Texture in Materials
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Module - 01
Introduction to crystallographic orientation or texture
Lecture - 01
Introduction

Good day everyone. Today, I will start the 1st lecture of the course “Texture in Materials” i.e., introduction to crystallographic orientation or texture.

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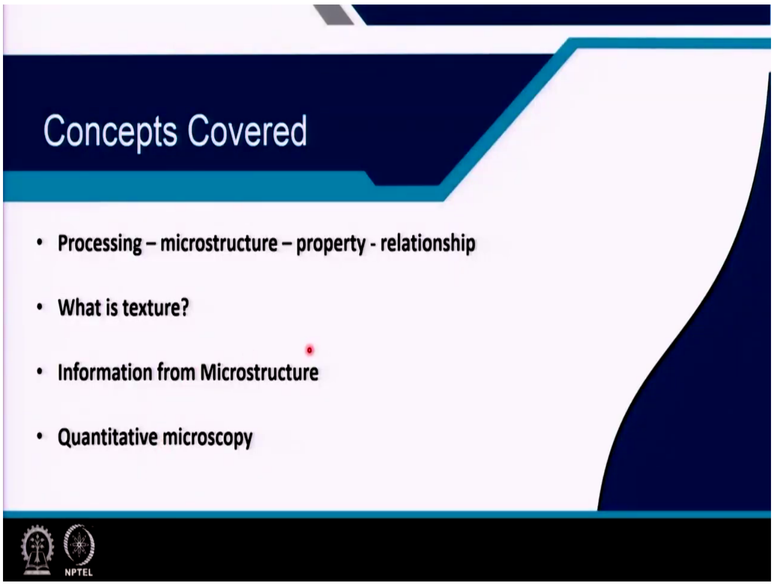

So, today’s course is on introduction to texture. The concepts that will be covered in this course are processing microstructure property relationship, what is texture, and information that we can obtain from the classical microstructures, and then quantitative microscopy.

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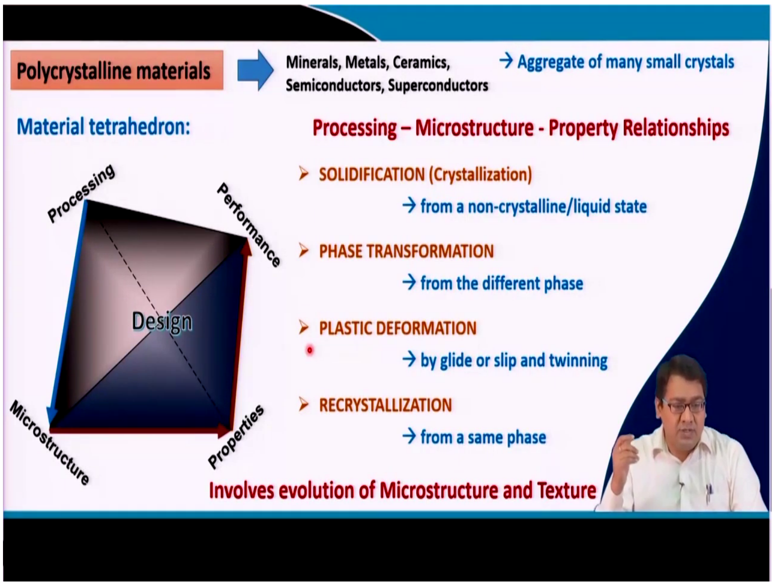

Let us start with processing microstructure property relationship. polycrystalline materials that are material, minerals, metals, ceramics, semiconductors, superconductors are made up of aggregate of many small crystals. A material tetrahedron in metallurgy or material science is being used to show the processing microstructure property relationship of these materials. Now, the material tetrahedron is used to design the material through some kind of a processing method and this processing method could be solidification, which is known as crystallization that occurs from a non-crystalline or a liquid state to a solidified polycrystalline state. Phase transformation – a transformation from a different crystalline state to another crystalline state say from face centered cubic to body centered cubic, or from hexagonal cubic to body centered cubic or vice versa.

