Texture in Materials
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Module- 01
Introduction to Crbystallographic Orientation or Texture
Lecture- 02
Texture and Anisotropy

Good day everyone, today is the 2nd lecture course on Introduction to Crystallographic Orientation and Texture, and today we will discuss Texture and Anisotropy.

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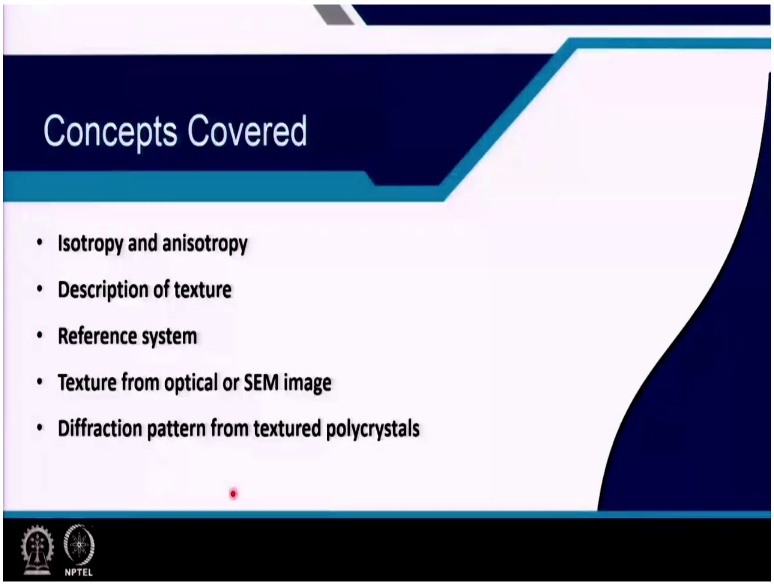

The concepts that will be covered in this lecture are isotropy and anisotropy, description of texture, reference system, texture from optical or SEM image, diffraction pattern from textured polycrystals.

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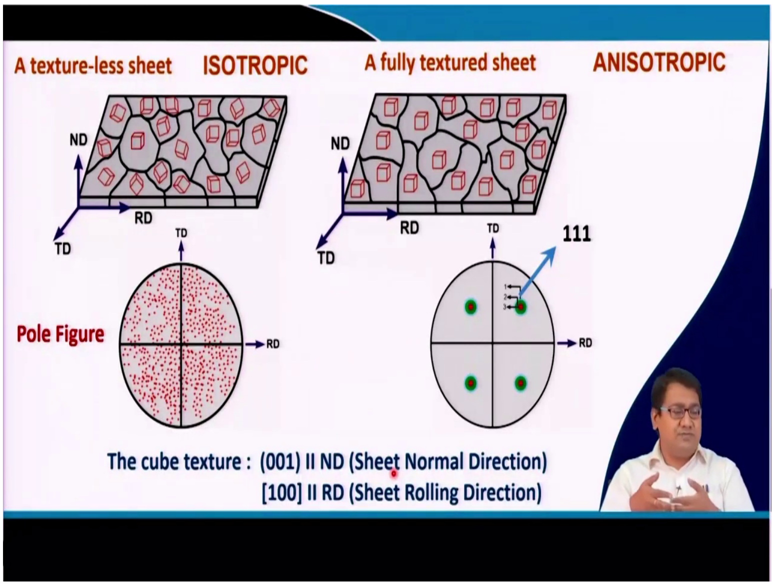

So, in this slide, I am showing two sheet metals; one sheet metal each sheet metals have a rolling direction which is the horizontal or transverse direction and a normal direction, normal direction is the direction that is normal to the rolling plane. So, why I am using this system R D, N D, and T D? Because most of the students are very familiar with this system, and that we all know that the rolling direction is basically known as R D, the normal direction to the rolling plane is basically known as the, N D and the transverse to both these directions are basically known as T D. And I am showing two sheets and one of the sheets, I am showing is a texture-less sheet. And what does it mean by a texture-less sheet? A textureless sheet means that there are multiple numbers of grains present in the polycrystalline material in the sheet metal. And each of these grains, if we are considering them as a single crystal; then each of these grains will have orientations, which are different and they are randomly present in them. So, if there are millions and millions of grains in sheet metal; then none of the grains or none of the accumulation of the grains many grains have a certain orientation, which gives an orientation peak.

