Texture in Materials
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Module - 06
Microtexture measurements using EBSD technique in SEM
Lecture - 34
Quantitative evaluation of Kikuchi Diffraction Pattern - III

Good afternoon everyone. We are doing Module Number 6 that is Microtexture measurements using EBSD technique in SEM. So, this is lecture number 34 that is Quantitative evaluation of Kikuchi Diffraction Pattern and this is part 3.

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So, the concepts that we I will try to cover in this lecture is we will continue with understanding how transformation techniques and we will go ahead and try to understand a little bit about in real life scenario that is in the SEM EBSD how basically how transformation is done using image correlation technique. And basically which I will say that it is a grey tone weighted you know transformation or Radon transformation developed by Radon and coworkers.

Later we will try to understand the Krieger Lassen method of peak detection in Hough space and this will give you all an idea that how in EBSD you know the Hough transformation basically is used to calculate the orientation and to extract information about the quantitative microscopy.

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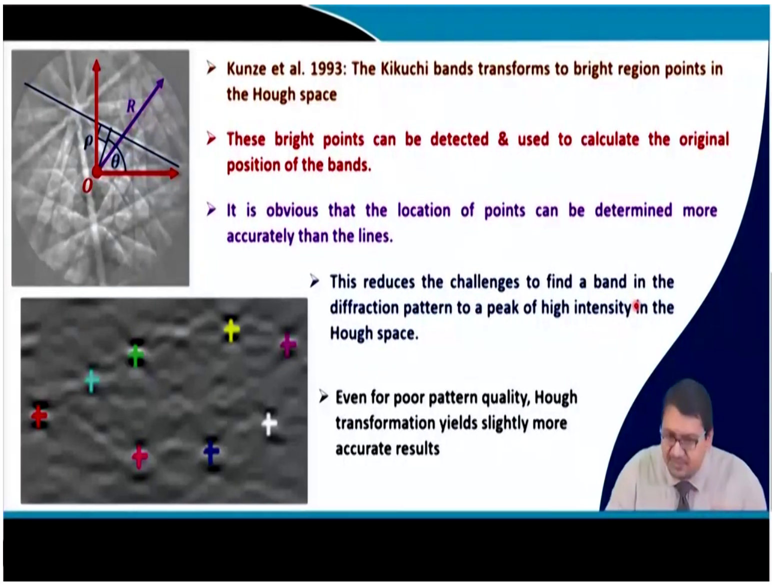

So, let us go ahead. So, as I said in the last lecture that the band which is present in the Kikuchi pattern the bands so, one of the band is basically a bright line; the bright line in the pattern space. This bright line which is the Kikuchi bands are basically transformed into bright regions of the Hough space and this was given this was shown by Kunze et al in 1993.

Now, these bright spots can be detected and used to calculate the original positions of the band. Now, you see that using that calculation that the band will have a particular rho and theta a point in the Hough space that is the rho theta space is determined and from the point a back calculation is done to determine the position of the band.

Now why it is done so, because usually the band sometimes it could be sharp and it could be diffuse as I said, but once the bands are transformed into a point it becomes very prominent and back calculating the position of the band from this points make the bands also very prominent right. So, it can be used to calculate the original positions of the band.

So, as I said that it is obvious that location of point from a diffused band and back determining the band makes it more accurate right. So, one can determine those Kikuchi bands or lines more accurately. Now this reduces the challenge to find the band in the diffraction pattern to a peak of high intensity in the Hough space right. Now so, even the poor pattern quality the Hough transformation gives slightly more accurate results right.

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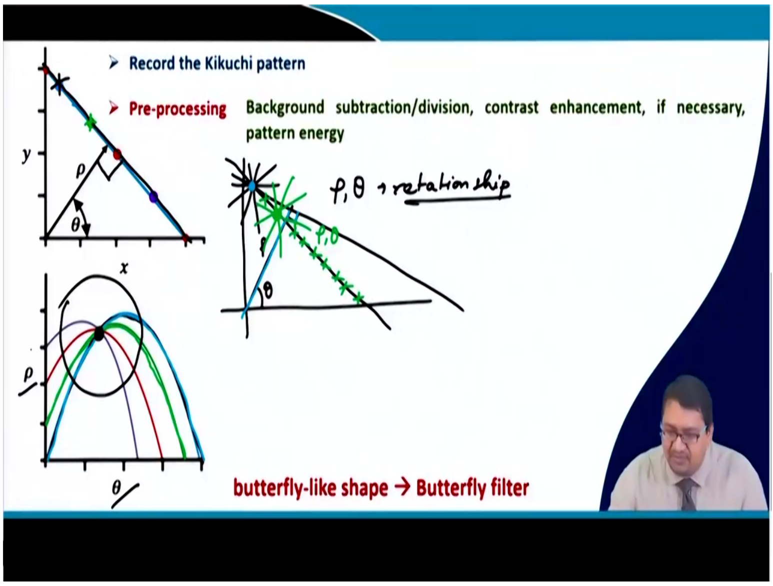

