Defects in Materials

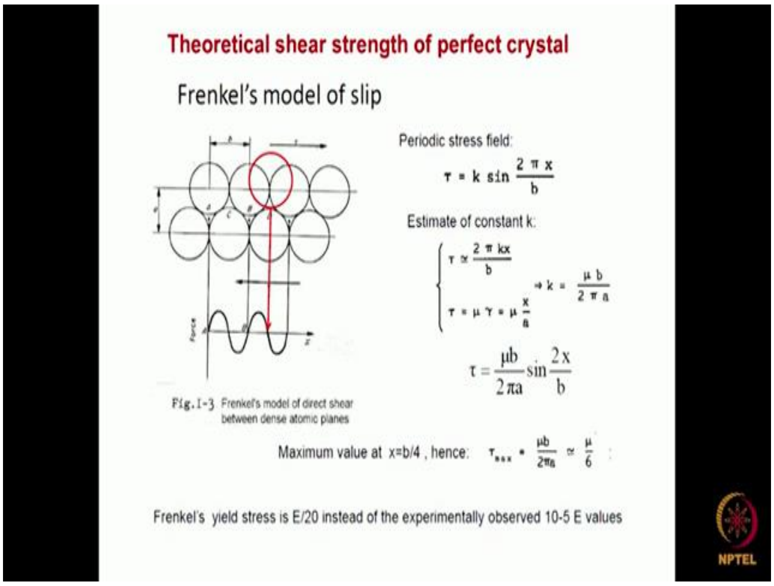
Prof. M Sundararaman
Department of Metallurgical and Materials Engineering
Indian Institute of Technology, Madras

Lecture – 17
Description of Dislocation 1

Welcome you all to this class on the Defects in Material. We have prepared the groundwork for finding out the stress and strains around defects. Now point defects we have considered earlier, now we will talk about the line defect. Some of the line defects that is the line defect which we know which exists in material is we call it as a dislocation. How do we people come to know that that is a defect like that the dislocation which is necessary, how was this concept introduced by Taylor Polanyi.

How did they say this concept is necessary? Because earlier in the beginning of the last century, when people had been looking at properties of the materials, they find that somehow or other they are not able to explain some phenomena properly. What are those phenomena's which they were not able to explain? You take a metal, if you are trying to deform this metal what will be the, because we know that metal kinds of atoms different planes. If a deformation has to propagate or the sample has to deform, the strength which is required critical strength which is the required is if you try to calculate it, it was seen to be equal to that of much or it was seen to be much lower than the theoretical shear strength the theoretical fracture strength of the material.

(Refer Slide Time: 02:22)

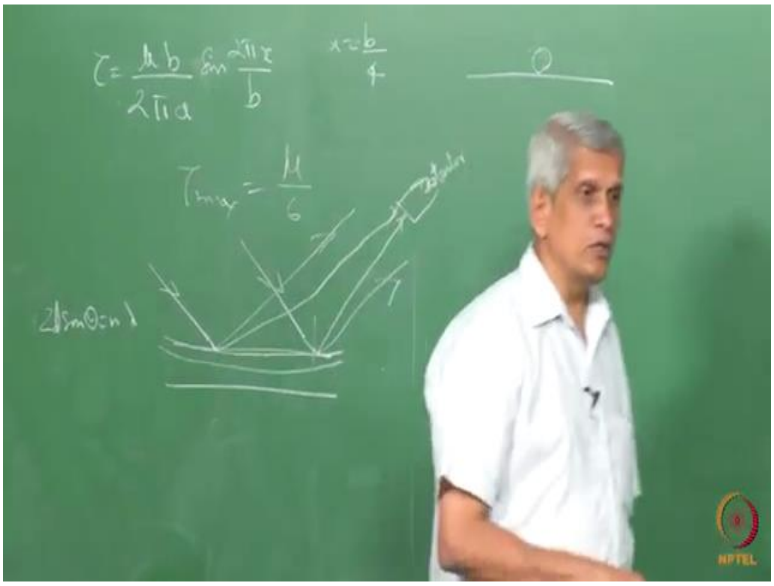


We can calculate what is the stress which is required this is called as a Frenkel's model of slip in which we assume that there are no dislocation which is being present. That before this concept of dislocation has been put forward, suppose this is one layer of atom and there is another layer of atom which is sitting on top of it. And if there is layer of atom has to be moved from one position to another identical position.

The stress field is that this has to be moved it should reach this position which is on top and then they should come down to an equilibrium position. So, moving from here to this position and then coming down that is essentially if you look at the stress field it is going to be essentially a cyclic stress field. So, this we can anything which is cyclic we can represent it in terms of sine function. So, that is what essentially which has been done. And we know that whenever we move from one position to another position, we are creating a displacement. And that displacement can be written in terms of tau equals mu into gamma is the shear strain and mu is the shear modulus. If we equate these expressions this expression and this expression, then we will be able to derive a formula of this type.

This formula when we take this value of x and, in fact, this is a term that is a it is not a correct term.

(Refer Slide Time: 04:04)



That pi is missing equals mu b by 2 pi a, into sin into x by b. This is how this term should be x equals b by 4.

Student: Pi by (Refer Time: 04:23).

That is one. So, this will become a maximum value. And if you take a b is equal to a, an assumption we make that they are almost have similar order, then the maximum value of the stress turns out to be which is required to cause deformation is tend to be mu by 6 it will be turn out to be. There are some different calculation which gives values of mu by 10 or mu by 30. That is the stress which is required for the sample to be deformed.

But what has been seen experimentally is that as stresses as low as 10 to the power of minus 4 or 10 to 1 in 10 to the power of that is 10 to the power of minus 4 or 10 to the power of minus 5, of those orders that is less than 10 5 or 6 orders value. We are able to deform the material; that means, that that has to be something, which is present in the material which should make deformation much easier that was the one observation.

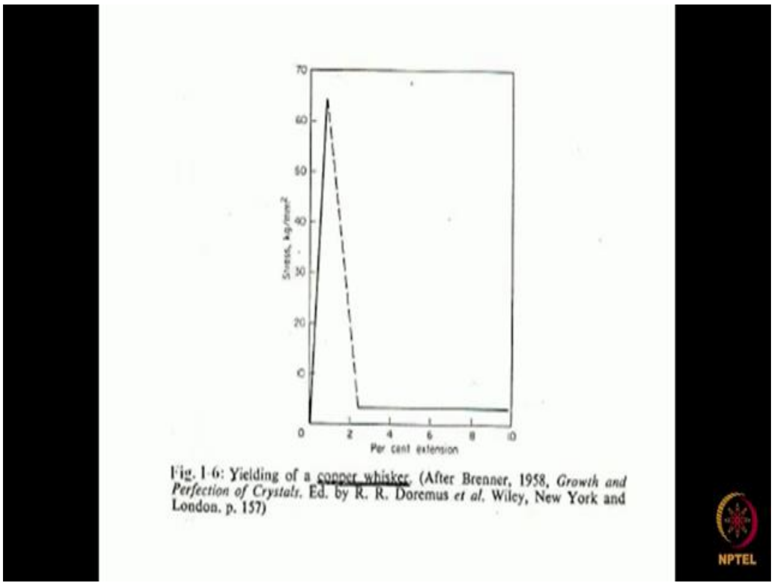
What was the next observation which was done? We have studied crystal growth right? Whenever we grow a crystal from a either from a vapour phase or from a liquid, if the atoms from the vapour or the liquid has to come and settle down on the surface and that is how the crystal grows. What is the rate at which it will come and settle? That one can calculate. Some rate at which is should form. It was always seen that the rate at which the crystal is growing is always much higher than the rate at which you should grow because that require some formation energy for the atom to come. That is if you have a surface like this, an atom comes and sit is on to surface. It has to make create some bonds, some formation energy is required for it to get stick on to it, but it appears as if that if it goes as a much faster rate; that means, that formation energy is being reduced. That is some defect which is being present which is aiding this growth that is another reason.