So, that each of these grains has a different orientation in a, 360 degree in three dimensions of the space. And so, if we look into the pole figure, we will find orientation present throughout this pole figure. And that a pole figure when we show, we give the rolling direction and we give the transverse direction and in the center, it is the normal direction. And we see that the intensity is not presented anywhere as a large intensity, it is present throughout the pole figure and no peak in the intensity is observed.

So, that means that this material has a totally random texture or you can say that there is no texture present in this material and therefore, the sheet is basically a texture-less sheet. These kinds of materials are impossible almost to develop in real-life scenarios. And these kinds of materials if could be developed will have an isotropic in the material property, so these materials are basically known as isotropic material. On the other hand, let us show another very ideal case in which all the grains are oriented in such in the same way; like that the R D, N D, and T D of each of these grains.

The excess of these greens is oriented along with R D, N D, and T D of the sample. And therefore, one can say if you look into any one of the grains, you have in the horizontal 100 parallel to R D, 100 axis parallel to R D; along with the N D it must be 001 parallel to R D and along with the T D it is 010 parallel to T D. So, all these grains have the same orientation and if such a thing occurs; then we will obtain strong peaks here. And I have shown you a pole figure and this is a 1 1 1 pole figure; do not worry, if you are not able to understand this thing at this moment. But soon you will start realizing that these are simple things as I said earlier and I will come to this in a much more detailed manner. And I am showing basically the 111 pole figure and therefore, these poles are basically coming from the 111 planes. And because of this kind of orientation in the microstructure and if we see that if this is R D and this is T D and this is N D; then that the 111 pole intensities become very strong at these points and such a situation exists, then the material is fully textured. And then this is a total anisotropic material with anisotropy in mechanical properties. So, that what I have done is that between each grain, I have put the same unit cell schematically to show.

Now, if the orientation of adjacent grains have the same, are the same; then the boundary between these two grains must not exist right, because the orientation difference between two adjacent grains will create a misorientation, and then only it can produce a boundary. So, therefore, such kind of polycrystalline material with such a high texture could not exist and so this is an ideal case. And if such a thing exists, then it becomes a single crystal all over. So, textured material like this must have higher high intensity of this kind of crystallographic orientation with respect to the important sample reference directions that is R D, T D, and N D, without which the meaning of texture is not there.

So, we must have a reference system of the sample, which could be anything x, y, and z. And then in this situation when the R D, N D, and T D are parallel to the 100 axes, a family of axis 100, 010, 001; then this kind of texture is known as cube texture or cube component.

It has 001 parallel to N D, which is the sheet normal, and 100 parallel to R D is the sheet rolling direction.

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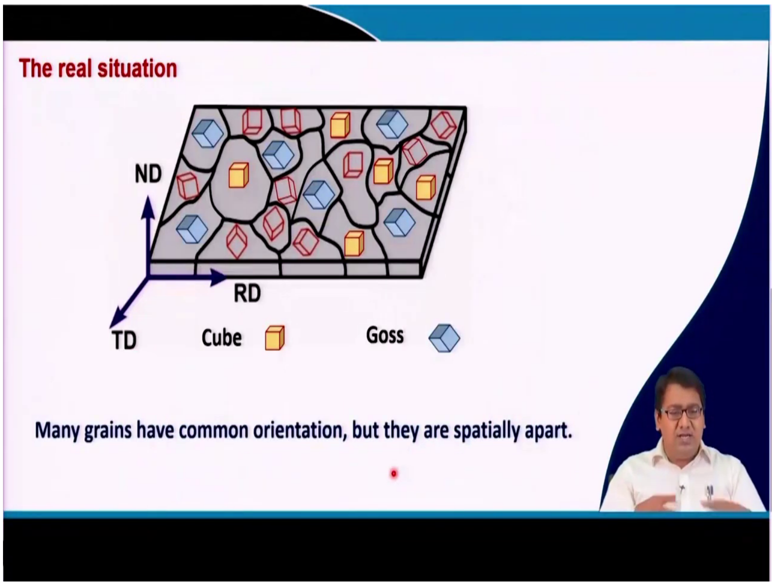

