Indian Institute of technology Madras
Presents

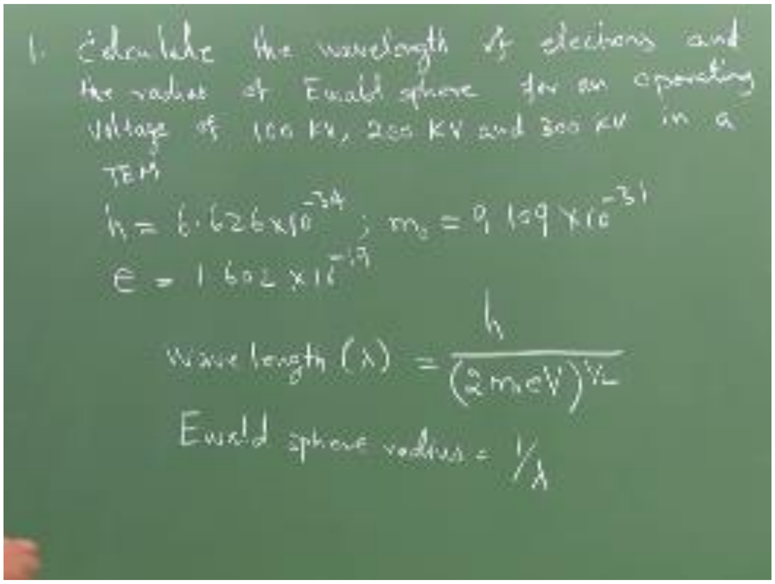
NPTEL
NPTEL ONLINE COURSE

Tutorial-2
Materials Characterization
Fundamentals of Transmission Electron Microscopy

Dr. S. Sankaran
Associate Professor
Department of Metallurgical and Materials Engineering
IIT Madras
Email: ssankaran@iitm.ac.in

Hello everyone welcome to this online course of material characterization organized by NPTEL we have been looking at the tutorial problems and then I would like to continue the tutorial problems in based on the transmission electron microscopy and yesterday we have seen some of the problems which related to abrasions and it's no crystallography and so on in a similar line we will also try to solve some basic problems which will give you a confidence in solving some of the assignment problems as well as in the problems in the examinations so quickly.

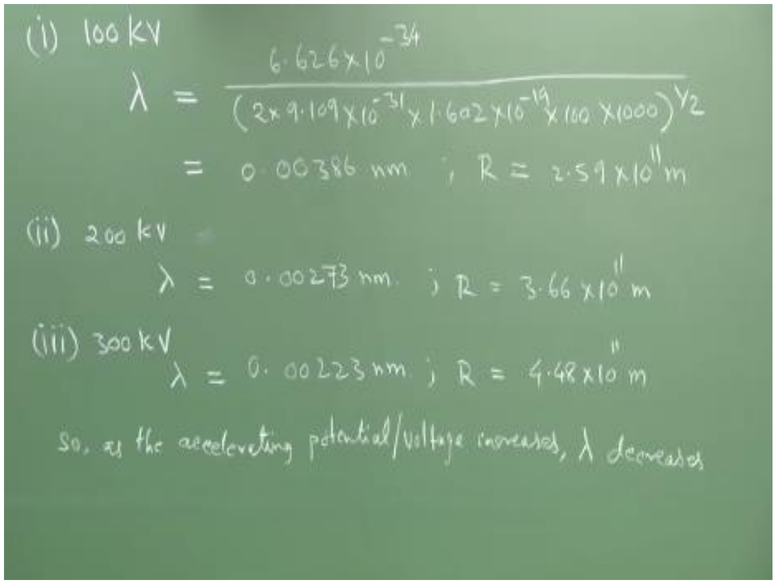
(Refer Slide Time: 00:59)



I will go to the board and then start solving this problem so the first problem is related to the wavelength of the electrons with increase in the accelerating voltage so they calculate the wavelength of the electrons and the radius of the evolves fear for an operating voltage of 100 kb200 kb and then 300 kb in a tem so how to go about it so we have the standard formula and then some of the constants are given in the problem for supplies constant and this is a mass and charged.

