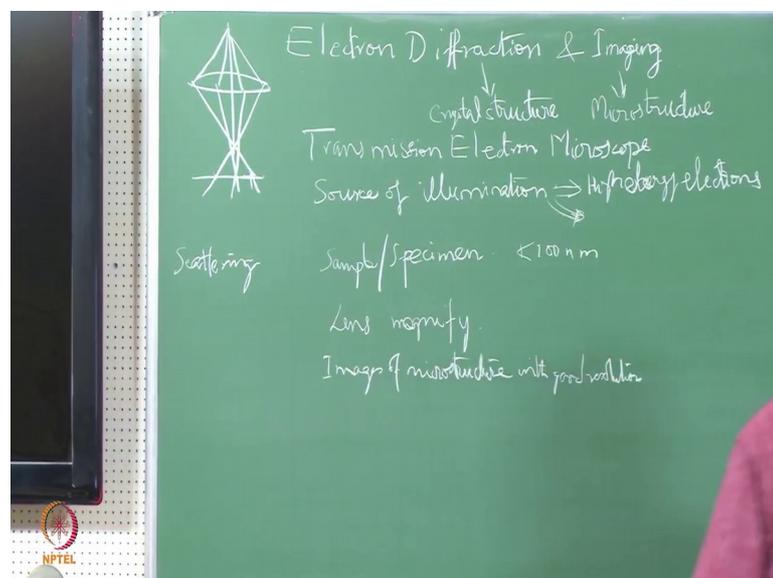


Electron Diffraction and Imaging
Prof. Sundaraman M
Department of Metallurgical and Materials Engineering
Indian Institute of Technology, Madras

Lecture - 32
Revision 1

Welcome you all to this course on Electron Diffraction and Imaging. As the name of the course is self suggest; it includes both diffraction and imaging. Throughout this lecture series I have been always using this term electron diffraction and imaging.

(Refer Slide Time: 00:40)



So, what does it mean by that? That is this just gives a hint that possibly using this technique of electron diffraction we can get information about both the crystal structure as well as the microstructure of the sample. So, like both this information diffraction gives information about the crystal structure, this we have studied in detail and imaging gives micro structural information.

But there are some sub divisions into it which may be come to shortly. So, both these techniques diffraction and imaging could be done in the instrument called transmission electron microscope. As we here the name microscope we think of optical microscope yes. In fact, this is quite similar to and optical microscope, where we have a source of illumination.

Then this illuminator light falls on the sample bar specimen, it interacts with it is specimen and then gives lot of information other ways itself that the radiation which is falling on it is scattered, and then we use lenses to magnify and then get images of micro structure with good resolution, this is what essentially being achieve.

So, when we (Refer Time: 03:14) of the source illumination, it could be a electromagnetic radiation like in the case of optical rays it is monochromatic light, which we can use it in the case of transmission electron microscope it is a essentially the source of illumination is high energy electrons these electrons are accelerated to very high energies and the voltage which is being applied is made. So, precise that the beam is highly monochromatic and then we choose a source so that, the brightness of the source is very high. So, when we wanted to get some diffraction information, the diffraction information essentially are the diffraction takes places in a sample, when the beam is highly coherent and monochromatic.

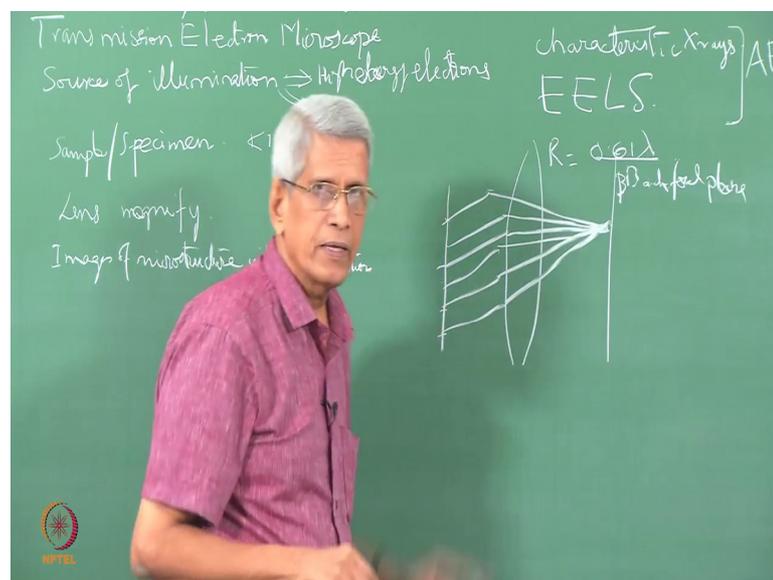
So, both are satisfied in the electron gun which is used in the transmission electron microscope, these aspects have been described in detail in the class. The beam which is generated from the gun that is made into a uniform one using a condenser lens and this beam falls on to the sample. That this interact with sample generally in a transmission electron microscope, the samples are extremely thin of the order of the thickness is generally less than 100 nanometers. So, since the sample is extremely thin, when the beam passes through the sample it interacts mostly in a elastic manner. So, essentially the scattering which takes place; the scattering is essentially elastic scattering. So, this is one of the conditions which has to be satisfied for diffraction to occur, and for this process to occur there are many ways in which we can consider the sample.