In real life scenario, both the situation of isotropic material and fully anisotropic material cannot form. And therefore, in a situation like this can you usually be observed, and in this situation that, there is a polycrystalline material and we know the important reference directions as it is a rolled sample. So, we have taken it R D, N D, and T D and we can see that there are various grains present in this material and some of the grains have orientations that are different from each other and a few of the grains have certain orientation, I have marked them as colored by red and yellow, red border and yellow area. And these grains all have cube components and therefore, they are cube textures. So, that if we look into this material, we will find a larger intensity of cube components forming when you observe the pole figure or by any other tool of measuring texture. And therefore, there will be a peak in this particular texture component representing these grains, right. On the other hand, there is another kind of texture which was observed and that a large amount of this component.

And we basically call it a Goss component or a Goss texture component and named after the inventor of this component Goss. And that there are a higher fraction of Goss components being present in the material. And therefore, the intensity with respect to these Goss components will be coming when you observe the texture and therefore, this material is the real-life situation of how a texture comes in the material or shows up in the material. And you can see that these texture components whether it is a cube component or a Goss component, are basically spatially apart. So, no two Goss component grains are together, no two cube component grains are together. So, whenever texture is developed in the material in a polycrystalline material by the process of any kind of processing, either it is a solidification deformation phase transformation, based upon its previous history of processing texture evolves. And when the texture evolves, certain orientations pop up with a higher intensity. In this case, we have shown cube and Goss texture for example. And all these textures are coming from multiple numbers of grains, which are present in higher volume fractions, and therefore, that high intensity is coming.

However, because of the polycrystalline nature, if I talk about deformation, the Cauchy stress tensor that is going into the material I am applying a deformation is different from the stress tensor, which is inside a grain or inside various parts of the grain; because to keep the grain boundary contiguity leading to a real-life situation which has texture intensities of various components, but each of these components coming from the grains which are spatially apart.

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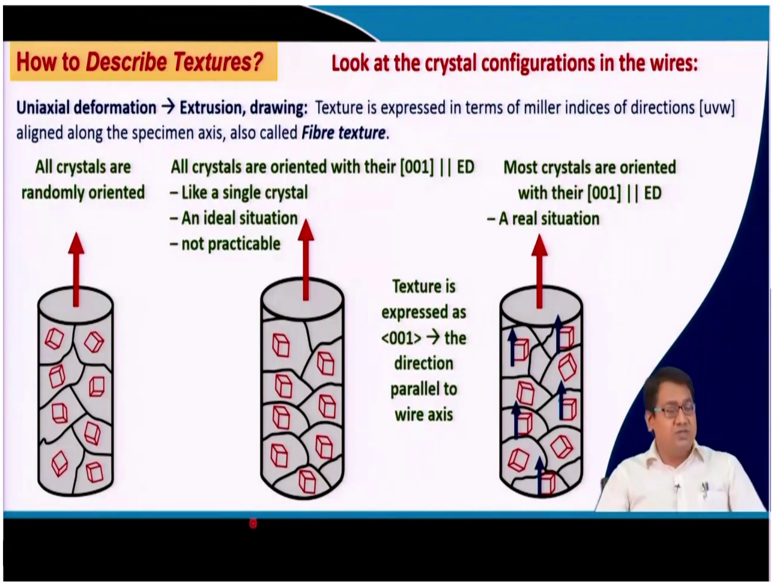

Now, the question is how to describe the texture? Now, if the texture is described for uniaxial deformation; a uniaxial deformation could be tensile deformation is a uniaxial deformation. But that during a plastic deformation process, uniaxial deformation comes through extrusion or it can come to the drawing of wires. So, if we look into uniaxial deformation, the texture is basically expressed in terms of miller indices; that is miller indices of the important direction. And what is the important direction for a material that is being extruded or in being drawing; is the extrusion direction or the drawing direction. And this has been shown by if; if this is the circular rod that is being extruded in this direction, so this arrow shows the important sample directions. And therefore, the miller indices of this direction in terms of u v w should basically represent the texture of the extruded or the drawn material.