So, if you look we initially had to record the Kikuchi pattern and after recording the Kikuchi pattern there has to be a little bit of preprocessing. So, there are you know the first pre processing has to be done and you will see that when you will go to take a sample and do a EBSD measurement in a SEM you know in a scanning electron microscope.

Then you have to do a background subtraction or division and the name may vary depending upon the you know the company microstructure microscope it is and the EBSD it is. There will be you know systematic way to improve the contrast. Sometimes you know pattern energy is you know considered to I mean improve the quality of the indexed pattern in a you know Kikuchi pattern image.

Now, a Kikuchi pattern image you see I have shown here schematic of it and say for example, it is an average of the you know thick Kikuchi band and that is the average of the Kikuchi band a line like this. And as I shown in the last lecture class that a perpendicular to it from the origin and how the origin is, a origin is basically the center of the initially a rectangular pattern is taken on the phosphorous screen and then it is converted into circular you know pattern.

So, that circular area is only taken and then you know the center of that circular area can be considered as the origin and from that origin one can calculate rho theta with respect to each band right. Now the rho theta is rho is the vector perpendicular from the origin to that band then that has an angle theta with respect to the x axis. And if you put the sample in a correct manner this x axis should be almost equal to the you know parallel to the rolling direction right.

For example, for a roll sample so, that we can know how to you know have the you know the rotation matrix between the crystal frame of reference to the pattern and the pattern frame of reference to the you know sample frame of reference and that is how we find out the orientation.

Now let me take the pen initially and let me try to show you that what I want to show here. So, if you look into this you know Kikuchi band; the position of this line which is basically perpendicular to this band is converted into a spot somewhere here and this spot is such a way then that it has a rho and it has a theta and this is the Hough space.

Now, this Hough space is obtained in such a way that you see that as I said that a line in a Kikuchi pattern is transformed into a point in a Hough space. However, you see if we draw a band like this and let us say that let us take a point in the band. A point in a band of the Kikuchi pattern space is converted into a sinusoidal you know curve in the Hough space and how it is so.

A point in a Kikuchi pattern consist of multiple numbers of lines, it can consist of multiple number of lines and infinite number of lines and each of these lines will have certain rho theta relationship; that means, if we take any line like this, it will have a certain you know rho theta for which that line will be perpendicular to and therefore, each point let me change the color right. So, here it is blue.

So, each point of this Kikuchi pattern may have an infinite number of lines passing through it and each line will have a certain rho theta right and this rho theta corresponds to a sinusoidal you know curve in a Hough space. In a similar manner if we look into another point say this point and if we say that ok there is another point somewhere here and this color green is just for you to understand then in this position also there will be several lines which will cross this point and each of this lines will have certain rho and theta.

And therefore, it will construct a another you know sinusoidal curve and like that several points will be at several positions and we have shown some red and violet colored you know points in the Kikuchi band of this Kikuchi pattern. And each one will produce a sinusoidal curve and each one that will produce this sinusoidal curve will meet at a certain point which is basically equivalent to the rho theta corresponds to this particular band.

And this point basically is the point which is determined to be the rho theta point for that particular band. If we look into this pattern it looks it has a butterfly like shape and therefore, it is called butterfly filtering of the Kikuchi band into a you know Hough point in a Hough space.

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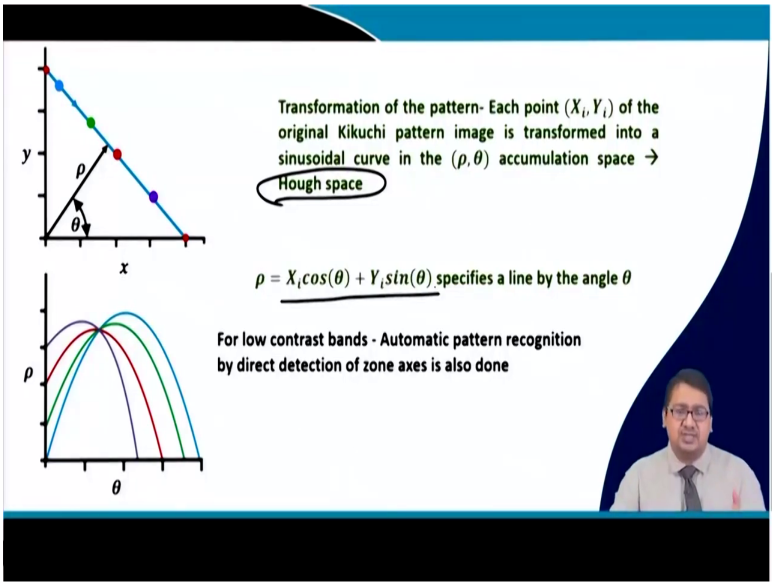

