it cannot come together to form us perfect dislocation to cross them into another 111 planes and thereby the deformation mechanism is devoid of recovery.

The deformation is sustained by the formation of deformation twins in this process and thereby the as the deformation the slip mechanism recovery mechanism and twinning mechanism basically changes from high stacking fault energy to low stacking fault energy the difference in the texture exists and therefore, that we obtained various kinds of components. In this case, we have identified copper component positions here S component positions here and brass component positions here right. So, and here right. So, copper, brass, and S components form in this position in case of high stacking fault energy material and therefore, it is known as pure metal texture or copper type texture. On the other hand, the position of the brass components can be observed very strongly in case of low stacking fault energy material texture that is alloy type texture or brass texture right.

So, just to let that while deformation plastic deformation by process of plane strain compression which is basically the process of rolling various kinds of texture components develop in the material and the important texture component that develops in case of the face-centered cubic material having a high stacking fault energy is the copper texture having 112 111 texture component. And this can be observed in the pole figure and this is the 111 pole figure at these positions and there are other positions too. On the other hand, the brass type texture and deformation texture evolves because of restriction in the recovery process and because of the formation of twinning the change in the mechanism from in case of low stacking fault energy and which is 110 112 types forms in the case strongly in case of this the second pole figure right.

Whereas the brass is also present in case of the high stacking fault energy copper texture in a slightly lower intensity. There are other components that develop due to recovery and recrystallization that is S component which is more prominently present in the case of high stacking fault energy 123 634 type of component whereas, the Goss and cube component may also form because of the recrystallization processes. So, various kinds of texture components may present at the same time in the material leading to changes in the component type texture into fiber and therefore, most of the time because various mechanisms take place at the same processing during single processing and therefore, we do not observe the texture in terms of the component rather we observe them in terms of fibers right.

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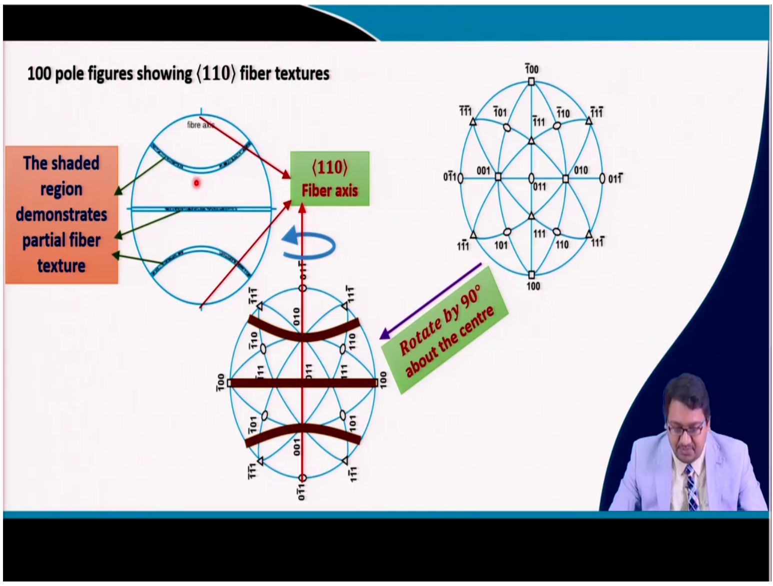

So, that what is a fiber right, that whenever say for another example if we take that when we do an axial deformation and axial deformation like an extrusion process or the process of drawing then the texture that develops forms a kind of a fiber with a single axis along that particular important sample reference direction that is the extrusion direction or the drawing direction or any other axial deformation direction. So, say we have taken a hypothetical example here and we have we are showing the 100 pole figure and here is the 100 pole figure and we are representing 110 fiber texture and what does it mean by that? It means how it means that in the 100 pole figure if we are seeing such kind of a fiber the what I have shown here is that the shaded regions are basically present and the non-shaded region is not present.

And so sometimes partial fiber may also develop right instead of the full fiber. So, sometimes full fiber may develop, sometimes partial fiber may develop and then the axis along which this fiber has developed is and the fiber is named after that axis. So, these 100 texture component fibers or texture fibers are basically nomenclatures as 110 fiber texture because of their fiber axis which is 110 in order to decipher this 110 fiber texture along this fiber axis we can consider either 110 standard stereographic projection or 100 standard stereographic projection anyone. So, I am using the 110 standard stereographic projection here and that the standard stereographic projection is something like that with center 110 and above and below is basically 100, but in this case, the fiber axis is 110. So, basically, we need to rotate this stereographic projection by 90 degrees about the center which is 110 and then we obtain a stereographic projection like this right. This stereographic projection is basically rotated by

90 degrees right, rotation by 90 degrees, and then we obtain this stereographic projection. So, that the 110s are parallel to the fiber axis right. So, if this is the fiber axis then the 110s are present here. Now if we can do that we see that the position of the 100 poles is here, here, here, and here. Now, if we are trying to plot the 100 pole figures then that it is a fiber and it has an axis this and so it can rotate by 360 degrees in any direction. So, we can rotate it, and if we do so what we can see that this 010 or from the poles from the 100 family will rotate somewhere like this and go from the opposite direction and come out somewhere like this forming a fiber which is like this right. On the other hand, this 100 will rotate and go towards this and this one will rotate and go towards this forming another fiber, the same will happen for this 100 where it will start to rotate like this go be from the back of this sphere and come out and rotate like this forming such kind of texture fiber right.

So, these are 100 texture fibers obtained in the 100 pole figure and these texture fibers basically represent 110 fiber axis and are known as 110 fiber texture and you can see that full or partial fiber may exist depending upon the experimental condition or the material or the process right.