What all the ways in which we can look at that sample? One we can look at the sample as consisting of some point scattering centers, which are distributed at some periodic intervals in the three dimensional lattice. This scatters each of the scatter points have got some particular scattering power and this is called as the atomic scattering factor that is one way to look at it. The other way to look at it is that since these are atoms which are present at periodic. So, there is coulomb potential which is associated with it. So, this potential is periodically varying. So, the electrostatic interaction between the electrons the charge of that electron their high energy, interacts with the coulomb potential and this

changes the path of the electron that the electron trajectory, that way also we can consider that scattering ok.

So, both the processes are used in the case of kinematical theory of diffraction, we use this as a scattering process which points enters which are scattering and then in the case of dynamical theory we assume that the instant electron is interacting, with coulomb potential. Apart from this elastic scattering has the electron beam passes through the sample some inelastic scattering also is taking place.

(Refer Slide Time: 07:44)

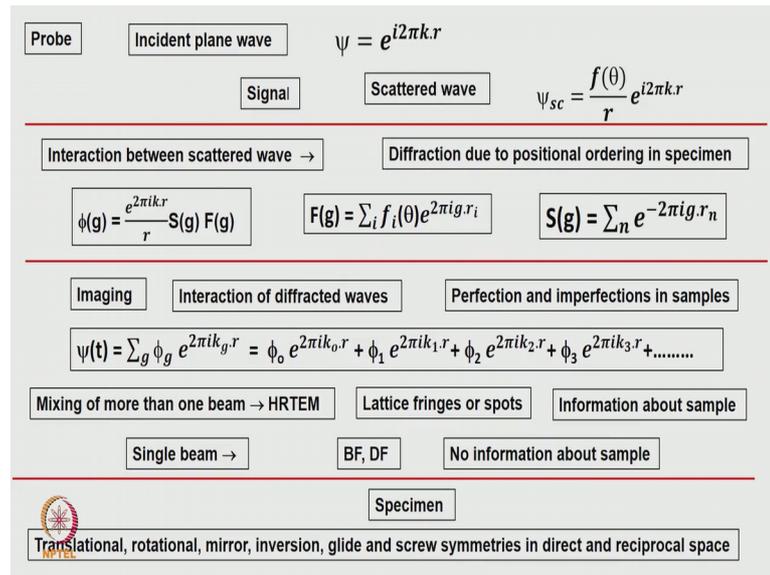


So, this inelastic scattering which takes place is used for spectroscopic techniques that is one it can generate characteristic x rays from the elements which are present on that samples, using this characteristic x rays we can find out the type of elements which are present and then.

We can find out how it is concentrate of the different elements vary by looking at the x ray in map, and this map could used to get information about the distribution of their elements in that sample. Similarly another inelastic scattering process is that as the electron enters into the sample even before the characteristic x ray emission takes place, the electron has to knock the primary electron or the incident electron has to knock out electrons from the different levels in that sample. So, the binding energy of electrons two different levels for each item is quite specific. So, the energy last by the incident electron, there is characteristic of the element which is present under sample.

So, this also could be use to get information of the electron information about the chemical composition of the sample surfers, and this technique is called as the electron energy loss spectroscopy. These two techniques combine together with conventional microscope, we call it as analytical electron microscopy all this aspects have been recovered during in the course.

(Refer Slide Time: 09:26)



Then another factor which is important is that, as I mentioned that here we can considers as scattering as point scattering centers, but what is essentially important is that the property of the gusses which used for magnification, especially the objective lens which we use to magnify the sample.

Why we have to magnify that sample why we have to magnify because when this interaction takes place the special resolution of these interactions, are the resolution wings both the special as well as the depth resolution or the temporal resolution we talk about it. Especially what we have to look at is the resolution wing point to point resolution in electron microscope is from one point to an another point, the image the features which can be seen that the ultimate limit is given by the rally criteria. That says that the rally criterion resolution is essentially 0.61 lambda by beta the angel which it is submits with a lens from that point.

So, this criterion of the resolution is what can be theoretically achieved, but what happens in the case of electron microscope because lenses are not perfect, because the