The third one was that, when we look at the X-ray diffraction if we assume that that sample is a very flat sample, onto which the X-ray beam is falling onto that sample. This coming in this direction because it is a 2 d sine theta Bragg light has to satisfy and lambda. And if I put a detector here, some portion of the signal will come and reach this detector, and that we can calculate it, but what was found was that, the intensity of the signal which is reaching this detector is turning out to be much higher than what it should be seen.

What could be the reason for that? Later on one of the possible reasons for that is that, if this surface itself though it surface looks flat, the planes which are responsible for diffraction if they are bent, and then what can happen? If it is a bent internally there is a bending is going to be there, and then a ray from here which also will be satisfying the Bragg angle and it will be reaching. A ray from here also sat will satisfy a Bragg angle and will be reaching. That means that from a smaller region itself, it is not exactly parallel rays no other rays are also coming into it adding to intensity; that means, that there may be some bending within the crystals. Then what causes the bending, if the crystal is a grown a perfect way; that means, that some defects have to be present which are causing this sort of bending.

So, that is how they decided that the concept of the dislocation was put forward in 1936.

(Refer Slide Time: 09:40)



And you know that, the other question which comes is that the line defects when we talk about are the equilibrium defects, they are not. That will come to later, but can we have materials which does not contain any dislocations yes it is possible. This we call it as a whisker. Small dimension sample which can be produced without any dislocations, but point defects will always be there in the material. If you take that material

Student: Sir, point defect y material will more than m material?

That, we can calculate it differently how it has to be; essentially, that point defect is inherently if the dimensions are sufficiently large, the point defects in the material lower the free energy. So, that is why they are existing whereas, dislocations one can calculate what is it is contribution to the configurational entropy. Because whenever a point defect is being formed, if you look at it, there is an increase in energy because atom is being removed from that site.

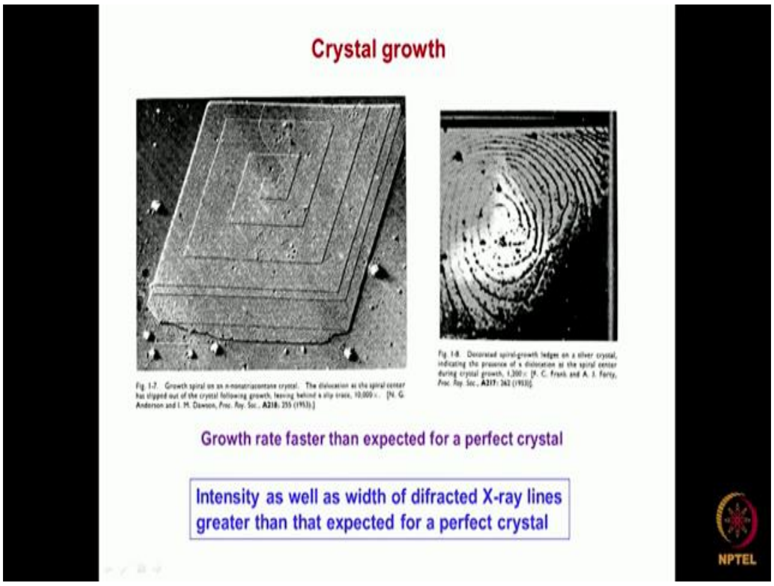
But when an atom has been removed, the different configuration which it can assume or different positions it can locate itself, that gives the entropy term. Entropy term is a one which is minimizes the total energy.

So, finally, it is between the energy which is required for the defect to be formed and then the configurational entropy the net one decides whether there is going to be a net increase or decrease, that will decide whether it is an equilibrium defect or not. In the case of vacancies there is a reduction in energy. In the case of dislocations essentially one layer of atoms which we are trying to put it, and that layer as such has to be positioned at some particular position. The energy which is required is high to introduce them, and the configuration number of possible configurations if we look at it they are small. Because of that the energy transfers to be positive always. This we will look at it from a different angle later when we consider about the stress and strain field around the dislocation.

Suppose we assumed that the material which does not contain a dislocation, we try to deform it. Then what is the strength which is required. This plot shows what is going to be the stress in the case of a copper whisker. We can see that it reaches up to I think here the scale allowed to change it k g to mpa, which I will do it. I think it is about 6 hundred mpa. You can see that from here when it reaches to a very high value where dislocation is generated in the sample. Then the dislocation is generated, the log or the stress comes down drastically. Now for the plastic deformation to occur we require very little stress correct.

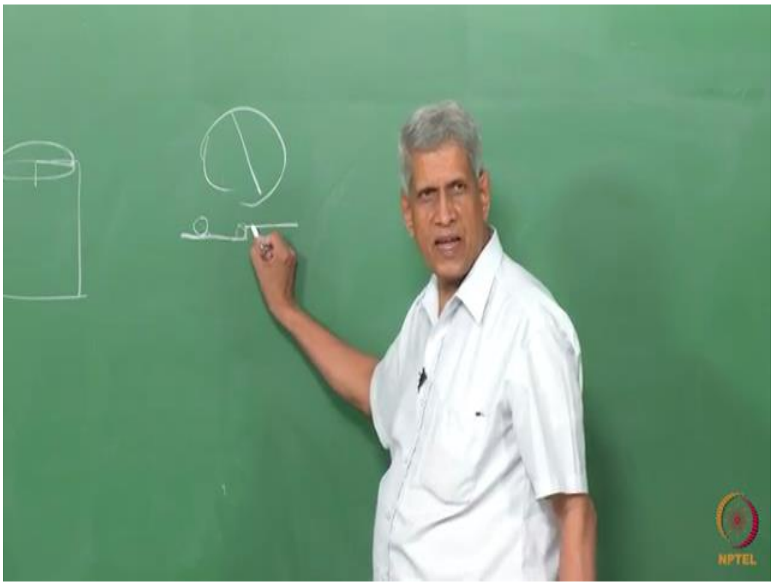
So, essentially from this you can make out that if dislocation is not there, really the stress which is required to a start deformation is very high. Or you can say that the ill stress becomes very high close to fracture strength it will go. Just before it reaches some dislocations are introduced, then it becomes much easier. So, immediately find that there is a relief in the stress. And then the dislocation starts moving at a much lower stress

(Refer Slide Time: 13:43)



So, I talked about crystal growth. And what is the proof of a crystal growth is that, when one looks at the surface of the crystal, one can see some sort of a ledges which is essentially a circular one. This is associated with essentially a screw dislocation which is being present there.

(Refer Slide Time: 14:06)

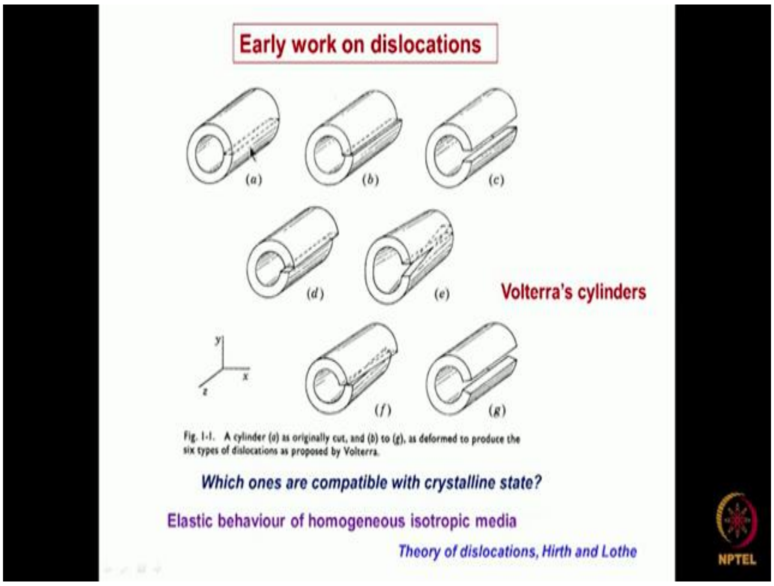


What is the, that is if a crystal is growing you assume that in this direction. We are looking at this surface. If a screw dislocation is present, that is from here to here, when you take one round that is always going to be a ledge which is present one step which is being present.