So we have the wavelength the relation between the electron volt in the wavelength is this so we can simply substitute this constants into this and then we know the evolved fear radius is 1 by λ so it is now straight forward we can simply substitute this of course we have to work out this for three different voltages accelerating voltages so now we try to do this part 100kv your λ=6.6 26 the 10^{-34} so for a hundred, hundred kilo volt acceleration you get the λ 0.003 86 nanometers.

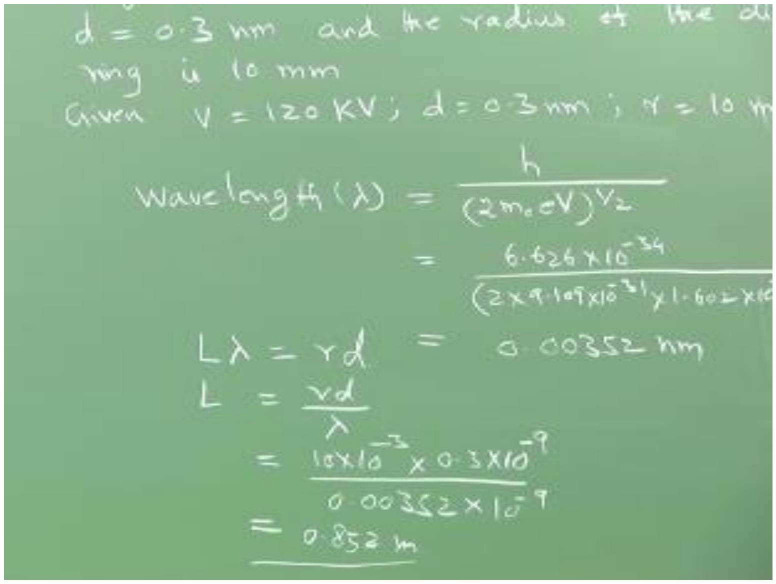
(Refer Slide Time: 05:13)



So similarly we can do the simple substitution for the 200kv you will be able to get this λ=0.00273 nanometers and for it is 0.00223 nanometers it changes only the very small in the fourth decimal change and for calculating the corresponding evolves fear it is simple so you write are in this case r=2.59*^{10}11 meters this case r =.3.66*^{10}11 meters in this case r = 4.48 so the, the concept you get in this problem is with the increasing the acceleration voltage.

Your λ keeps decreasing and once the λ keep decreasing the evolves fear radius will keep on increasing so that if you follow the lecture it clearly shows that why you in the case of electron microscopes you have a plenty of diffraction spot occurring on a screen while in x-ray you have very few diffraction peaks you are able to see in the given spectrum so that explains concept so probably you can write one line as the accelerating potential or voltage increases λ decreases so we can write like that.

(Refer Slide Time: 09:42)



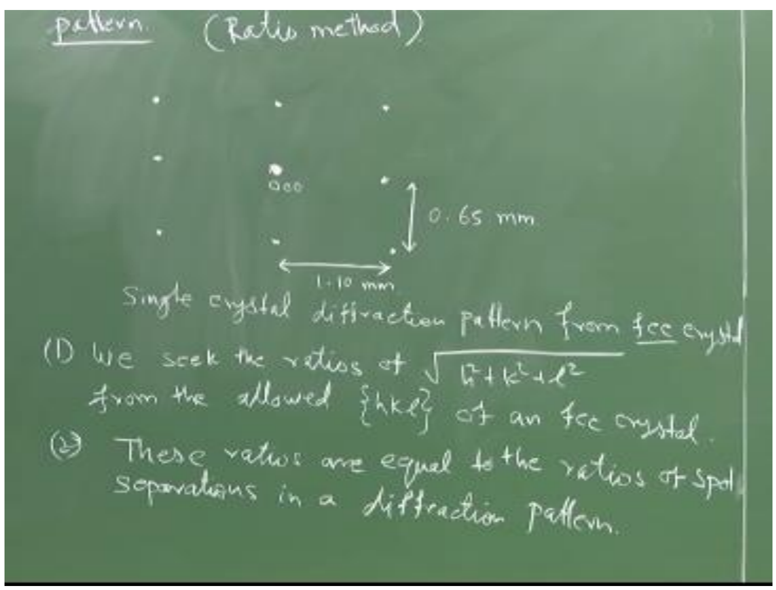
So we move on to second problem so the question is find the terminal length in a transmission electron microscope with a operating voltage of 120kv for a material with d-spacing point .3 nanometers and the radius of the affecting thing is about 10 mm so you should recall the lecture notes which talked about a camera length what is camera length in a camera length is the distance between the specimen stage and the screen what is what is the distance that is the distance and then if you recall there is a relation between a camera length with the diffracted spot spacing.