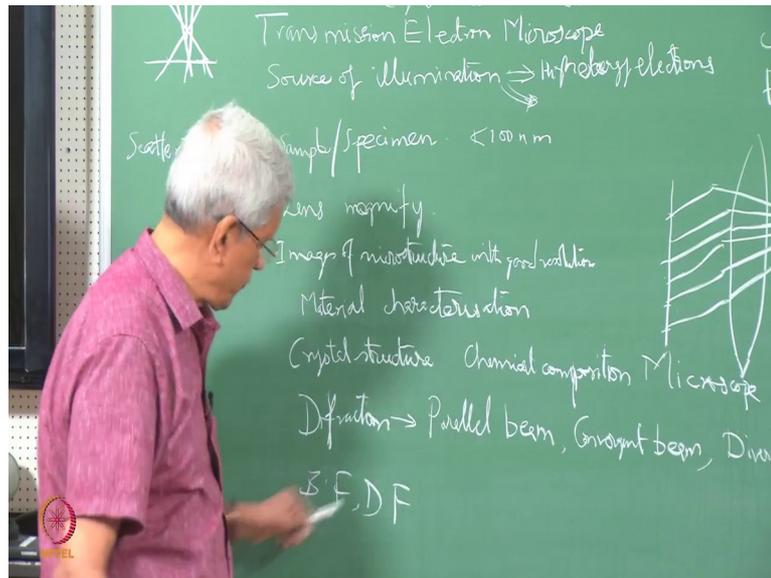
lenses are not perfect the resolution which we achieve is 100 times worse than what is essentially happening in that sample; that is for a point object we do not get a point image as we have studied earlier, instead we get a disc of least confusion. Because of this the in fact getting an image of a point as a point image we are getting, as we can see this is for a spherical aberration I am drawing it. So, for all the other aberration also can look at it. So, at the Cartesian plane if you look at it there is a spread. So, for a point this is what it is (Refer Time: 11:52) intensity is getting spread over that large area, this brings to on the resolution.

Other than that the most important property which you have studied about any lens is that, all the rays which are scattered from different points on the object or brought to a focus in the image plane. Whereas the rays which are scattered from different points on that sample that is rays which are scattered from various points on the sample surface, in a specific direction suppose these are all scattered in this particular direction all these are by a length focus is it all of them into a particular plane this is called as the back focal plane. So, in the back focal plane we essentially get information about the rays which has been scattered and different directions they are got to a focus, and this is nothing, but the diffraction pattern are this we can call it as the Fourier's information of that object is available in the back focal plane.

Again another Fourier transform takes place and which gives in the image plane you get image about that sample; how to draw the ray diagrams and find out the back focal plane as well as the image plane, all these aspect we have covered in detail. So, what is essentially important which is a characteristic of the lens if there, at the back focal plane we get diffraction information at the image plane we get that image information. If the incident wavelength incident radiations has got a wavelength which is quite sufficient to resolve individual atom positions, then we should be able to get image of the object that is the atomic resolution of that object in that image plane. In fact, in modern microscopes this is possible and this aspect we have covered in the class.

So, this is the most important information about lens. So, essentially when we use lenses, we get diffraction as well as the micro structure information and then we that is using elastic scattering then we use inelastic scattering interaction of the incident probe with the sample, then we can get information about the chemical composition.

(Refer Slide Time: 15:01)



So, as we started this course we mentioned that when we wanted to characterize a material and when we say that the characterization is complete material characterization. The information which is required about the sample is crystal structure, then chemical composition, then micro structure. From whatever we have briefly discussed and which has been covered in the course of this lecture all these information could be obtained in an electron microscope.

That is the crystal structure information from the diffraction pattern, chemical composition interaction chemical composition information from the inelastic scattering which is taking place, and the micro structure information from the magnification of the scattered radiation we can get it. Not only that the chemical composition information using inelastic scattering we can get distribution of the elements on that samples. So, essentially there are different types micro structural information which we can get ok.

So, having discussed so far they would the basic aspects of what all information which we can get it from a microscope, what are the different ways in which these different technique could be operated. So, essentially what we mentioned is diffraction and imaging. What all the various modes in which the diffraction could be carried out? This aspect which we considered as parallel beam then convergent beam, then divergent beam these is all the various types of beam which we can used.

Parallel beam diffraction is the one which is normally conventionally used to get information about the to find out the lattice parameter and in the parallel beam diffraction mode only we get images of the sample, you seeing specific diffraction beam that is going for two beam condition and then using the transmitted beam are the diffracted beam to get information about the bright field or dark field image of the sample, ok.

Then the convergent beam diffraction is used to find out information about are this technique itself is called as the CBED and this techniques gives information about the; you can be used to get to measure lattice parameter very accurately.

(Refer Slide Time: 18:25)



Lattice parameter strain in the crystal, then we can get 0.2 and space book information. These aspects we have covered in detail how all this information could be obtained using convergent beam diffraction. Then these divergent beams are essentially because. So, far in this we consider the beam as a coherent beam; whenever in inelastic scattering passes takes place that beam turns out to be incoherent beam.