So, alignment of that important sample reference direction and the crystallographic important sample crystallographic axis basically represent the texture. If u v w that is the miller indices of the certain direction that coincides with the extrusion direction or the drawing direction; this u v w is basically known as the fiber texture, so we call it u v w fiber texture for that material. This is the first figure. In this that the direction of extrusion is this, but the grains are random. So, the unit cells of the grain are not oriented in a certain direction. So, each grain has a different orientation; therefore the texture is random, no certain u v w could be associated with the extrusion direction or the drawing direction. So, this texture is basically will be a random texture or there is no texture present in the material. On the other hand, as I said earlier that, if all the crystals are oriented with a certain crystallographic axis; in this case, 100 axes parallel to the extrusion direction or the drawing direction, then this becomes again an ideal case, and then it becomes a single crystal and it cannot be made in a real-life scenario, therefore not practicable.

In real life scenario what happens is that most of the crystals will be oriented in a particular orientation say in this case in this example; most of the grains are oriented along 100 or 001 parallel to the extrusion direction. And they are spatially separated by grains, which have different or which are differently oriented. And so, the texture, in this case, has to be expressed by 100 fiber texture parallel to the extrusion direction. So, before we leave this slide, I will say that the first two figures are basically related to the ideal case, where the orientations become random after the processing and the orientation become highly textured with all the grains oriented in the same direction. It becomes an ideal case because it becomes a single crystal and the third case, which is the real-life scenario.

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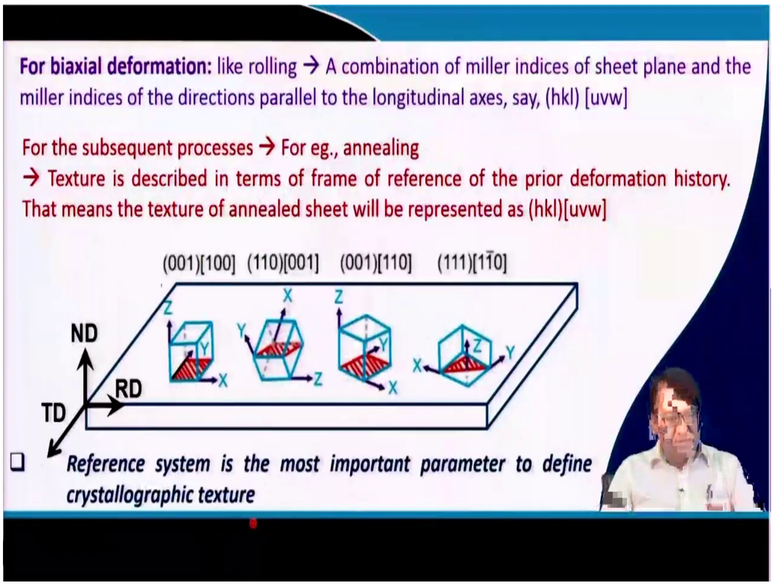

In the case of biaxial deformation, such as rolling or one can say plane strain compression-like plane strain forging methods. A combination of miller indices of the sheet metal and the miller indices of the direction is needed. Say for example, if it is a rolled sample; then the rolling plane, the normal direction of the rolling plane is important.

So, the rolling plane is important. So, the texture is expressed in terms of the rolling plane say that is h k l; on the other hand, the rolling direction is very important. So, the texture is expressed in terms of the rolling direction, which could be u v w. So, even for any subsequent processes after the rolling, either it is a cold rolling or hot rolling; for example, any processes such as static recrystallization methods like annealing, the texture is described in terms of the same frame of reference of the rolled sample. Even if the previous processing is not rolling or any other process; then also the texture is represented in the important sample reference direction of the previous process and therefore, in this case, it will be always h k l, u v w even after the annealing.