In the case of poly crystalline pattern it is a radius of the ring pattern and in the case of single crystal pattern it is the, the distance between the center spot that is a transmitted fought with the any one of the diffracted beam are there is a standard relation you can use that and then we can solve this problem so we will write the wave length expression n first so first we find the wavelength λ similar to the previous problem then be the relation we know the relational λ = rd.

So where l is the camera length the wavelength this is the distance between the transmitted part as well as the affected spot so in the case of a ring pattern it is a radius of the ring or in the skate of us in the case of a single crystal spot pattern it is a distance between any one of the spot and the transmitted beam and d is our material interplanar spacing so we can find the camera length l is equal to rd / λ and then you get this by simple substitution.

So you get camera length is around 0.8Phi 2 meters so you see that this relation is very important relation in the case of solving the diffraction pattern indexing so this will be useful so the, the next problem which we are going to talk about is using this relation how we can solve or index the single crystal electron diffraction pattern so we will take up some simple example and most of these students find it difficult to index them because they have no they have not understood this basic calculation and then how to what are the critical things involved in the calculating the the distance or either from the film or it is from the digital photograph measuring the distance is a crucial thing.

(Refer Slide Time: 18:29)



And then how to get the right index pattern so we will take up some simple exercise for a single crystal diffraction pattern indexing today and then we will move on to a poly crystal indexing in the next class suppose if we take a pattern like this and which has got the distance 1 point10 millimeter in this direction and 0.65mm this direction.

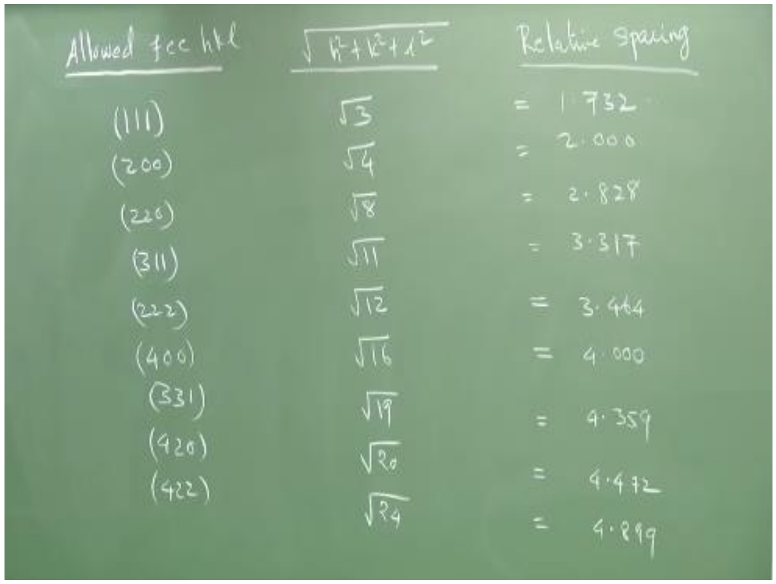
Suppose if you have this kind of a pattern and how to proceed further what you should understand here is there are two three methods possible what I am going to demonstrate today is the ratio method this especially used when there is no symmetry of the pattern is known for example if you do not know the symmetry for example at least I can identify this is a rectangular pattern or a square pattern or a hexagonal pattern and so on.

If you are not able to recognize the pattern for example this is not exactly I would say a symmetry is known or something like that but this method is used also when the camera constant is not known or sorry camera constant is known so excuse me camera constant is known then this method is preferably used but nevertheless we will not take those into consideration we will assume that we do not know any data on those parameters.

So how to go about it so when you look at the pattern like this in a film or from the digital recording media and if you always you see that the center spot is a transmitted beam it started with 0 0 0 okay so from there how to proceed so let us write down some procedures suppose if we assume that this is Forman FCC crystal let us look at how to proceed first.