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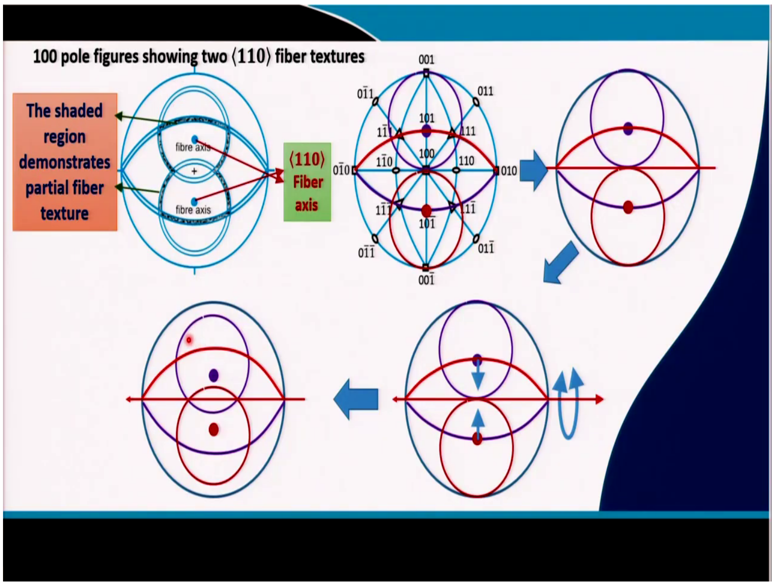

We will give another example showing another 100 pole figure with two 110 fiber texture. In this case, for example, partial fiber exists only like this right and these positions do not exist these fibers do not exist and such kind of texture may evolve. And such kind of texture in 100 pole figure showing 100 texture fibers represent 110 fiber texture because it has a fiber axis of 110 somewhere.

Now, let us decipher this kind of texture using 100 stereographic projections and here I am showing the 100 stereographic projections and that if we consider these and these are the fiber axis because these are 10 110s right. This and this as the fiber axis and then let us talk about any one of them say, for example, this one and then we are showing the 100 poles and if I rotate this fiber axis then this 100 pole will rotate like this and go like this right. On the other hand, if we take another 100 poles which could be either this one or this one because they are 180 degrees to each other and therefore, they are the same. So, they also rotate while this axis is rotating rotate and go like this from here to here. On the other hand, if we consider this 101 the fiber axis then the same thing can form because of the rotation of this fiber axis leading to the formation of rotation in this 001 pole and in these 001 pole right.

So, that if such a situation exists then with respect to these axis we can obtain 100 texture fibers like this right. Now, this violet rotation is the violet-colored rotation of the 100 texture fibers along with the 11 along this violet 110 fiber axis right and the red colored rotation is on the basis of this 110 in red color right. If now if we consider this red one and we shift this fiber axis a little inside then what will happen that this fiber axis will shift towards the center and all the fibers will also shift little upward right. Similarly, if we take the violet color 110 fiber axis and try to shift it a little below then this same thing will happen right. So, we obtain a similar kind of fiber, and thereby when we will look into this kind of situation where the 110 fiber textures fiber axis are present at these points then such kind of 100 texture fibers will develop in the 100 poles. Now, these 100 texture fibers can be full or they can be partial. So, here we are showing the full 100 texture fiber they and here we are showing partial 100 texture fiber and they represent 110 fiber texture right.

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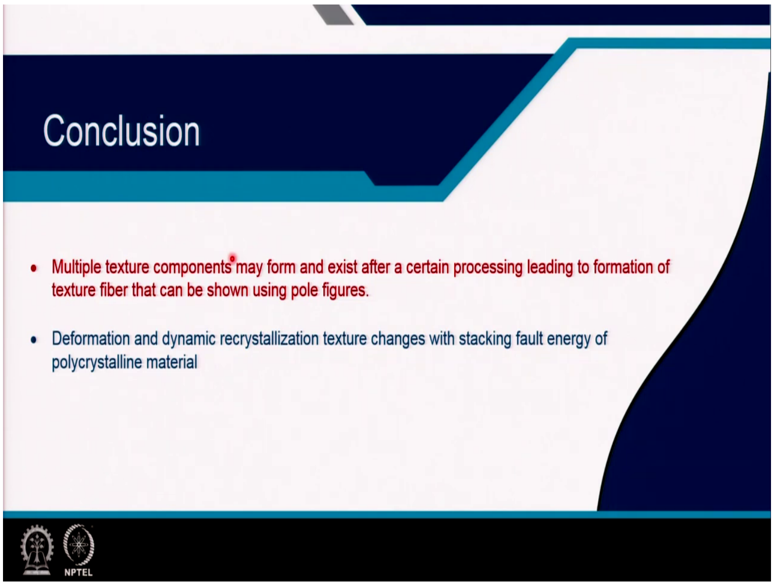

So, from this class, we can conclude that multiple texture components may form and they may exist after certain processing whether it is any process solidification, casting or phase transformation, plastic deformation, recovery recrystallization processes any process. And leads to the formation of rather a fiber texture rather than forming a component right or components various components and this can be easily observed using the pole figures and therefore, most of the researchers use pole figures to represent this.

Deformation and dynamic recrystallization processes change when the stacking fault energy of the material varies and thereby the texture evolved or the pole figure observed vary and thereby we can see them at as sorry as different fiber texture formation in case of high stacking fault energy material or low stacking fault energy material or even in medium stacking fault energy and this is basically known as texture transition. And we will talk about this in some classes later.

Thank you.