Plastic deformation processes, that is by of slipping of dislocations and formation of twinning leading to obtain a different kind of microstructure. In addition, other methods like recrystallizations, which occurs in a same phase by reducing the stored energy of the material. So, processing of the material is being done to obtain a desired property, so that it can perform or it can give performance under that circumstances, which is required for example structural, electrical, magnetic, chemical properties. Now, the processing of the material not only changes the microstructural morphology, but it also changes the texture. So, as the processing involves change in both microstructure and texture, the texture must be considered while considering the property changes in the material through any kind of processing available.

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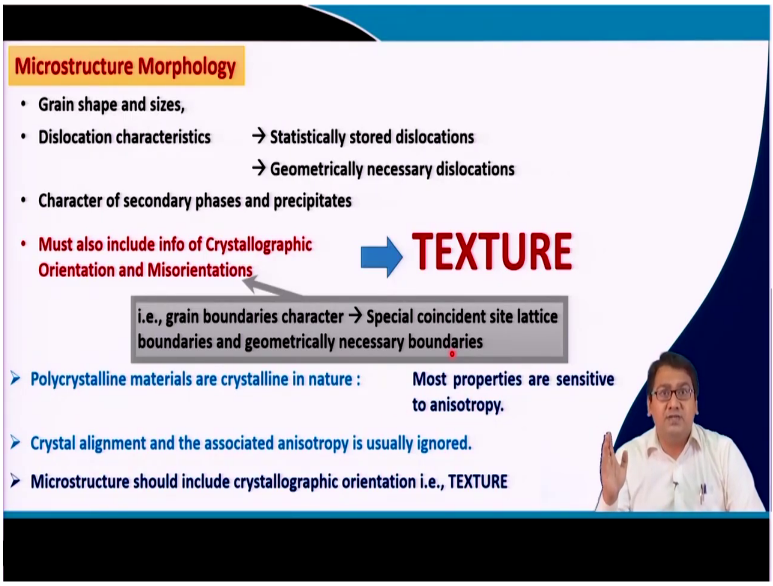

So, what do we know what do we understand by microstructural morphology. Microstructural morphology shows, the size of the grain, the shape of the grain, it shows the dislocation characteristics such as how the statistically stored dislocations are present, or they are in large quantity, or they are in small quantity, what is its density, the presence of geometrically necessary dislocations could be understood.

The character of the secondary phases and the precipitates present are also important while characterizing the microstructural morphology. Now, however, in classical metallurgy, you only consider these aspects, but we forgot the aspect about taking into account the texture. Microstructural morphology and its characterization must also include info of crystallographic orientation and misorientation, which is texture. Misorientation, on the other hand are related to grain boundary character, which could be related to the special coincidence site lattice boundaries, and also to the geometrically necessary boundaries, which have smaller misorientation as compared to the grain boundaries. Now, what do we know? Polycrystalline materials are crystalline in nature. Most properties are sensitive to anisotropy. Crystal alignment and their associated anisotropy is usually ignored in classical metallurgy. Microstructure must include crystallographic orientation, which is known as texture.

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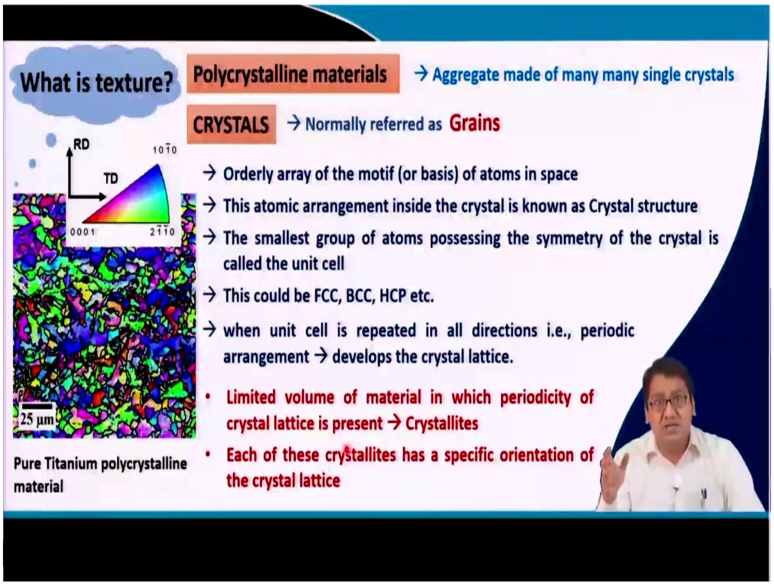