This will come to later. And whenever is that sort of a step which is being present on the sample surface, surface if you find that there is a step which is going to be there, that is this sort of a step you assume that the surface is there this is a step, if an atom has to come and sit on this point. How many bonds which it has to make is some number of bonds. If the same atom comes and sit is here the number of bonds becomes less; that means, that at the ledge it is easy for you to get attached this is how they grow faster.

Burgers vector nothing defines nothing, but a ledge, but even before this concept of dislocation has been put forward even in the 18th century. That Volterra has put up this one, that what are the ways in which the defect could be introduced in any material.

(Refer Slide Time: 15:33)



One you take a hollow cylinder cut out from a sample. You can just make a cut and then you can get lateral placement. That is one type of a defect which we can introduce it. He was looking at it that when a material deforms or failure occurs. What are the ways in which these failures can start? Then another is that this itself can be we have cut, this has just opened out like this. This is one type of a defect which you can look at. Another is that we have cut this sample, but there is a displacement which is going to be in these directions.

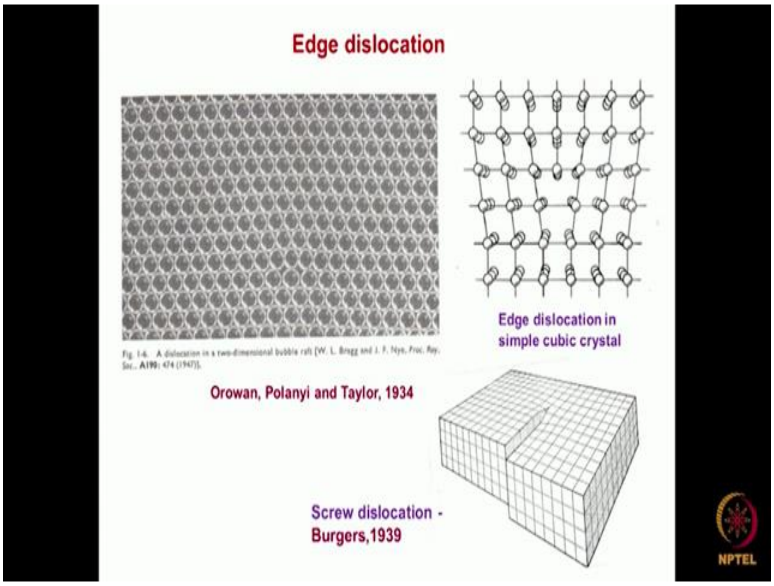
Student: These are way intentionally doing?

No you just listen to me. Then this is an another one where is a wedge shape which we can create it, where the wedge goes or this pulled it, this is pulled in. This is one way. This is other way is where it is essentially there is a shift also is given just not pulling. These are all the only modes in which you can create a defect in a material. It does not matter whatever you consider it.

That is for example, suppose we consider this dislocation look at it. This is perfectly a circle which you can see it. This if I take it like this, I can just leave a cut and leave it, it looks as if it is the same another is that because of the cut something this opens out like this. This is one which can happen. Other one is that this itself is like this, that is the step which can be created. So, this is also one way in which material failure can start. Another is that this itself is moved, but it is moved displaced inside. This is another defect one is that it can cut which comes like this, like this it can also happen, that is this will be like this sort of a thing. That is now you see that these are intersecting and going like this what is the other way in which it can occur. That this can move like this. This is the way it can happen, one is inside and another is outside. So, these are all the only possibilities in which you can introduce a defect.

This is something which was done long time back. What is the consequence of it, when ideas about crystal structure or fractures, none of these things were known? The consequence of it is that, with respect to the lattice geometry some of them are consistent with it. That is essentially, what is beauty of this. This is the concept which has been used to define a dislocation in the material.

(Refer Slide Time: 18:41)

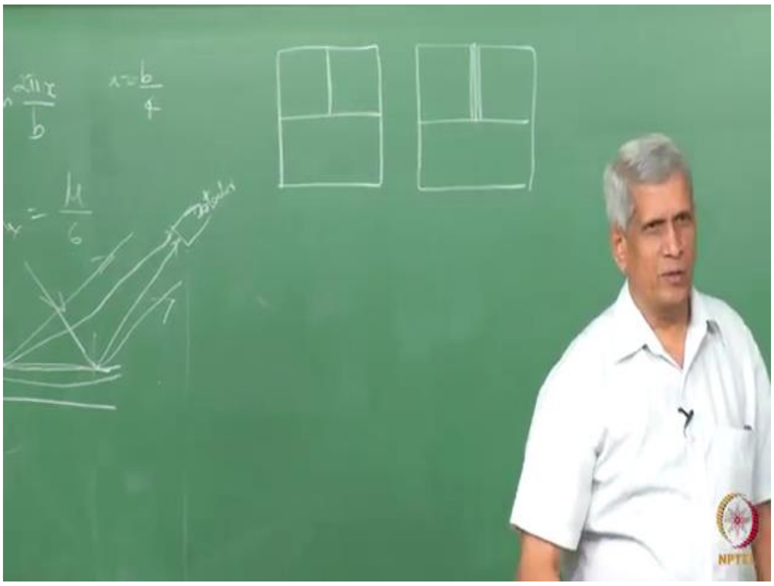


This is essentially another one which has done by Nye and Bragg. We are back in 1947. This is using a soap bubble, they create a bubble and it is a two dimensional surface it generates. When it generates two dimensional surfaces can there be any defects which are being present in this. Can you look at a defect here in this?

If this look at it. It looks everything looks all right, but there is somewhere a defect is there. I will just show you around this region now if you look at it, with respect to atoms there is a displacement is going to be there correct. This is a type of a defect which was proposed as a defect which is present in the sample. Here what is it being shown, this is shown up for an edge dislocation.

What is that is suppose we have a perfect lattice into which we make a cut.

(Refer Slide Time: 19:48)



That is we take a perfect sample. Make a slit up to this point pull it apart. Then introduce under region which has been pulled apart. Add one more layer, then the whole thing will be, if you look from here to here, this is the perfect lattice because all layers are because the separation between them again here the same lattice translation vector and here also it is going to be there.

But if we go from here to here what do we see? At this particular point there is going to be an extra layer which is coming into that, so that one which separates between these 2 layers where the extra plane is ending. This defect is like a goes like a line from one end of the sample to the other end. This is called as the edge dislocation.

Similarly, here what is it being done? You take the material which is because I take a circular round is perfect one. Then if I move it like this, that is essentially after making a cut here along this line up to some point. Then that portion I try to shift it by a lattice translation vector and then try to join them. So, if you look everywhere, the atoms are going to be joined, except it is going to be there at that point. So, this is one way to look at the dislocation defect. That is a defect which is being present by far away from the defect if you try to look at it.

All atoms are in lattice position, but there is one point along the centre, the defect is being, that is why this is called as a line defect. These are all the 2 models which has been put forward. Is it clear? This is a simple edge dislocation model was put for a cubic crystal

Student: (Refer Time: 22:27).