See here is an example of sheet metal, a sheet metal says, for example, it's a aluminium which has been rolled; say, for example, warm rolled or hot rolled and so plastic deformation took place. And plastic deformation took place by mostly slip and it can also take place by twinning and depending upon the alloying condition and the stacking fault energy of the material. And that is because the plastic deformation is taking place at a temperature higher than the say, for example, recrystallization temperature. And then there will be orientations, which could be associated with deformation as well as recrystallization. So, in this case, that, one kind of texture developed, and the unit cell of these grains forming this kind of texture, that is 1 1 1, 1 1 bar 0 type texture develops at a higher intensity say for example, but they are especially apart.

On the other hand, one can observe few grains with this kind of texture, the unit cell is shown here; this is 001, 110 types of texture and such kinds of grains will also be present in a higher fraction or higher volume fraction. But they will also have to be separated by means they also have to be separated that is especially apart. On the other hand, other mechanisms like deformation, dynamic recrystallization, and even cooling process and the temperature lead to the formation of this kind of orientation and we know that this is known as the cube texture orientation, that is 001, 110; on the other hand, this kind of orientation, which is basically the Goss orientation 110, 001. And we just a few slides back we came to know the name of these and all this texture could be present at the same time after a rolling process and these textures are present at different grains and each of this texture grains, textured grains will be spatially separated. And there will be other grains whose texture may not match with any of this texture, but they would be not showing a higher intensity in the tool, which could be a pole figure which shows the texture. And so, that whenever we are showing these textures, we are showing that with respect to R D, N D, and T D. And these are important because the texture is always represented in terms of the reference system, which is the most important parameter to define the crystallographic texture.

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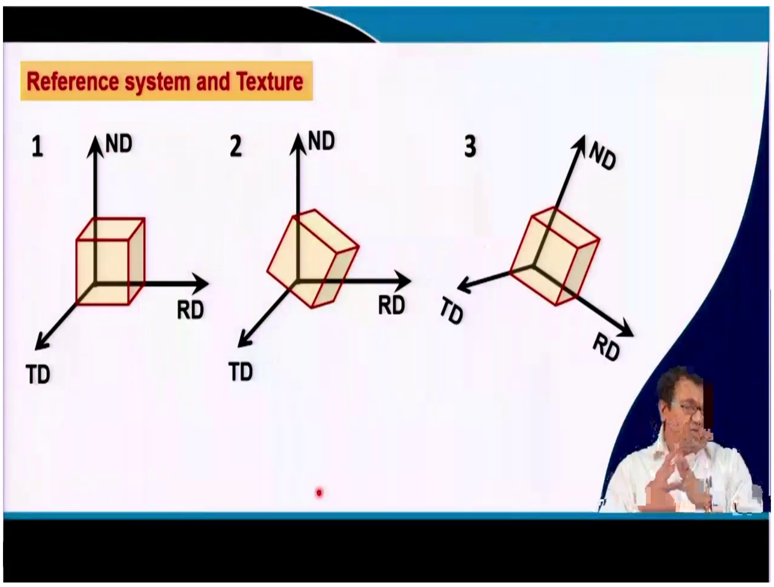

So, why reference system is important? if you have a certain material that has a sample, certain material means a sample that has an important sample reference direction say x, y, and z. And if it is rolling, as I said I will always use rolled material to show that sample reference system; therefore I have used R D, T D, and N D. And if the crystal frame of reference is arranged like this with respect to the, sample frame of reference. So, we have a texture, a texture is basically a relationship between the crystal frame of reference and the sample frame of reference. So, if the orientation of few grains is like this; that means the texture is different than the first one. So, the first one has a different texture and the second one has a different texture.

On the other hand, if you look at the third one; not only the unit cell has been rotated like the second one, but in the third one the sample, important sample reference axis is also rotated. And therefore, if that, what we can find out is that basically because the texture is the relationship between a crystal, important crystal directions, and planes with respect to important sample directions and planes.

Then the texture of this third number, basically equivalent to the texture of the first number, whereas the texture of the second number example is different from the first and the third number example.