So, the transformation of the pattern like each X Y point of the Kikuchi pattern image into a sinusoidal curve in the rho theta you know accumulation space is basically by which the Hough space is you know created. So, as I said that in this case rho is equal to X cos of theta Y sin of theta right and it specifies a line which is at an angle theta from its you know normal and the angle theta is with respect to the x axis which is R d.

So, you see that image correlation techniques are used in order to convert all these lines in terms of points and they form because of this kind of calculation each point of the Kikuchi pattern lines are converted into sinusoidal type of curve it looks like butterfly pattern. And this butterfly pattern will have a certain intensity, because you see the intensity of the Kikuchi bands are converted into this butterfly type of pattern which is basically highly intensified at a small region that is a point which is rho theta point of the Hough space.

In this way even if any Kikuchi band has a little lower contrast. The automatic pattern recognition easily recognizes the you know the those patterns because the intensity of the Hough spot is a little more prominent than the you know the intensity of the you know Kikuchi bands. And this helps us to directly determine the zone axes of this Kikuchi bands too.

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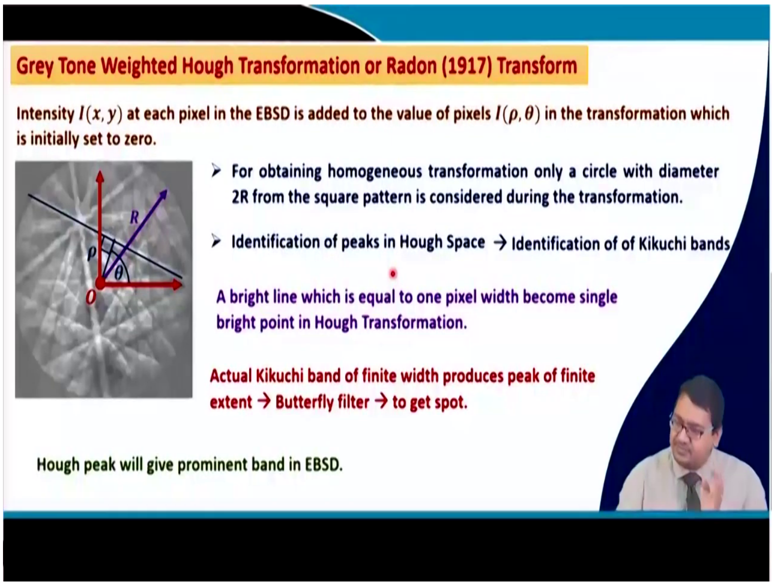

Now, you see that the method by which actually the Kikuchi bands are transformed into Hough space are basically known as grey weighted you know Hough transformation or you see Radon transformation. Now, the intensity I x, y corresponding to the Kikuchi pattern; that means, this pattern right. At each pixel of this Kikuchi pattern that is each pixel of the EBSD is added to the value of intensity in the rho theta space ok.

And initially this initially of this transformation this you know rho theta space is set basically to a zero intensity, now you see the actual you know Kikuchi band of a finite width produces a peak of a finite extent right. So, you see a band which will have a certain width say for example, a finite width will that high intensity band will transform into a intensity peak in the Hough space to a you know to a finite extent right.

And this extent will be like you know a sinusoidal a multiple sinusoidal curve which looks like a butterfly type pattern and therefore, it is known as butterfly filter to obtain a bright spot. So, how transformation basically gives more prominency, more prominent band in EBSD.

So, what do I mean is that a Kikuchi band which could be your diffused band is taken and then it is transformed the intensity of a maybe a very you know diffused intensity of that band is transformed into a spot using this butterfly filter to obtain a spot which is relatively more intensified relatively more you know observable ok or distinguishable and therefore, back calculated to obtain the actual position of the Kikuchi bands. So, the calculated Kikuchi bands are more prominent right.