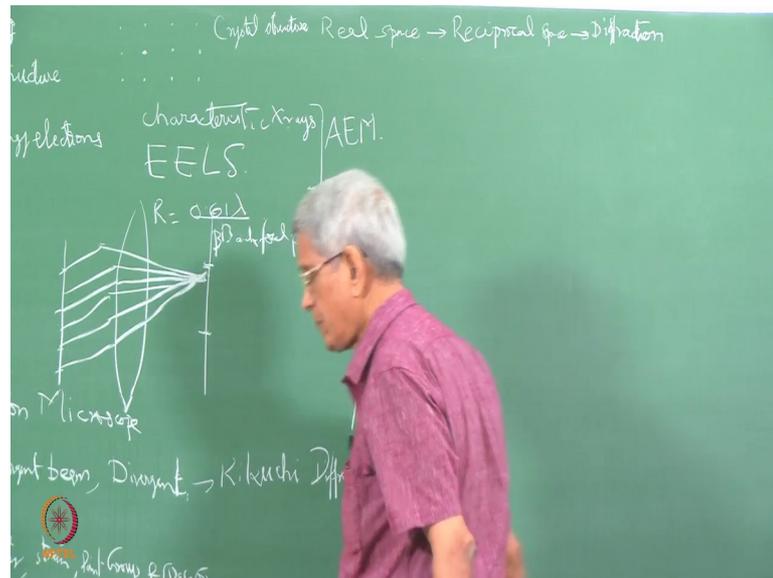
If this incoherent beam is elastically scattered again because the material is ultraslan material then what it gives rays to is what is called as a kikuchi diffraction. So, this kikuchi diffraction the source of kikuchi diffraction the source of illumination of the source of diffraction is within that sample, because of that when we till that sample by the same angle this diffraction pattern also shifts and this could be used to orient the

sample accurately and also this could be used to find out the lattice parameters quite accurately.

This aspect also we have covered in detail, then imaging not only the bright field and dark field there is another method of imaging which we called as the wig beam imaging. Wig beam imaging is one in which the diffracted beam is made so weak. So, that it satisfies the kinematical condition this has some advantage that as specially when you wanted to look at the diffract structure like dislocation whether if they have split into path shells what is the separation between them in the bright field image it very difficult to find out the separation, but using this wig beam technique we can get information about that, this aspects we have covered then another is lattice fringes or this is called as phase contrast microscopy those aspect also we have covered.

But what is essentially important is that all these things this which we have covered, but in reality if we wanted to understand are characterizes specific defect, what is essentially important we should be able to quantify the information which we get it that is one aspect which has to be consider. In fact, quantification of this various aspects also has been covered in sufficient detail, what all we have done it I will just briefly mention. So, first let us look at crystal structure information how we can get it. In this we said that we can use diffraction technique to get this information. So, the thing which have nots understand, but is relationship between crystal structure diffraction and there is an another concept is that the crystal structure when we talk of we talk in real space ok.

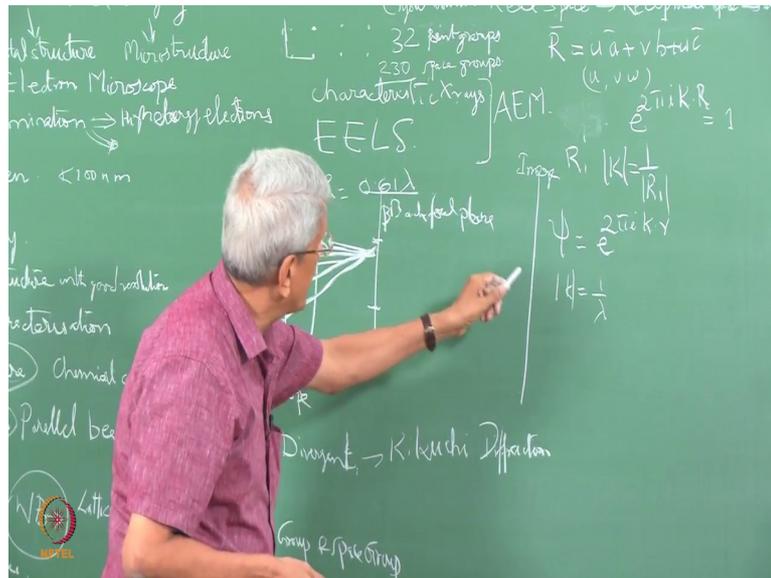
(Refer Slide Time: 22:25)



And then we have to consider what is called as the reciprocal space. So, in the crystal structure information crystal structure essentially determination requires real space, then reciprocal space and this reciprocal space is related to diffraction. So, all this aspects that is. So, when we think of a crystal structure we do you wanted to understand it or we do you want to get information about the crystal structure, because the properties are determined by the symmetries which are associated with the different types of crystal structures.

So, we know that there are seven class of crystal structures are there, within those seven classes we have fourteen types of Bravais lattices are possible in three dimensions and within this fourteen Bravais lattices around each lattice point we can put different types of motifs, there are this motifs can have some specific symmetry which are associated with the. So, the symmetry which are associated with each of this around the motif what all the symmetries which we can have in three dimensions, there are only thirty two distinct point groups are possible, ok.

(Refer Slide Time: 24:00)



This when they are arranged around the space lattice, they give rays to 230 space groups these are all the space groups into which the crystals all the crystals which there from fall within one of the space groups; essentially what is important is there to. So, this information will be consider we started which some crystal structure and came, but what is the information which we are going to do when we look at the sample, what we get is there diffraction pattern, ok.

From the diffraction pattern we have to go and the identify what the crystal structure is, how to do that that part of it we that depends upon the conditions which are associated with are what is called as the extinction conditions. How what all the types of reflections which will be suspend or the reflections which will be absent, which are the reflections which are going to be fundamentals, which as the reflections in the case of an order (Refer Time: 25:11) which are going to be super lattice if we get these information using those information we can try identify what all the crystal structure to which this the specific sample belong, ok.