The question comes that, what is texture? So, as I said that polycrystalline materials are aggregate of many small crystals that are present inside it. In addition, you can see this figure, which is of pure titanium. In addition, you can see that this microstructure contains many grains and they are shown in different color. Moreover, they are shown in different color because they were taken from SEM scanning electron microscopy based electron backscatter diffraction technique, which is a quantitative microscopy. These colors are not random colors. These colors represents the color with respect to a specific orientation that is the specific crystallographic plane perpendicular to the screen. And that there are few green grains, which are representing {2-1-10} planes. Blue grains represents {10-10} planes. In addition, these could be tallied with respect to this color key code, which is the IPF – inverse pole figure code. Moreover, we will talk about these things later in the part of this course.

Therefore, crystals, which are normally referred as grains, are orderly array of the motif or basis of atoms in space. This atomic arrangement inside the crystal is known as crystal structure. The smallest group of atoms possessing the symmetry of the crystal is called the unit cell, and this could be FCC that is face centered cubic, BCC that is body centered cubic, hexagonal closed packed system – HCP etc. When unit cell is repeated in all direction that is periodic arrangement of the unit cell could develop the crystal lattice. Whenever the unit cell is repeated in space in three-dimensional space, it produces a crystal lattice, the limited volume of the material in which the periodicity of the crystal lattice is maintained or present is known as the crystallite. In ideal situation, a grain should be equivalent to a crystallite unless and until some kind of misorientation is present inside the grain. And you must know that all grains have an hierarchical structure. And they might have sub grain cell structure inside the grain, they might have some geometrically necessary boundaries made up of arrays of dislocations inside the grains. Therefore, in real life scenario, a grain could be made up of many crystallites. So, the periodic arrangement may not be maintained within a grain, but could be maintained in parts of the grain through some divisions, which are boundaries, but not grain boundaries have misorientations which are lower than the grain boundaries and known as the geometrically necessary boundaries. So, each of these crystallites has a specific orientation of the crystal lattice.

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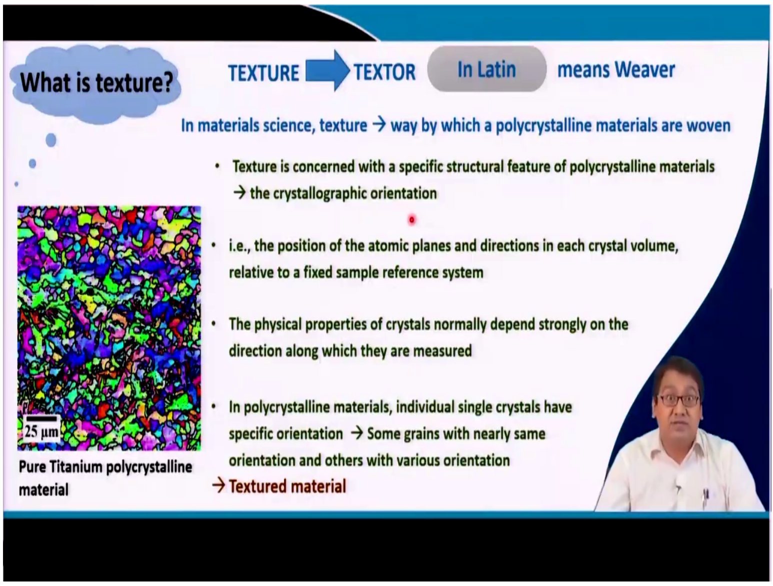

Therefore, these crystallites when present in a poly crystalline material produces a microstructure which consists of texture. Now, texture comes from the Latin word which is Textor and which means the weaver. And in material science, texture is the way by which poly crystalline material is woven. So, if we define texture, texture is concerned with a specific structural feature of poly crystalline material the crystallographic orientation. That is the position of the atomic planes and direction of each crystal volume that is crystallites relative to the fixed sample reference system. Here the word relative to the fixed sample reference system is very important. The physical properties of crystal normally depend strongly on the direction along which they are measured. The polycrystalline materials, individual single crystals have specific orientation, some grains with nearly same orientation and others with various orientations. Therefore, they are textured materials.