So, for obtaining homogeneous transformation very important thing as I said in the previous slides also, first a circle with a certain diameter a circle with a certain diameter is taken from the you know rectangular pattern that is obtained means rectangular Kikuchi pattern that is obtained for this Hough transformation technique right.

Identification of peak of the Hough means identification of the bands in the Kikuchi pattern. The bright line in the Kikuchi pattern if it is considered to be one pixel thickness or width becomes a single bright point in the Hough transformation right.

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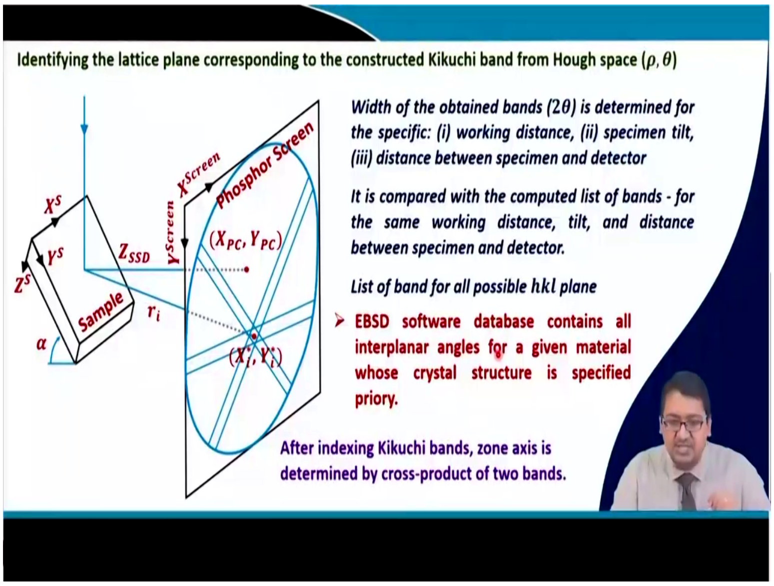

So, in case of electron backscattered diffraction in an SEM while the sample is tilted at 70 degrees the phosphor screen is basically kept at 90 degrees and it is away from the incident beam. Now, in this case you see identification of the Hough space rho theta points are done from the obtained Kikuchi bands and from this Hough space you know the constructed Kikuchi bands are obtained.

So, the corresponding constructed Kikuchi bands are obtained and this constructed Kikuchi bands with right which basically is equal to 2 theta is determined for that specific you know working distance means the working distance of the sample with respect to the electron gun.

The tilt exact tilt of the sample which is most of the time 70 degrees, the distance between the sample and the phosphor screen right that is the you know the camera or the detector. So, it is basically what we have we already in the software there will be computed list of bands ok. All the bands for the same working distance, for the same tilt angles, for the same you know distance of the specimen with the phosphor screen.

So, now these computed list of bands are compared with the constructed Kikuchi pattern that is obtained and then all you know all possible bands are compared that and then the different hkl planes corresponding to these you know Kikuchi bands are calculated. So, see EBSD software database will have to contain all interplanar angles for a certain material. So, it will have the database of each and every material for who which the crystal structure is known right.

And it will be specified priory and even if it is not specified for certain you know alloy or certain compound ceramic or something one can make it using the information about the crystal structure it is Wyckoff number and other things one can make it in that in the you see the software.

So, there in new softwares there are places where one can just you know make this information and then the software can compute the list of bands that can form for you know different working distances, different tilt angles, distance between the specimen and the phosphor screen.

So, after we obtain the Hough space and we construct the Kikuchi band; that means, once we have index the Kikuchi bands the zone axis can be determined between two bands and thereby the N D can be determined and then thereby the R D can be determined using the formulation that we show in the you know last to last lecture and thereby you see the software also calculates the orientation in the using the EBSD.

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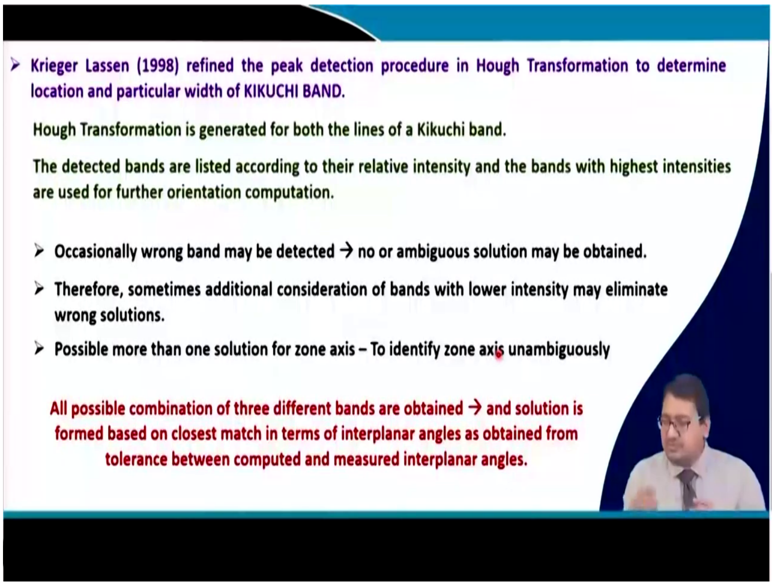