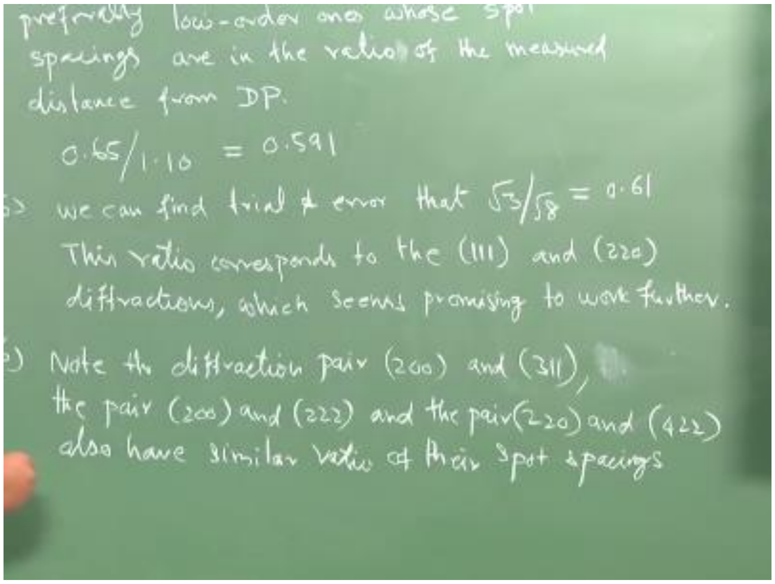
We seek the ratios of $H^2+K^2+L^2$ from the often FCC crystal so first what you have to do this the first step is to we seek the ratios of square root of $H^2+ K^2+ L^2$ from the allowed hkl often FCC crystal and these ratios are equal to the ratios of spot separations in the diffraction pattern so that means the ratios of this distance these two distance will be equivalent to the ratios of some of the allowed.

(Refer Slide Time: 25:43)



This hkl indices ratios so we need to list so first list they allowed first make a list of these ratios in table so we will make a table now so what we have done now is we have generated a table what are these indices these are all allowed FCC hkl so we have done that square root of H^2 K^2 $+L^2$ like this and this is relative spacings this to be compared now the next step is what we will do first we have to look at this I will write down the procedure.

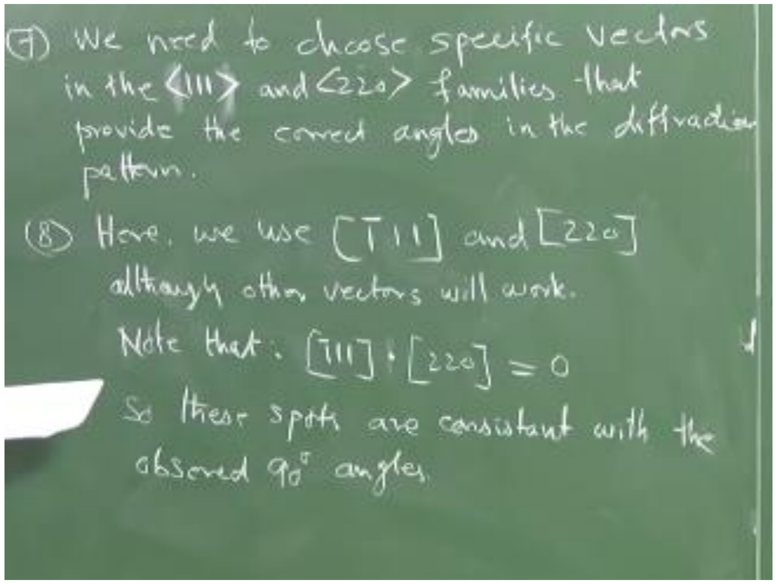
(Refer Slide Time: 29:29)



So that this is the procedures so I will write this as a procedure number four now look for by fractions in table so the fourth procedure is now look for a diffractions in the table preferably low-order ones that means you should you should not look at these things initially you should look at low order reflections and who is spot spacings are in ratio of the measured distance from the diffraction pattern so we have now the distance here what we have given this distance and this distance.