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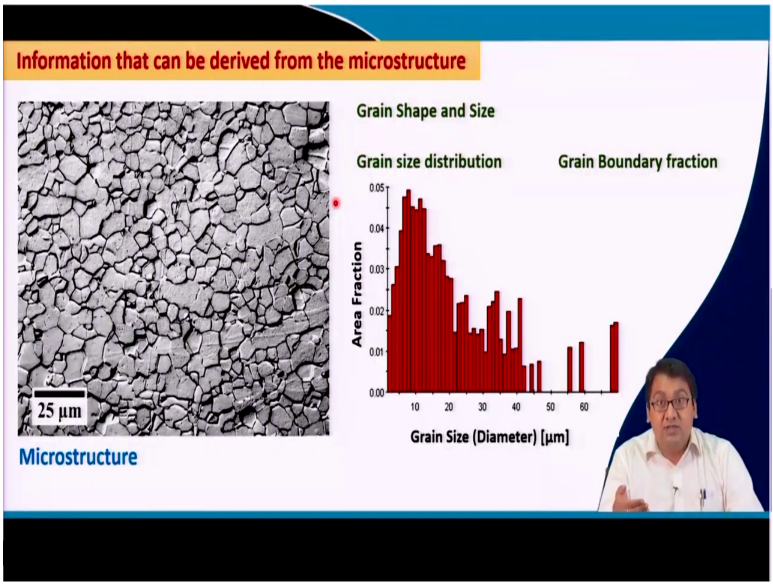

So, texture is a very important part of the microstructural morphology that usually in classical metallurgy it is ignored. In classical metallurgy from a optical on an SEM image, and the microstructure shows equiaxed grains and from this optical or an SEM image, we can obtain that what is the grain shape. And we can do a linear intercept measurement or we can measure the area of each grains using some kind of software, and find out that, what is the grain size or an average grain size of the material. We can even found the grain size distribution. But these will be done by manual method. And even we can find out that what is the grain boundary fraction in this microstructure, but we will not able to quantify appropriately first of all properly the grain size distribution. Secondly, even though we can find out the grain boundary fraction, we will not be able to find out that, what fraction of grain boundary is of what misorientation? That means, the deviation between two grain separating out by that grain boundary? what is the angle of deviation? what is the axis of that deviation? we will not be able to find out. Therefore, the analysis of texture and quantitative microscopy is required in order to understand more deeply the microstructural morphology.

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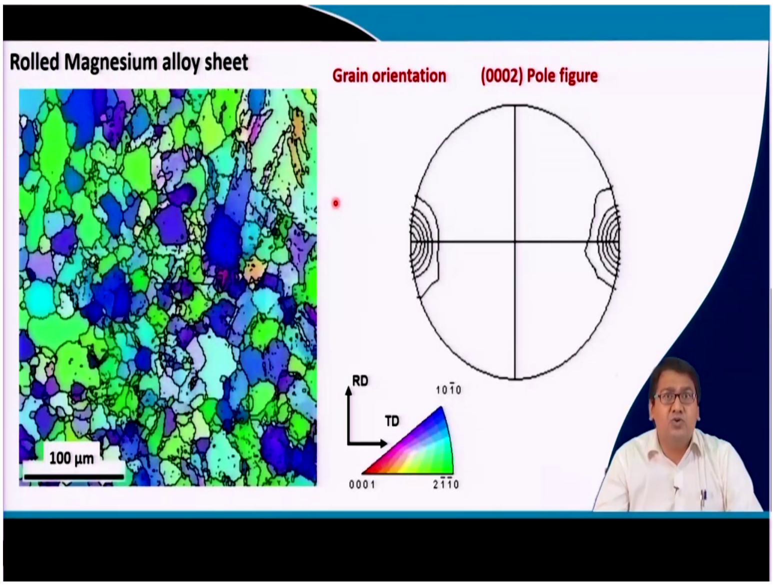

Here I am showing another rolled alloy magnesium alloy sheet, and you can see it is a colorful microstructure again. Nevertheless, as you can see that this colorful microstructure represents the quantity microscopy and the colors represents the respective crystallographic planes. One can relate it with the triangular color key code, and can tell that ok most of the microstructure are along {10-10} and {2-1-10} planes. Therefore, if we look into this microstructure, we can get many information more, apart from grain size or the grain shape or the grain size distribution, which can be very appropriately calculated, but we can also get the information of texture.