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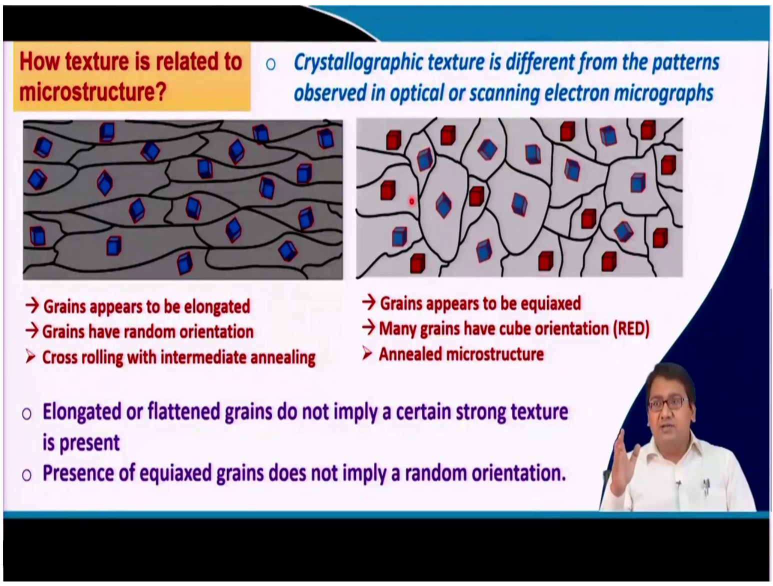

We usually in classical metallurgy sometimes, relate the texture with respect to the microstructure; microstructures which are basically obtained from optical microscopy or

SEM imaging. Now, here are two figures that I have shown and that the grains are elongated along with the horizontal directions. And this elongation in the horizontal direction by looking into it, it seems that it must have some kind of processing behind it, right. And now this elongation from that elongation, we might conclude that ok as all the grains are elongated in a certain direction; that means the orientation of all of these grains will be also similar or same.

Therefore, we may conclude that this is textured material. But it is to let that elongated grain does not refer that the material is textured. The elongated grains may also have a different texture and may lead to a weak texture; even if it is not a random texture, but it may lead to the formation of not a strong texture, but a weak texture. And it can happen if for example, in a simpler plastic deformation process, if we take a sheet metal and did a rolling and then we rotate the sheet metal by 90 degrees and did another rolling cross rolling a small amount of cross rolling. And this may happen that there is an elongation present in the sheet metal, elongated grains present in the microstructure of the sheet metal and, but the texture is not that strong or not that obvious. On the other hand, we have shown another microstructure. And this microstructure has grains having, few grains having which are differently textured and we have marked few grains with red-colored units and all of these grains have the same texture.

So, obviously, if we look into the quantitative microscopy and the unit cells which are red in color; we can obviously see that ok this cube kind of texture is highly present in the microstructure. But this is not obvious when we look into the equiaxed microstructure obtained from the SEM imaging or the optical microscope. And one can predict that ok it seems that this is not a highly textured material, because it is having an equiaxed microstructure. So, grains may appear equiaxed, but still, they may have certain orientations, which are present in higher amounts and this could happen to an annealed microstructure, which is obtained after rolling. So, elongated or flattened grain does not imply that a certain strong texture component is present. On the other hand, the presence of equiaxed grains does not imply a random orientation. So, we can also obtain or observe the texture of the polycrystalline material with the help of a simple diffraction pattern.

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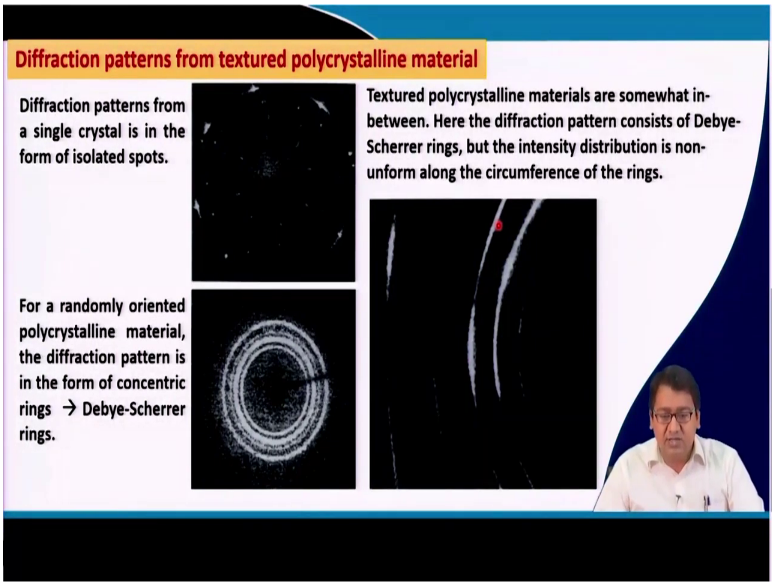