Those aspects we have covered in detail. So, essentially what is important if the type of symmetry which are associated with it. In fact, each of the crystal structures if we look at it if for example, if it is a triclinic structure if we take it that does not have any symmetry which is associated with it. If a particular crystal structure if we obtain that is with the monoclinic lattice if you obtain monoclinic lattice has got centrally one to fold

symmetry. As we have studied earlier the reciprocal lattice also exhibits the same symmetry of the crystal and similarly the diffraction pattern also. So, if we look at the diffraction pattern taken in a different direction, if you find that only two fold symmetry is present along a specific direction then the crystal has to be a monoclinic structure. On the contrary if we find that along three particular directions we are able to get a twofold symmetry ok.

But the lattice parameters are not turning out to be the same in any direction then the crystal structure will turn out to be essentially orthotropic, this way like if we look at hexagonal lattice then we will find that we will be seeing 6 fold symmetry in the diffraction pattern we will be observing it which we have studied, similarly in the cubic crystals also six fold symmetry will be exhibited by the diffraction pattern in one direction. But looking at, but in the case of hcp only along one direction along the c direction the 6 fold symmetry is exhibited, whereas in the case of FCC in the diffraction pattern if we look at it along of 4 100 directions in the crystal we will be getting this sort of a pattern.

Looking at these information from the diffraction pattern which has been taken in different directions, we can try to find out to which crystal system the particular sample belongs to once you know what the crystal system from that we can tell what is the sort of property which the crystal should exhibit now especially with respect to a mechanical property are with respect to the magnetic property, are with respect to the (Refer Time: 28:04) behavior Piezo electric behavior all these properties could be determined. For which understanding the crystal structure is important and the relationship between real space and reciprocal space is another information which is very important is essentially is that when we wanted to mathematically represent a crystal structure ok.

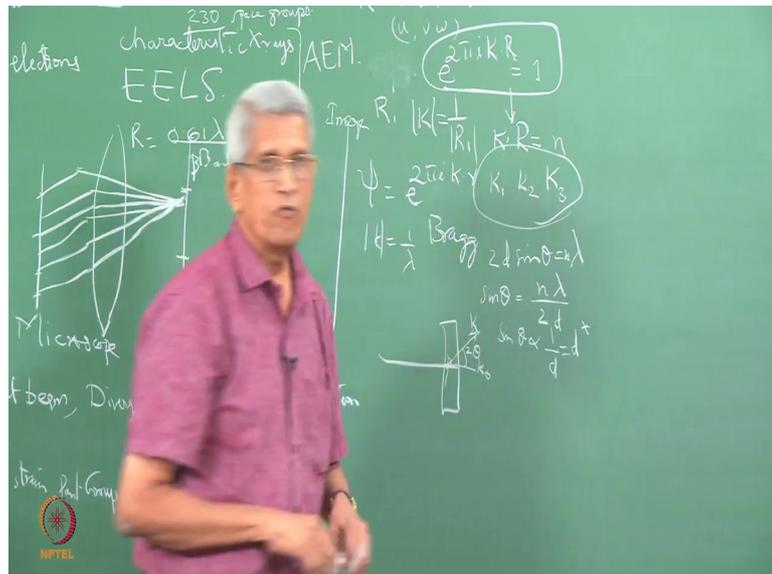
We have to represent it as a periodic quantity there are two ways in which a crystal structure could be represented one we can represent this crystal as with respect to one any coordinate system, which we can choose it with respect to that atoms are at different positions then you can be defined with the vector $R = u a + v b + w c$ where a, b, c are the lattice parameters along the different directions, and u, v, w are the distances in different units which we have to take along each of these directions. So, using this factor and u, v, w are all integers positive or negative with this all the lattice points could be described this is one way to describe. But if you wanted to describe the

periodicity the way in which we can look at it, if that it can be described as the functions ψ to exponential $2\pi i \mathbf{K} \cdot \mathbf{R}$ this should be equal to 1 this is the condition where \mathbf{R} is the any vector in the lattice.

And \mathbf{K} is a vector which is inverse of the period suppose a period in some particular direction is R_1 then models of \mathbf{K} will be $1/R_1$. This how looked at it is that in this periodic lattice suppose we allow in electromagnetic radiation to pass through. Electromagnetic radiation as a plane wave if we consider it, this is the way we represent it plane wave of ψ equal $e^{i \mathbf{K} \cdot \mathbf{R}}$ where \mathbf{K} equals $1/\lambda$ a (Refer Time: 30:44) \mathbf{K} equals $1/\lambda$, a λ is the wave this we know very well. If this wave enters into it and when the period of the wave that \mathbf{K} matches with that of the periodicity in a specific direction, then the crest of the wave all will be touching this lattice points ok.

Similarly, we can find out so many directions for which different \mathbf{K} values we can obtain, for in all this cases the \mathbf{K} and the \mathbf{R} if you see the magnitudes are inversely related. And the direction if you look at it that will be in the same direction as the vector \mathbf{R} the \mathbf{K} is going to be. So, that is essentially what is being given here.