So, finally, Krieger Lassen in 1998 he did a more refinement in the peak detection technique in the Hough transformation; means he wanted to determine the location and the particular width of the Kikuchi band. So, Hough transformation you know the Kikuchi band contains two lines right and it has a thickness. So, Hough transformation is done for you know both the lines. So, the detector bands are listed according to their relative intensities also.

So, the Hough transformation is you know done for both the lines of the Kikuchi pattern of a Kikuchi band and then for each band each detected band the intensity is you know recorded or each band is listed according to their relative intensity and the bands with highest intensities are used for further orientation calculations etcetera right. So, it the bandwidth higher intensities are used to do the orientation computation.

Now you see that sometimes what happens if as you have seen that only three bands are required to obtain the orientation information. But sometimes what happens that recording only three bands with higher intensity and sometimes you know indexing of this band becomes wrong ok or you know wrong bands are detected.

So, you see mainly you see when it can happen when the electron beam is falling on a surface which may have a dislocation you know bending lattice bending due to dislocation presence or in the grain boundary. So, no or near to the grain boundary sometimes so, no or ambiguous solutions may be obtained.

Now, therefore, in order to you know get more refined information sometimes additional consideration of bands of lower intensities had to be considered ok. So, as to eliminate wrong solutions so, there could be possibility that more than one solutions of a zone axis could obtain from the Kikuchi bands or Kikuchi pattern. So, in order to identify the zone axis you know unambiguously all possible combinations of this at least three different bands that is needed are obtained ok.

And the solution is formed based on the closest match in terms of the interplanar angles as obtained from the tolerance between the computed and the measured interplanar angles ok.

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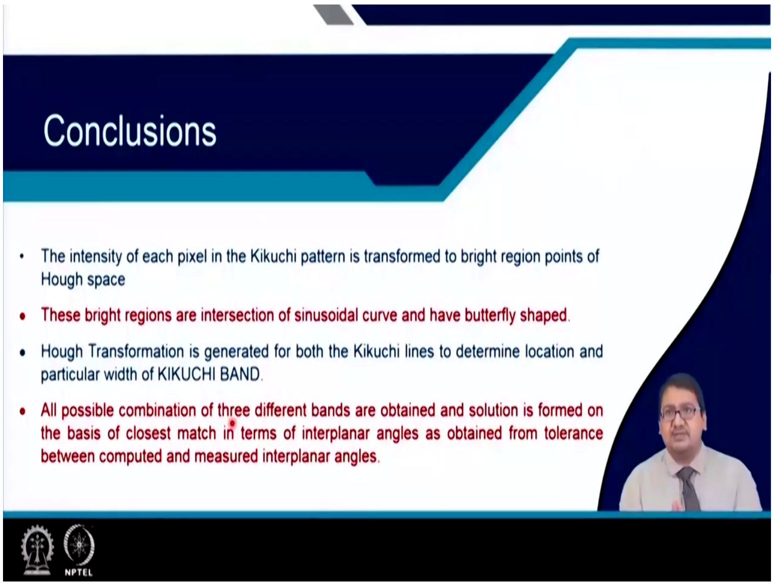

So, you see that the intensity what we can conclude from this lecture is that the intensity of you see each pixel of the Kikuchi pattern is transformed into bright regions of the Hough space. And from which you know the Kikuchi bands are basically back calculated for more accuracy.

These you know Hough spots are bright regions which forms by intersections of the sinusoidal curve formed from each points of the bands of the Kikuchi pattern right. And they are have they have the butterfly shape therefore, they are sometimes called butterfly filters. Hough transformation can be generated for both the Kikuchi lines of a certain Kikuchi bands to determine the location and particular width of the Kikuchi bands given by Krieger Lassen.

Then all possible combination of the three different bands are obtained and the solution is formed on the basis of the closest match in terms of the interplanar angle as obtained from the tolerance between the computed and the measured interplanar angles ok.

Thank you very much for this class.