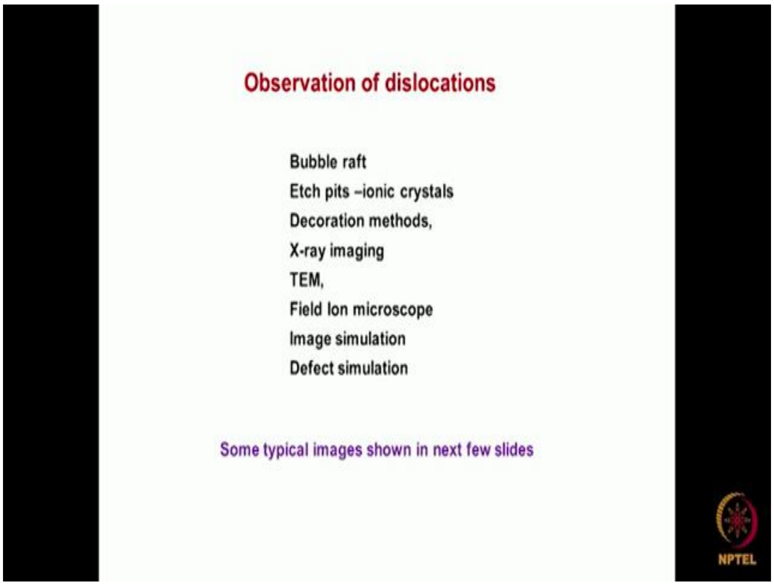
How are these defects created? This is a way of looking at how these defects could have been created. We assume that this is a model which is a explanation. What is the reason for these defects to form during the growth itself they do take place? That is because there are thermal vibrations which are associated with them atoms which are being present. When they come and get attached the thermal vibrations can cause finally, they arranged into some sequence, suddenly you remove the vibration lower. It will all be trying to settle down into some portion. Now suddenly you find that some region there is a mismatch which has come, that mismatch is what is this type of defects which are going to be there screw dislocation or an edge dislocation.

But how can we think of that this one. This is one way we can think of that this is how this defects have form. So, there are 2 types of defects which we see. One in which the in this if you try to look at it, what is the line direction here. The dislocation line is going from one side to the other side of it. And the defect which has been introduced here also if you look at the step is coming in the same direction as that of the line direction. So, these are called the screw dislocations. This is something like if you take a screw, I try to rotate one rotation I move one pitch forward. Again I will go forward like that it happens. So, from here to here, if I try to move from here rotate it like this, and try to reach here I come down one pitch has happened. So, that is why this is called as a screw dislocation.

Student: Straight line.

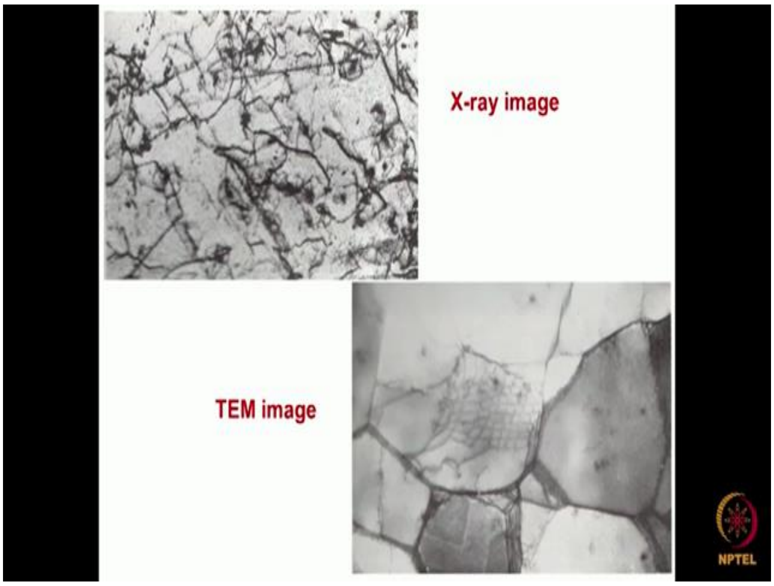
That step will come. So, this is called as a screw dislocation. Here, what it happens here? If I go from here to here suddenly, I find that there is a step which is going to be there in the perpendicular one in this direction, correct an extra plane which has been added. So, these are called as an edge dislocation. That is if I take a circuit like this it is not a step which is going perpendicular to this screen. It is in the lateral direction. So, that is called as an edge dislocation.

(Refer Slide Time: 25:14)



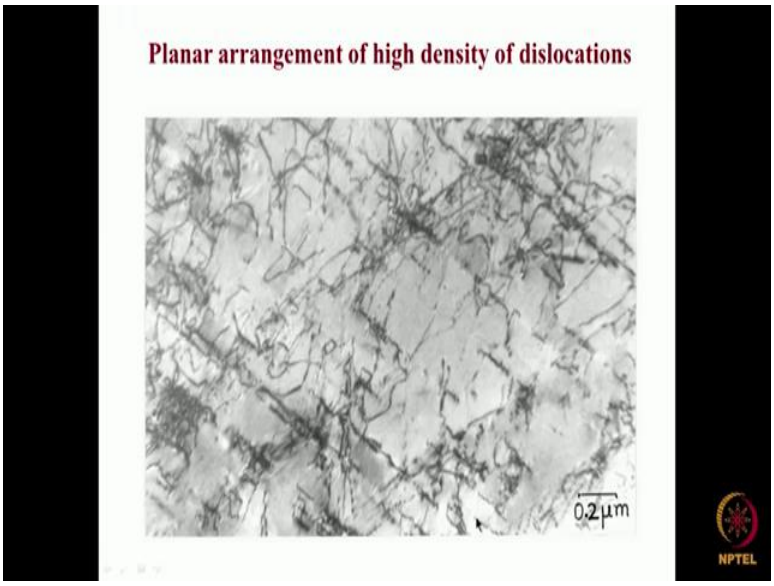
What are the ways in which these dislocations have been observed? Or what are the modes of experimental observation, or what are the results concerning the experimental observation of dislocation one?

(Refer Slide Time: 25:30)

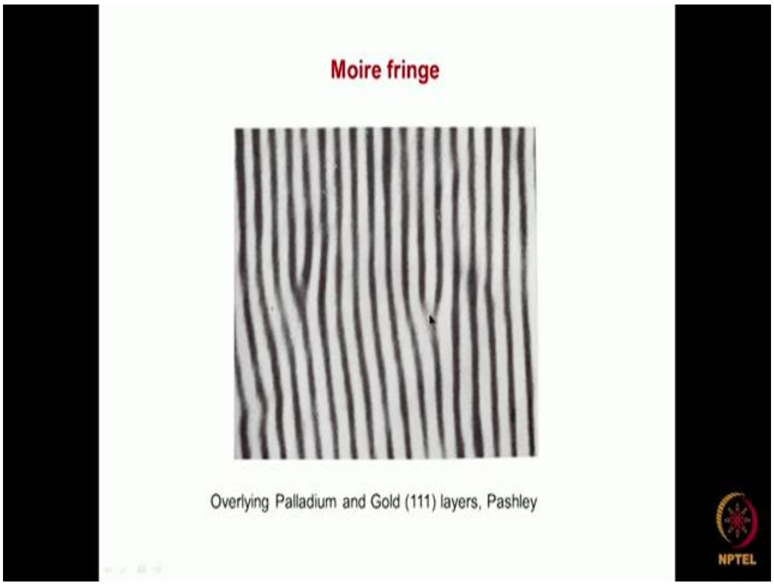


Electron microscopy we can use it to observe dislocations X-ray imaging can be used to observe dislocations. This is one example where the X-ray one can find dislocations in the material TEM we can use it.