This is a 0002 pole figure. Please do not get confused with the pole figure suddenly. And we will come to it and slowly you will see that this is just another tool another scale to measure the texture. So pole figure is a scale to measure texture and that the 0002 poles are in both the directions. Therefore, we can measure the texture actually. Therefore, we will come to this in very detail and you will see that this is so simple.

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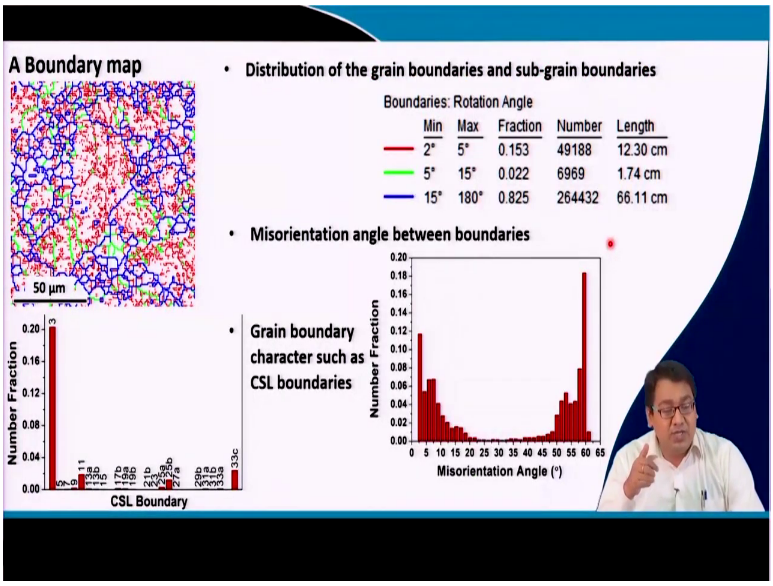

Now, from the quantitative microscopy, we can do a very nice grain boundary map. We can show that what is the distribution of grain boundary. And see we have colored the map the grain boundary map into red, green and blue color based upon our what it helps us, and we do like that to solve the problem.

So, that red color boundaries are mapped the misorientation angle of these boundaries are 2 degree to 5 degree, the green color boundaries are 5 degree to 15 degree, and the blue color boundaries are 15 degree to 180 degrees. So, we can map the boundaries and color them, that is to quantify them on the basis of their misorientation. We can say that ok the 2 to 5 degree boundary fraction is 0.15; the 5 to 15 degree boundary fraction is 0.022; the 15 to and higher angle boundaries are 0.825. We can give the number of the boundaries, the length of the boundaries in micrometer, in centimeter etcetera. We can find the misorientation angle between the boundaries, and then we can distribute them and show their number fraction. So, we can obtain a very quantitative information of the microstructure not only very detailed very vivid, but we can use them and correlate them with the mechanical property or the deformation behavior, or phase transformation, or solidification technique, and healing mechanisms, and we can get a more in depth analysis from this information.

So, not only that, but we can find out grain boundary character from this microstructure because that is a quantitative microscopy. And then we can find out the presence of coincident site lattice boundaries. And here is the figure showing the coincident site lattice boundaries from another microstructure not this one. And we can see that there is a large presence of sigma 3 boundaries, and then there are presence of sigma 11, sigma 25 b and sigma 33 c boundaries for that material. And this is done over a steel sample. So, we can get much more in depth information about the quantitative microscopy by this method.

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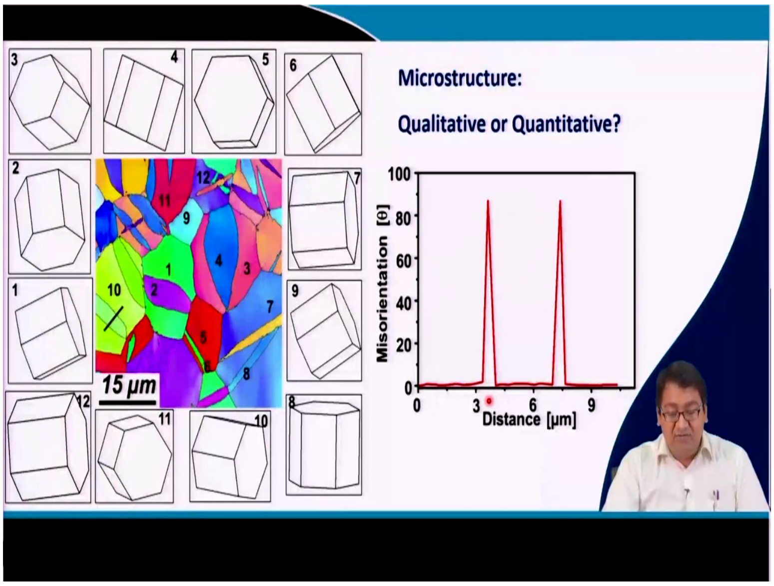