(Refer Slide Time: 31:43)



So, if we use that condition we will be getting a condition like this, for this condition to be satisfied $\mathbf{K} \cdot \mathbf{R}$ should be equal to an integer, for all values of integer this will turn out to be 1. \mathbf{R} for this value for any specific value of \mathbf{R} which we choose it that can be

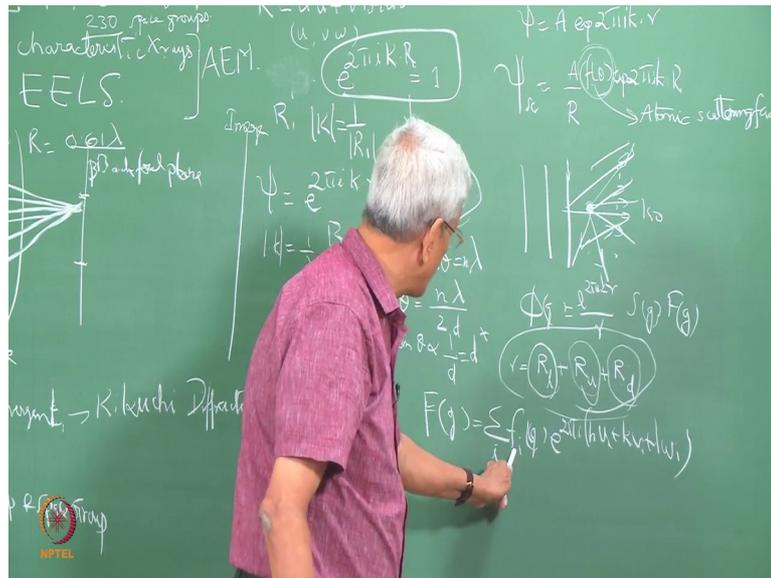
many values of K and this K has got a magnitude which is inverse of R . So, this space is called as a reciprocal space and this space will exhibit all the symmetry of the real space and another is that for the 3 vectors which we choose.

So, unit vectors to the present the primitive translation vectors the translation vectors of the primitive unit cell then we can find out values of K , K_1 , K_2 and K_3 which are going to be translation vectors after the reciprocal lattice of the primitive lattice, with which we can consider these aspects and the property of the reciprocal lattice all this things which we have consider. Why this reciprocal lattice information is really necessary? Because when we consider diffraction we use the Bragg condition for diffraction ok.

The Bragg condition for diffraction essentially is $2d \sin \theta = n \lambda$ are essentially what it means is that when a beam is entering into a sample in a specific direction, that can be with some particular in vector notation we will call is a K_0 the vector direction and this beam is scattered in a particular direction which is K , this angle which it submits this will be essentially between them is 2θ ; and the if Bragg diffraction takes place then $\sin 2\theta$ should be equal to $\frac{2}{dR}$ what is going to be there d spacing of this planes, R we can see that that $\sin \theta$ is essentially proportional to $\frac{1}{dR}$ this will be proportional to we can write it as d^* which is the reciprocal space. So, the information about the scattering angle when the scattering takes place, from that information what the information which we get about the sample is in reciprocal space ok.

From that knowing the symmetry of the crystal structure we can go back and get information about the crystal structure. So, when the study this study from real space to reciprocal space to diffraction, in the same information we can get in the diffraction also when we consider diffraction what do we exactly do, we consider plane wave ok.

(Refer Slide Time: 35:06)



The plane wave essentially is we represent it psi equals A into exponential 2 pie i K dot r, there K is the equal to 1 by lambda where lambda is the wave length of the incident radiation. When this wave is coming in this direction it is interacting with the particular atom, and we assume that it is scattered uniformly in all the direction.

When we wanted to find out the amplitude of the wave in the different directions then you right that this scattered amplitude will be equal to A by R at some particular distance, into f of theta exponential K R this is how we write it; that means, that this is 2 pie i in all the cases I should be there. That means, that this factor is the one which decides there is if a plane wave is coming and hitting this sample, how this plane wave is going to be diffracted are scattered in the various directions if you look at the amplitude of the scattered rays in the various direction, this is determine by this factor.

This factor is called as the atomic scattering factor, this atomic scattering factor essentially gives information about in the case of x ray diffraction that depends upon the density of electrons in the sample are they distribution of electron density in the material that is what essentially give. That information we can obtain from the diffraction patterns diffraction pattern studies using x rays. In the case of electron diffraction this f of theta is going to determine on how the incident electron is going to interact with the electron.

So, it is essentially the electrostatic potential how that is distributed that sort of an information which we can get it or we can say that the atomic scattering factor depends

upon how the incident electron in the case of electron microscope, it interacts with each of the atom which is being present this is that information. But we know in that sample the atoms are presented regular intervals at periodic positions from each of this positions the electron wave that Broglie wave will be scattered by this particular type of an factor.