(Refer Slide Time: 25:46)

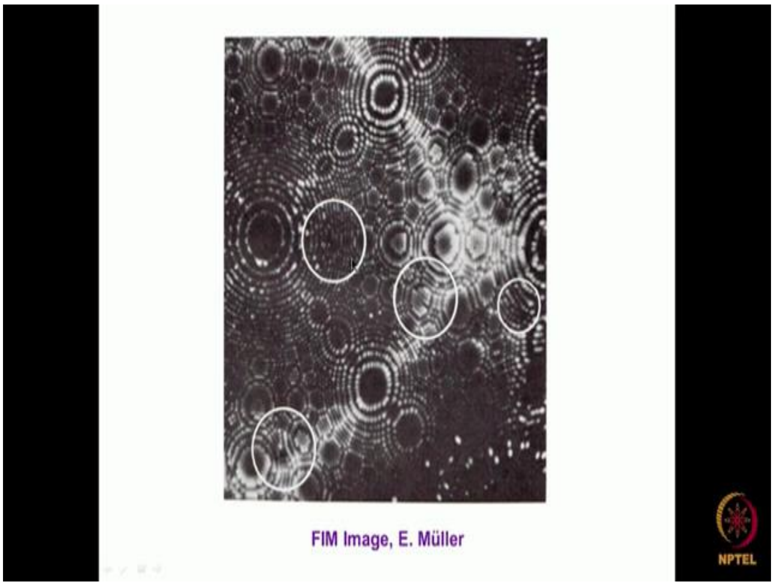


(Refer Slide Time: 25:48)



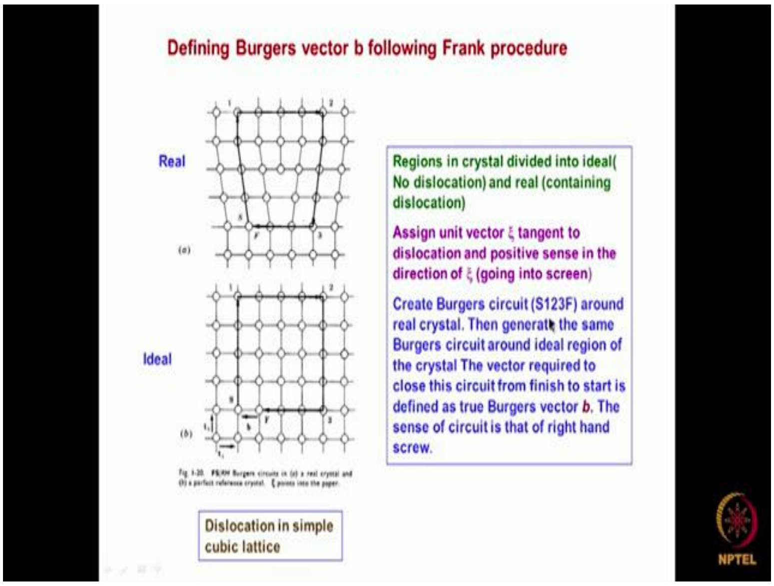
Then another is an electron microscopy I thought earlier with more moire fringes, we can generate something which looks like this if you look here as well as here. This looks like a the way we have seen from the lattice structure, how the dislocation looks like the edge dislocation.

(Refer Slide Time: 26:09)



Another is using atom probe, also one can see some extra planes like here to here. If you see there is an extra plane which comes in this region, this is an indication that there is a dislocation which is being present; so all these regions if you look at it where which have been circled. In that region if you look at it. There will be some extra layer of this right atoms will be coming. This is one example that is using atom probe you can do it.

(Refer Slide Time: 26:45)

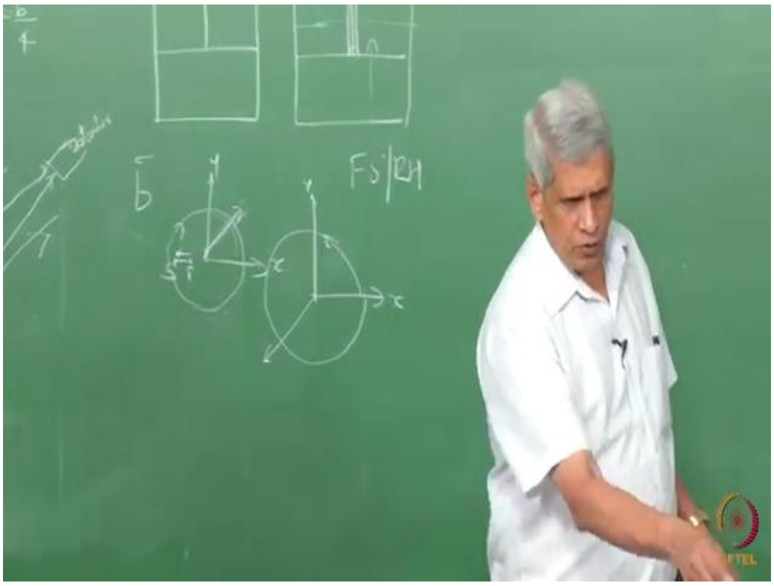


Now, let us come to a definition of the burgers vector of a dislocation. This is what a procedure is called as a franks procedure. Now we had just got a model of how to model a dislocation. Now the next question which comes at how do you define the burgers vector of a dislocation. To define the burgers vector of a dislocation what is it which we do, for any which one for any work it to you if you have to quantify it we should choose a coordinate system. So, what is the coordinate system which is being chosen here is that,

Student: (Refer Time: 27:30).

The extra plane that is; which is the plane, in which this extra plane is lying, that is from this plane to this plane correct. So, in this direction this is chosen as the x direction, perpendicular to that. And normal to that is chosen as a y direction. And the direction in which the dislocation is going, that is chosen as the z direction. In this specific case the positive sense of the dislocation or the z direction is going into the screen.

(Refer Slide Time: 28:13)



So, the coordinate system which is chosen here is x y the z is in this direction into the screen that is how it is define. Suppose we start from any position yes, we move around it and 1 2 3 4 lattice translation vectors we have moved. We reach this position then move some distance around it here. Then move by the same distance back here, then move back then, we can come to a point where the finish point. We have come to a identical point, but we have taken a

Student: (Refer Time: 28:53).

Path or we have travelled along around the dislocation line. And reach the starting point we are completed. Now, we choose a region of the sample which does not contain any dislocation. I do identical displacements. If I do that, then you will find that here it is only 4 steps which are required in the negative x direction to reach starting point. Here when you take the 4 step you find that from the starting point to that is finish point to a starting point there is a gap. This is defined as the burgers vector of the dislocation. This burgers vector b is always is a negative one correct? Because with respect to a coordinate system which we have defined. This is the positive x direction, but the step is from finish to start it comes this vector is in this direction. This is a convention which is used to define to I find out the burgers vector.

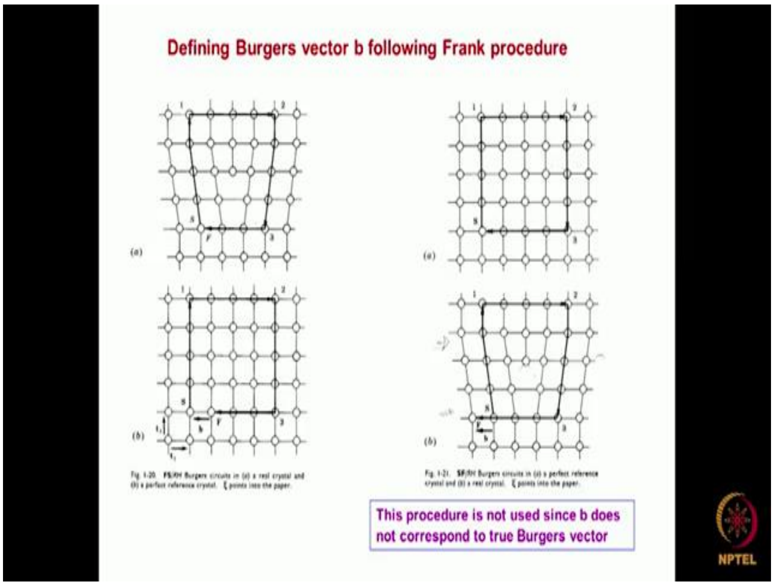
So, what is important is first coordinate system? X is this one, y is in this one, and the z is going into that line sense of the dislocation is going into the paper or to the board. Then the burgers vector b will be defined in this way. This is called as the finish to start right hand convention. Because what is being done is that here we are doing a right hand screw that is this is the direction in which we are moving around. Right like a right hand screw we are trying to do that. This is right?