So, let us start if we, take a single crystal ok which is very strongly textured; of course, has only one orientation with respect to the sample reference frame. And therefore, if we observe the diffraction pattern, we will observe spots. And we will always observe spots in the diffraction pattern. So, there will be isolated spots. Now, if we take a randomly oriented polycrystalline material and how we can do it? We take a polycrystalline material, we put it in a ball milling, we make it powder and we get a lot of particles in it and each of these particles will be polycrystalline, but there will be lot of particle powdered particle. And then let us put that powder in a certain X-ray transparent box and do the diffraction using an X-ray or electron microscopy, ok. And that we will obtain Debye-Scherrer rings and these Debye-Scherrer rings will form concentric circles like this of the same intensity; 1, 1, 3, 4 different concentric cycle circles have formed with the same intensity.

Now, if we take a textured polycrystalline material; the material is textured, then what will happen? Here the diffraction pattern will again consist of the Debye-Scherrer ring, but now the intensity distribution is non-uniform. So, it will have a strong intensity somewhere. And the intensity will reduce and becomes less than zero and again it will become strong somewhere; because it will form stakes of strong intensity and low intensity in the Debye Scherrer ring showing that the material is textured. So, non-uniform Debye-Scherrer rings will concentric Debye-Scherrer rings will form in a textured polycrystalline material.

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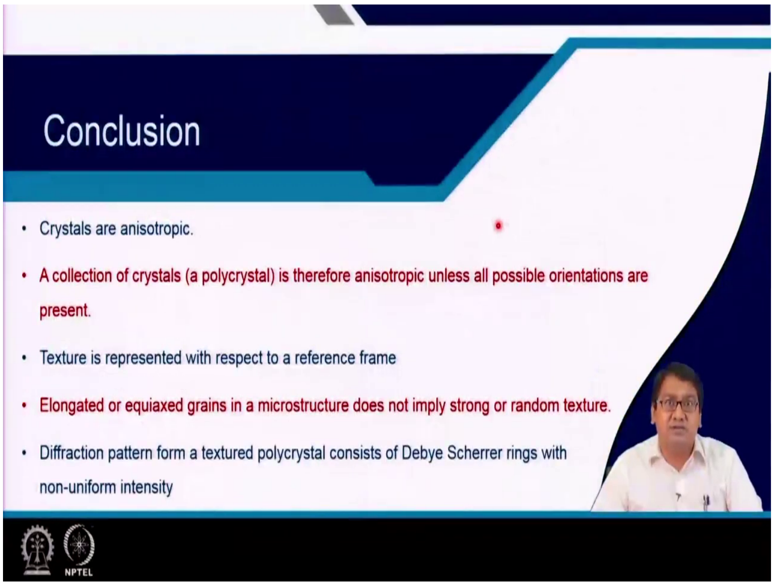

So, from this lecture what we can conclude? We can conclude that text crystals are anisotropic in nature, right. A collection of crystals that is polycrystalline, polycrystalline material is, therefore, an isotropic, unless all possible orientations are present. The texture is represented with respect to a reference frame right; that is it must be represented with respect to an important sample reference directions. Elongated and or equiaxed grains in the microstructure do not imply strong or random texture presence. So, from the optical image or the SEM image, one cannot comment on the texture of the material. The diffraction pattern from the texture polycrystals consists of Debye-Scherrer rings with non-uniform intensity.

Thank you.