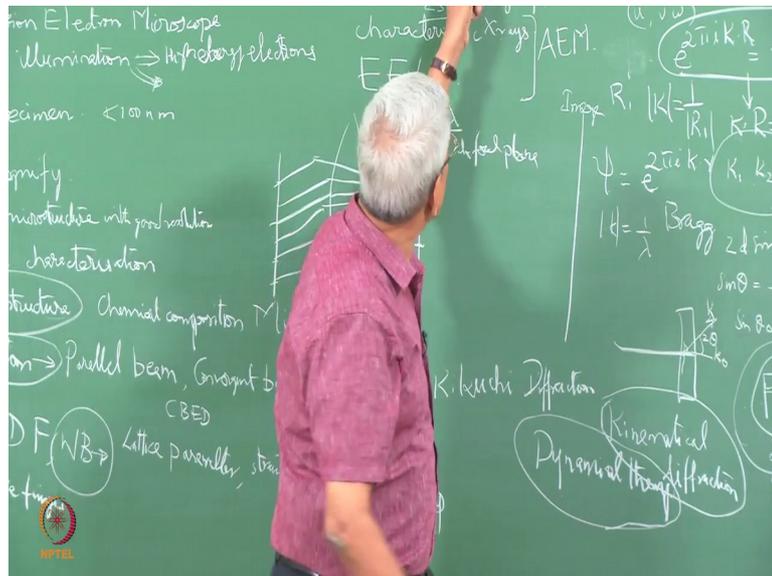
But what is essentially important in a specific direction if this is the incident beam direction K_0 , in another direction from all the atoms how that scattering is going to take place. If all the scattered waves there amplitude add together then we say that the constructive interference takes place that is what it gives rays to a diffraction pattern, all these aspects which we have studied then from the full volume of that sample that how many scattering centers are going to be there in the material, we have to take that into consideration on that basis then we will be getting that the amplitude S_g will be equal to k_r by r into two terms will come S_g and F_g what is S_g and F_g and before we go to that another important aspect which we have to consider is that, this sort of a diffraction when we consider it this is called as the Laue type of a diffraction ok.

From this we can find out what is the condition for a Bragg diffraction that is what is the relationship between them. All these aspects which we have studied, but what is essentially important is that the total scattering when we have to consider each atom when we wanted to describe what is the way in which it can be describe. One way which we can describe is that all the atom position that R can be described as R_l plus R_u plus R_d , that is that is if it is a primitive lattice only R that is how R if it is non-primitive lattice how each unit cell can be represented by one point what is the position at which is occurring; R_u is how atoms are distributed within the unit cell, R_d is suppose in some region defect is there and the atom is displaced from the particular lattice position that deviation which is being given. So, this is the one which has to be subtracted and this gives rays to these terms.

So, essentially in this what will happen is that the F_g will be F of i g into exponential $2\pi i h u_i$ plus $K e i$ plus $l w$ all these aspects which we have studied this gives what is $f_i g$ this is essentially the atomic scattering factor for each atom position in the unit cell, and this F_g gives the total atomic scattering (Refer Time: 41:44) that total scattering factor are the total scattering from each of the unit cell. When all the like that so many unit cells on which the beam is falling, so, this is the one S_g the number of unit cells which are there that sample that gives this information S_g .

So, that gives what is going to be the amplitude of the each of the diffracted diffraction pattern which we see in the sample that amplitude will be able to get it. What is essentially important is that in this Fig we know that depending upon what positions the atom occur, they give rays to special conditions which are called as the conditions for which the depending upon whether it is an FCC R I BCC crystal what are the extinction conditions which for which particular reflections, that we will be able to see the weather constructive interference will take place are destructive interference will takes place on that basis we can find out whether it is body centered lattice, are whether it is a face centered lattice, are whether it is a night centered lattice all this information which we can obtain.

(Refer Slide Time: 43:12)



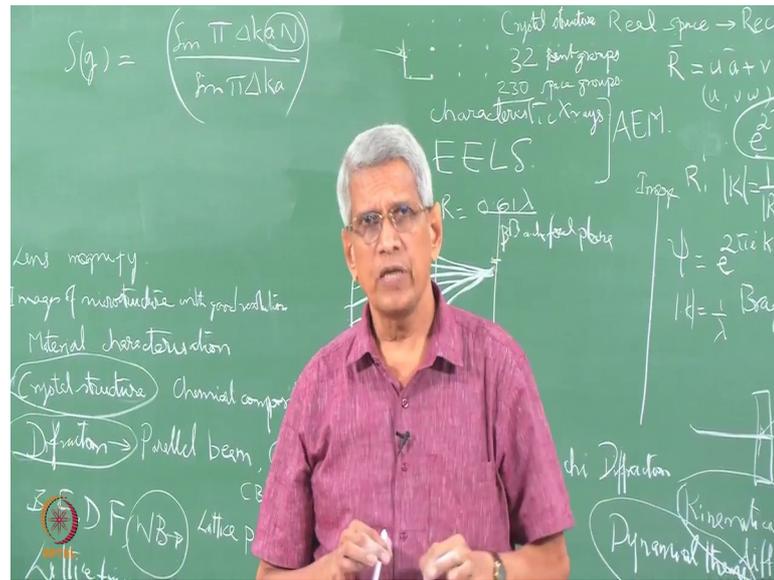
And in addition to it when it has got grid symmetry are a screw symmetry they also give rays to special conditions for what all reflections which will be present and which reflections will be systematically absent using these information we can get information about the crystal structure it is point two point space group symmetry could determine. In fact, that is what is being done in the case of x ray diffraction. So, x ray diffraction is used to get information about the point two point space group symmetry the complete crystal structure information of the material or the sample we can obtain, but what is important is that this structure factor which we have written.