This is some books it is define the news this way. There is another convention which people follow. Other convention is that if I take this is like this, other options x y, you take the line sense of the dislocation coming out of this sample. And instead of taking burgers circuit with right hand screw, you take the left hand screw that is go in this direction and try to come back. This one can do it as an exercise. Then only we find that the finish to start will be in the finish, will come here start will come here that becomes that sign changes it becomes positive.

Both the conventions are being used by different people, one has to always define the convention and use it accordingly. While reading books quite often, this can need to some sign changes in the expression. That normally arises because of this sort of the way the convention which they follow to define the burgers vector of the dislocation. Is it clear?

That is essentially what we have taken here. What we have done here is that, we first do a burgers circuit around the dislocation and then take a region which is does not contain any dislocation, do a similar procedure and try to find out what is going to be the gap which is going to be there, and in which direction magnitude of the gap and you when you point out the direction that defines the vector. And generally in all the crystals this is going to be the lattice translation vector. Dislocations which exhibit where the burgers vector or lattice translation vector we call them as perfect dislocations.

(Refer Slide Time: 33:27)



Here I am just trying to show you a comparison. It appears that if I, if I try to do a burgers circuit around a real crystal that is in a region which does not contain any dislocation, and then I do the same burgers circuit around them.

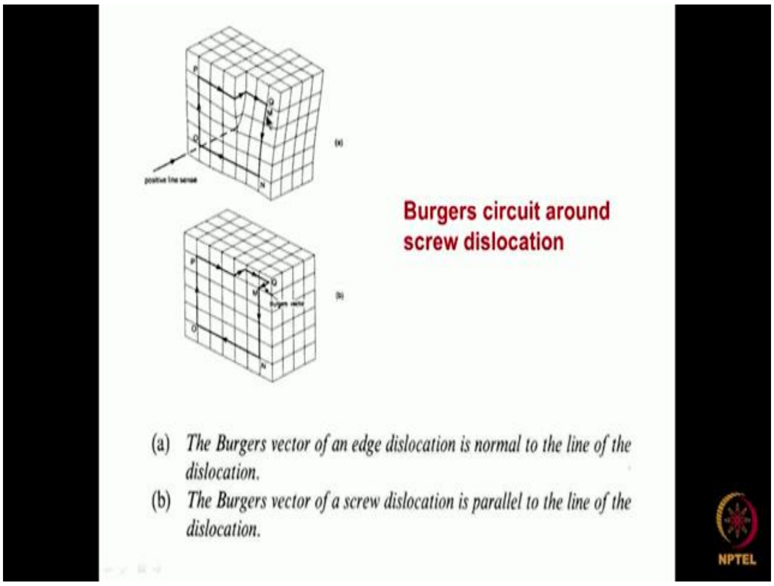
Student: (Refer Time: 33:50).

Around the core that is around the region which contains the dislocation, then also we can define the burgers vector correct. In this definition, that is from the start to finish is how the burgers vector is being defined, but normally we do not use that because suppose I start from here, and try to come back, from here to here this distance near the core the atoms are displaced from their lattice sites correct. So, it is not a perfect value of the lattice translation vector which could be slightly different.

So, if you use this convention to measure the burgers vector. It may not be a lattice translation vector. So, this convention is never used. The convention we which one has to follow is only this one. That is first you take a right hand screw conveyor that circuit around the dislocation, and then do it on a region of the crystal which does not contain a dislocation, and find out the direction in which the burgers vector is there, the magnitude also is defined now in a perfect lattice.

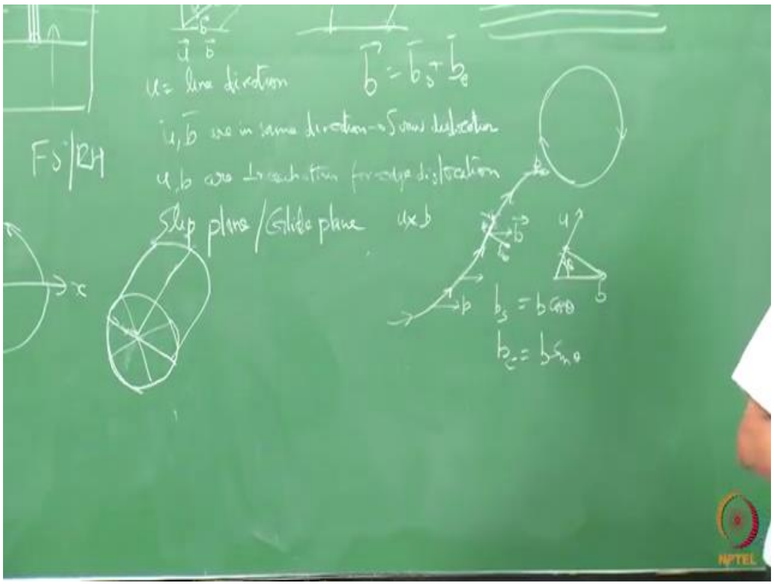
This way, So, far we talked about is with respect to an edge dislocation. How do we go about and do it with respect to the screwed dislocation?

(Refer Slide Time: 35:26)



So, similar burgers circuit if we can take it start from any region; take the right hand convention. This is what I am showing it with respect to a right hand convention the line sense you can see that this in the direction. This is x and this is y, now you see that after this we have come back to a original position, like starting point. The same thing when we do it around here in the perfect lattice, we make every step. Now we find that that is going to be a gap which is going to come. So, this is defined as a burgers vector. Is it clear?

(Refer Slide Time: 36:10)



So, what is essentially important is that, in the case of an edge dislocation, if this is the line direction of the dislocation. This is the line direction, this is the burgers vector, burgers vector is that it is if the line direction we define as u, b is the burgers vector, u equals line direction. Line direction and burgers vectors make an angle of ninety degree correct. What happens in this case of a screw dislocation? U and b are in same direction for this is a screw dislocation, whereas u and b are perpendicular to each other for edge dislocation correct.

So, this is something which one has to understand. And if a dislocation has to move, how is the slip plane defined? Slip plane is slip plane or sometimes it is called as a glide plane, defined by u cross b the cross product is what it is going to define that plane. So, if you are taking the cross product this is nothing, but this is the plane which is going to be if this is u and this is b this is the plane correct. Cross b that is a plane in which the dislocation will move,

So, an edge dislocation will move only in that plane, let us what is going to be u cross b. And if you try to find out it does not define a plane correct because u and b are in the same direction. That means that no slip plane is defined for an screw dislocation; that means, that if a first screw dislocation is there, that is any plane around this that is if a screw dislocation is there, either this plane or this plane any of this planes which are cutting through that, all of them could be all of them are potential slip planes for screw dislocation, but then the question comes is the which is the plane in which finally, the dislocation will move. That is determined by in which plane if the dislocation has to move the frictional stress is less.

That is suppose in this particular plane, you assume that the atoms are all densely packed, then the roughness will be less right. That is the plane on which it can move very easily, whereas, if some other plane, if it is going to be very rough, in that plane it will not be able to move very easily, or the energy which is required is going to be very high. It is something like this one if you are driving a riding a cycle on a road. And the road is quite bumpy because lots of stones are big stones are being put. Then with the energy which you put in lot of energy is required to go on that road.