So, here is another information that we can that here is a microstructure quantitative microscopy obtained by scanning electron microscope by the electron backscatter diffraction method. This is the microstructure of pure titanium and this is a biomedical grade titanium. We are doing an in depth work on this. We are understanding that how to increase the strength, so that a thinner section could be used in the body of and human being when it is required without allowing them with vanadium and aluminum, which is usually used commercially. So, you can see that these microstructures have various grains. These grains are of different color. And this could be mapped with the help of inverse pole figure color key code, triangular color key code that I have shown in the earlier slide, but I have not shown it here. We can not only show that, but we can also find out what is the orientation, or what is the relationship of the unit cell with respect to this microstructural important reference system.

Let us say that the microstructures important reference system is the horizontal one which is x and the vertical one which is y. And with respect to that, you can see if I choose a grain one and it has a orientation which is like this with respect to the x and y. If we choose a grain 2 and it and this is this one and this is you can see that this is a small twinning that had occurred inside the grain 1, and you can see the twinning leads to the rotation of the unit cell by nearly about 90 degrees in this case. You can see all this orientation of all the different grains and we have marked it with respect to the number of the grain. We have serial number the grains with respect to the unit cell. So that we cannot only get information of the overall orientation of the material that is a cumulative orientation or cumulative texture of the material, but we can obtain information from each and every point each and every pixel light of the material. Therefore, that in this case the researcher has obtained information of the unit cells or the orientation for each grain and which is an extremely in depth information. On the other hand, a line has been drawn in the grain number 10 and we have measured that the misorientation between this grain boundaries. We have found out that misorientation is nearly 85 degrees. We can even find out the size of the grain in between them.

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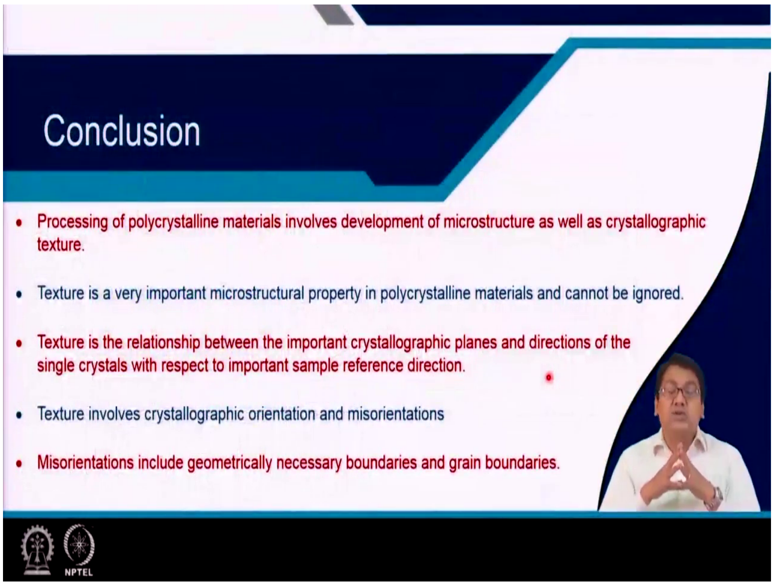

Finally, we can conclude that processing of a polycrystalline material involves development of not only microstructure, but also crystallographic texture. Texture is a very important microstructural property in a polycrystalline material, and it cannot be ignored. Texture is the relationship between important crystallographic planes and directions of the single crystals with respect to important sample reference directions.

Texture involves crystallographic orientation and misorientations. Misorientation include geometrically necessary boundaries and grain boundaries.

Thank you.