One basic assumption on which all this entire derivation has been done is that as the beam passes through the sample only one scattering event takes place. So, when we consider only one scattering event, this we call it as kinematical theory of diffraction. So, are kinematical diffraction that is what it is being done. This is valid for the case of x rays because the x ray interacts weakly with matter, whereas in the case of electrons in an electron microscope they interact strongly with the electron which has been scattered in a particular direction before it comes out of the sample it could be scattered again. So, multiple scattering can occur in that case we have to use what is called as the dynamical theory. So, what we can understand is that in the case of x ray kinematical theory could be used to get information about the crystal structure.

So, conventional using parallel beam when we get the diffraction pattern, using those diffraction patterns if you wanted to determine the point group and the space group symmetry it is not possible because the dynamical theory is the only one which has to be applied and because various type of diffraction like double diffraction takes place the spots which kinematical theory does not allow, those reflections could be present because of all these information.

Generally, the electron diffraction conventional electron diffraction pattern is not used for determine determining the crystal structure information like point two point space group symmetry. But looking at the symmetry we can get some information about what are the crystal class to which the some in crystal systems to which it belongs to all this information which we can obtain in a electron microscope, then the other aspect which is important is what is these function $S_{g_{ok}}$

(Refer Slide Time: 46:42)



This function $S(q)$ gives it will be essentially \sin pie this is the sort of an expression which will come which you might have all remember. This that depending upon the small deviation depending upon the size of that sample, because a into n represents what is going to be the size of the sample in it is particular direction. Depending upon that size this will give a condition for the intensity of the diffraction spot to reach a minimum value. Essentially what it means is that if the sample has got an infinite length then we will get a very short diffraction pattern, while if the sample size is very small the diffraction spot will have a lot of broadening. So, are in other words.

Depending upon the extent of sample size in different diffractions, we are able to get information about the shape of that sample. So, the streaking will be present in different directions in the diffraction pattern. In fact, in the microscope since the sample is which is used is extremely small as I mentioned less than 100 nano meters, generally streaking is present perpendicular to the a sample thickness in the diffraction pattern. So, this is what it is responsible for many imaging characteristics of the sample; because of this even when we till that sample you find that the diffraction patterns in the parallel diffraction if we take it the pattern to remain for the long time, that is one of the reason why we do not use it to find out the lattice para meters very accurately.

So, essentially what we can make out is there the structure factor which is given by F_g and then this particular factor is the shape factor which decides how the diffraction spart

for the diffraction pattern the streaking occurs in different directions that informant. So, that is why it is called as the shape factor which depends upon the shape of the second face particle. Suppose as second face particular shape is there assume there it is not a spherical one it is an ellipsoidal one. So, one direction it has got a major axis is very large size and the minor axis is centrally small in a width. So, because of this we will be getting streaking in different directions and in fact, looking at the streaking itself as we have learned we can find out what is going to be the morphology of the precipitates, that information we can obtain from the diffraction pattern essentially ok.

What we have done so far is over all we have covered how what all information which we can get it using the various types of diffraction. Similarly if we use the imaging capability of the microscope, because as I mention image plane is the one in which the rays which are scattered in different directions brought to a focus. By choosing either the transmitter are a diffracted beam we can get images if we use only the central beam un diffracted beam, then we call these as bright filled image and if we use any of the diffracted part, because if from some particular region diffraction is taking place, more diffraction is taking place that region will appear bright in the image.

So, correspondingly in the bright field image that region will appear dark. So, normally bright field and dark field could be complimentary to each other these aspects of with all the details we have covered in the class. Not only that I had also mentioned that there are various in which this imaging could be done; either if we wanted to image dislocation then what we have to do is that, we have to use in a low index sonax is pattern which we have to take it and if we try to image the dislocation, all the dislocations present in the sample could be image ok.

Suppose we wanted to get are quantify are characterize the particular type of a defect then we have to image the defect using different g vectors, that aspect of it we can use it to get inform in that case we use at two beam condition that is one central beam and the diffractive beam which is used. And then the other case is that if we choose so, many diffracted beam allow all of them to the interfere again, that will give rays to a lattice fringe contrast which is called as face contrast microscopy, and that could be use to get information about the distribution of atomic distribution are the atomic resolution microscopy.

These are all the various methods and some classifications I had given how to go about look at it. What we will doing is that in the next class so far we have covered up to diffraction the image part of it. So, how we can characterize that image, because we just mentioned that bright filed dark field could be obtain, but what is essentially important is that how these images different defects, how we characterize them looking at the image.

These aspect we have studied a brief summary of it, we will take in the next class. I will stop it here.