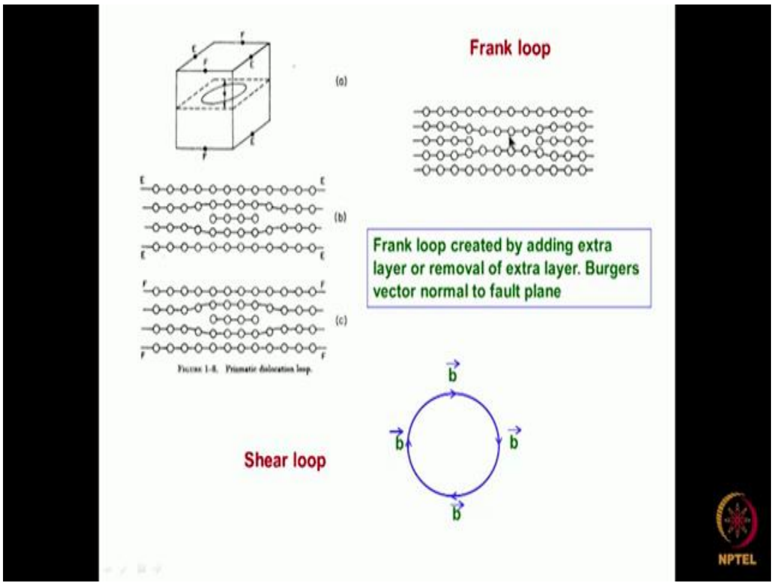
Because of and the road which is smooth the same energy you can go it very easily. So, that is the one which you would prefer to go exactly like that that dislocation also chooses that one which requires less energy to move. So, those are all the ones which are chosen the slip plane, but what is the one condition is that whichever plane in which the dislocation moves, that the line direction will be lying in that plane.

But it is possible that if there is an obstruction to a motion of the dislocation in that plane, since slip plane is not defined it can try to climb into any other plane, in which the burgers vector is lying. In which the burgers vector of the line direction is lying; that means, that suppose a dislocation is moving in this plane, as screw dislocation moves in this plane, it sees an obstruction. Then if there is another plane which is there, it will try to climb one to it. Suppose this plane also has got a lower the energy which is required is the same as that of this plane it will just cross slip.

That is why we normally say that the screw dislocations it is easy to cross slip. Whereas, for edge dislocation a cross slip is going to be very difficult. This will come back to this aspect of it when we talk about specific dislocations in different type of crystal systems, but at this stage what one has to understand is that for edge dislocation the slip line is defined. It is given by the cross product and by the same cross product; if we take it for screw dislocation the slip plane is not defined. So, any plane which contains the line direction it is a potential slip plane for the dislocation that is clear

Then what are the types of dislocations which we can have. We have considered a screw dislocation. We have considered an edge dislocation. There is another type of dislocation which can occur, which we call it as a frank dislocation. Or these are also called by the name prismatic dislocations. How can they form? Suppose we take a sample. We take it to very high temperature. Lots of point defects are produced in the sample. We quench it to room temperature. This happens most of the time in the case of aluminium samples it has been seen. The quenched sample, these point defects if they are able to move at some particular temperature, they can agglomerate together on some particular plane, if they agglomerate together on a particular plane.

(Refer Slide Time: 43:45)



What will happen is this is the sort of a structure it will be formed, because one set of atoms are missing this is equivalent to point defects which are generated right. This is only a cross section which we are showing it. If you look at it everywhere, that is one extra plane has come on this side of it. And extra plane has come on this side of it. In between there is nothing is there right.

This is a 3 dimensional view of it. From this you can make out that, the burgers vector is always going to be in this direction. The direction in which this defect is lying is in this particular one. Burgers vector is perpendicular to it, but this is not the slip plane. These types of defects are called as the frank defect. For this particular defect, if we try to find out, this is the direction of b, and if we consider this as the close packed plane. And the line direction will be this is essentially a sort of a loop which is being formed. Because one defect is layer is then a we are only seeing a cross section of the cut section.

So, the line direction will be in a circle which is going around. If you look at it in the perpendicular at from the top if you see, it to be like this is the line direction. And the burgers vector is perpendicular to it like this. It will be there. Burgers vector line direction are perpendicular to each other, that is the one which defines the slip plane; that means, that if it slips, it has to move in this direction right there is on a cylinder it moves. Is it clear?

So, these types of defects are called as frank loops or frank dislocation or prismatic dislocation. The same thing can happen in another way. That instead of vacancies, it could be point defects which can agglomerate in a plane. Like what is being shown in this particular case. This also gives rise to the same type of a defect. So, this is called as a vacancy type of a loop. This is called as an interstitial type of a loop, but both of them create dislocations.

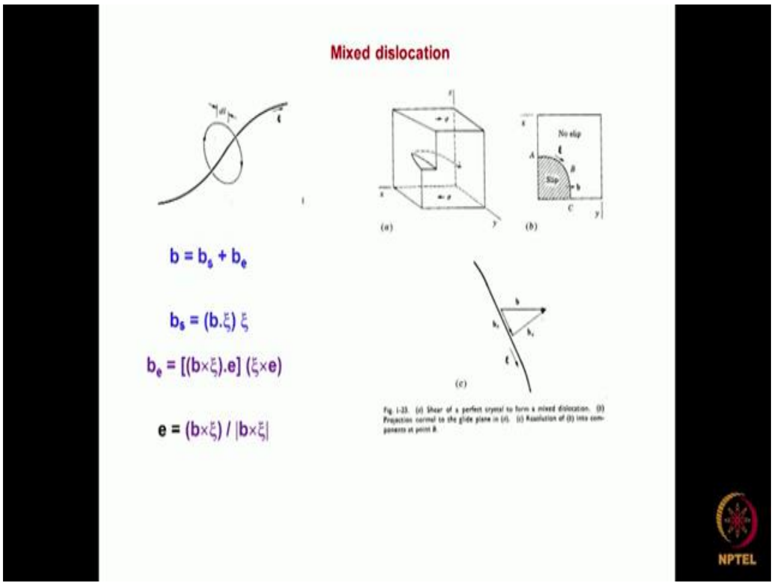
Then there is another type of which loop which we can have is which is called as a shear loop. And I will talk about it why this loop which it forms is that, whenever we talked about at dislocation right, but we never mentioned where is it starting. We said that some dislocation is there some cuts of is we are looking at it. Where it starts and where it ends, that is very important. The dislocation can never.

Student: Start.

Start within the centre of the sample. It has to always be from outside. From that is dislocation can never begin or end within a material. It has to be only from surface to surface, it will be moving from one surface to another surface the dislocation line will extend. That is the first thing which you have to consider it.

This you can do it as an exercise. You assume that a dislocation is ending within the bulk. Then you try to look at it what sort of a, if you try to view it we will be able to make out it is generating another dislocation in some other direction. Essentially, indicating that it just cannot end within the material. So, in the polycrystalline material what happened is that, the dislocation begins and ends, from one end of the grain to another end of from the boundary. That is so that cannot dislocation cannot stop within the material this is one thing which one should always remember.

(Refer Slide Time: 48:17)



So, far we talked a dislocation which is essentially a either edge or a screw dislocation. But there is no need that the dislocation line has to be that is when it is perpendicular that burgers vector, and the line direction are perpendicular we call it as an edge. When the burgers vector on the line direction are the same direction we call it as a screw. It can happen in so many cases a dislocation line which we see it, but the burgers vector is going to be in this direction, like here also burgers vector is in this direction.

So, if you see the line direction, this is the line direction. So, here the line direction burgers vector is in the same direction. There can be some other position it could be inclined. So, these types of dislocations are called as mixed dislocations this is the type of dislocation which we normally see in most of the material. It is only the mix dislocation, which we see.

Student: It is possible pure edge, is it possible pure edge dislocation material.

Yes, under some conditions they do form in material. It is not that they do not edge dislocation screw dislocations form. Perfect screw can be seen, but most of the dislocations are of mixed character. So, if it is of a mixed character, if we know the burgers vector if you know, because as the lattice translation vector, and if this line direction here is u, I can find out the component of this burgers vector in this direction as well as perpendicular to it this is, I will call it as b s, and this will call it as b e. These 2 define the component of the burgers vector, correct, b s is essentially the screw component of the mix dislocation. And b is the edge component of the mix dislocation.