So we will take that into that ratio and then we will see what we get so what is the ratio point .65 / .10 = 0.5-1 and we can find soil and error that square root of three by square root of 8 is equal to 0.61 so this ratio corresponds to so the next is we can find the trial and error that square root of 3 by square root of 8.61 and this ratio corresponds to 111 and 220diffractions which seems to be promising to work further on this before we finally zero in on this indices this at least looks promising so what is the next step note the diffraction path 200 and 311 they are bad 200 and 222on the path 220 and O22 also have similar ratios of their spot spacing.

(Refer Slide Time: 35:57)

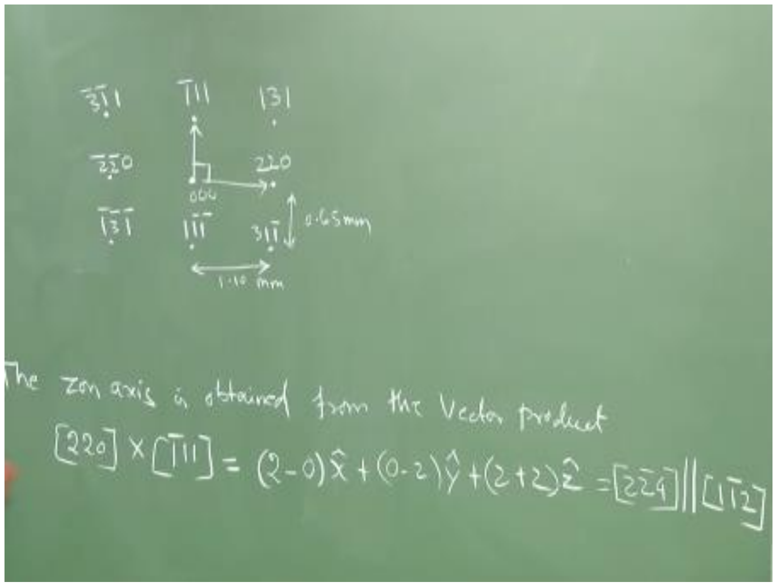


So if we go with this rule and the other diffraction pair like 200 + 311 and the other pair 200 and 222 the other pair 220 and 422 also have similar ratios of their spots patience so how to decide that this is these two are the only one which is going to be correct which one is correct so now we have to choose the other set of rules which point number seven we need specific vectors in the go to families that I am throwing in correct alright.

So the next step is we need to choose a specific vectors in the 111 and 220 families that provide the correct angles in the diffraction pattern so, so if you look at the, the pattern it has got both these two indices have the some angle so we will redraw that here we use so the next important thing one we need to look at it since we have to take two vectors from these two families we have chosen these two though others also will work but the condition is you have to have this dot product should be 0 that means these two vectors are perpendicular to each other.

That is what we have seen in the initial spot we are trying to solve that spot I will redraw them once we go to the next step so that means this is consistent with these parts or consistent with the observed 90^{O} angles so with this condition we can eliminate the other possible vectors for example those vectors all these vectors we can eliminate the other possible paths we can eliminate because all the vectors in their families are at 90^O degrees angles.

(Refer Slide Time: 40:45)



So now we can since none of these pairs have the angles between them of 90^O with the initial inspection we can now try to complete that diffraction pattern so this is 000 and we'll take two vectors one is this one is that let us label this as 111 and this is 220 because these two vectors are 12 90^O so at 90^O that is what we have found out from this relation and then now we can fill up this because other, other spots are the linear combination of these two vectors we can do that.

And this is the zone access is obtained from the vector product that is 220 in two is equal to2-0x 0-2y+2+2z=224 parallel 112 so the cross product of these two vectors gives this and then which is nothing but a parallel to this plane one bar 12 so that is how the zone axis is calculated so we will solve similar problem maybe one or two more to get more familiarity with this indexing and this is a manual indexing today you have the software available but and of course what we are now trying to solve is a very simple cubic system.

And if you go to the much more okay less symmetric system then these calculations will become much more tedious and that is where do you require a computer program to do this and today we have all the software is available but never the less you should know what is the calculation behind all the software and that is the primary aim of this exercise you should know you should try with some of the basic things and we can try we will solve some few more exercise like this for a cubic system as well as for the polycrystalline system in another tutorial class so with that I will stop this tutorial class and then I will try to continue in the next class thank you.

IIT Madras Production

Funded by

Department of Higher Education

Ministry of Human Resource Development

Government of India

www.nptel.ac.in