So, now what we have done it is that to find out any get any information about the mix dislocation, we can spread them into screw and an edge component. And that way we can do a calculation to find out the stress and strain fields associated with it. And then combine them together we get the total stress and strain field. To tackle the problem associated with the mix dislocation. How are this dislocation defined? That is what essentially is being shown here that how the because in these figure if you concert psi is used to define the line direction. And burgers vector this is a component of the burgers vector in the line direction this is the one which is perpendicular to it.

When we have to define that these can be written in terms of if you know the angle theta between them the line direction and a burgers vector, that is if this is a u, this is the burgers vector we can find out the component which is going to be there in this direction, if we know the angle this will be b cos theta, will be the screw component, will be b sin theta correct. That will be the edge component. That is a simple way in which we can write it, but in a vector notation if you wanted to write it is a little bit more complicated.

The vector notation if we write it, this we will write it as b will be equal to b s plus b e. Correct this is how we will write it. And the definition of b s is equal to, that is what we are considering it is b dot u. That is if burgers vector is incline you find out the component of it in this going to be there. What is the component of this, which is going to be there in this one is b dot u, u is a unit vector line direction?

So, that gives the value that multiplied by the unit vector in that direction will give you as a vector. So, that is how you define it. Similarly, we have to define it for a edge dislocation also. What is it done in the case of an edge dislocation? In the case of an edge dislocation it is a little bit complicated, but it is not very difficult. B cross u if you take it what it will decide this is b this is u.

Student: Perpendicular.

It will be perpendicular to it that is how we defined that; and if we divide by b cross u, what it will give, and a unit vector which is going to be there in the direction. But what does b cross u actually mean? This essentially if u is a unit translation vector it is b sin theta.

Student: (Refer Time: 54:31).

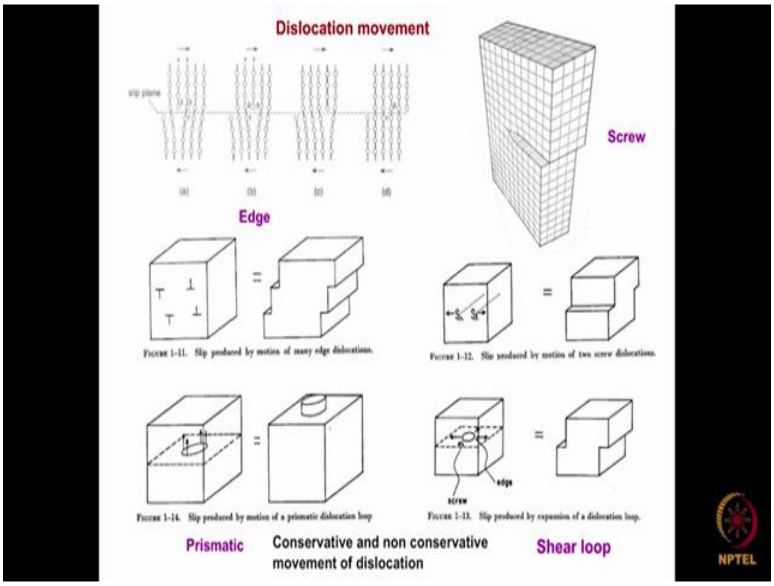
Correct, that will be nothing, but a vector which is perpendicular to it. Correct? But essentially what we have to find out is that you take a b cross u, that gives a magnitude b sin theta, take a dot product with respect to e, which is b cross u divided by that unit vector that gives you a constant value, that is what this expression gives. Then multiply it by this is the line direction this is the vector e is a vector which is perpendicular to it there is perpendicular, it is out of the plane of this paper. And each dot product is cross product will be perpendicular in this direction that is the vector.

So, you take the magnitude and take the vector in this direction, that will define burgers vector of the,

Student: Edge.

Edge component; that is how it is being defined, but otherwise it is a very simple one, but when you have to define it vectorially this is the way it has to be done.

(Refer Slide Time: 55:57)



Then another thing also is that which we have to consider is. So, far we consider dislocation says something which is starting. But what normally happens is that that is dislocations of the one which the movement of those dislocations is the one which is responsible for deformation of the material, or slip to take place in the material. How does the slip take place? Let us look at it here. That is, in this sample there is one dislocation which is being present here. If you look here 1 2 3 4 5 layers are here, correct top also 5 layers are there. What is essentially being done is that with respect to a bottom the top layer has been applied some stress. So, that is pushed. So, that it is just the bottom that is layer at the back maintains continuity. So, this layer has been pushed by one lattice translation vector. Then it has to introduce some defect within the material. This is what a edge dislocation is now around this.

When I apply a shear stress, what it will happen is that if by some means, if because I am trying to push this into this side. Then this atom will come instead of this atom will come closer to here, if these joints together then this will become that is what is being shown. You see that this one has 1 and 2 are joined, then the 3 has now become the extra plane. Then again on another push, that is 1 and this and the 3 will join together this has come here when this and this to join together as step has been created. Now in between this region if you look at it there is no dislocation right. Now a perfect plane which is being an maintained.

This is the way a dislocation moves, but finally, there are how many bonds are being broken. Only at this region a bond breaking is taking place correct at a time. So, that way breaking a bond here and joining it breaking a bond here and joining it this way it is able to move. This is equivalent to the case, which we considered initially started with. If there are no dislocations are there if by one lattice translation by vector we have to move one layer over on top of the other. The entire layers have to be that is from here this has should be moved entirely by one lattice translation vector here like this, correct? That need not be done.

Suppose this has to be done. What will be the energy which will be required? We can take an example of it you see this room. A carpet has been put here. Suppose I will have to move this carpet from here to some step which will have to move it. What is the way which one can prove it? I can hold that end and just pull it, will this carpet move? If I just hold it to the pull it because what is the total frictional energy, how much this whole total area it has to cover.

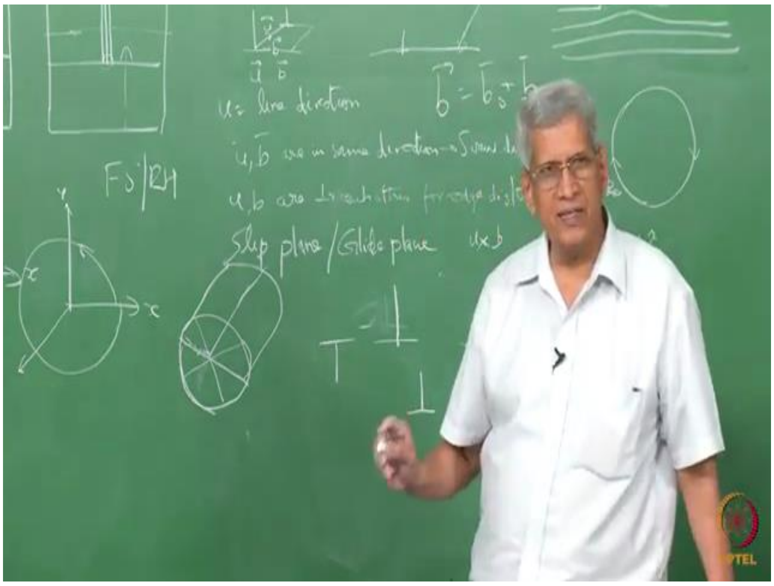
Student: Yeah.

That is going to be very large. It is not very easy. Instead what is the way in which I can make it move? At one and of it I introduce a rod. Just I roll the rod, and bring it to the other end this carpet rod has moved; that is equivalent to only that point is being lifted and pulls down lifted and pulls down. Energy is being spent only there the rest of the region remains that same. By doing that with less energy we can move this carpet, exactly like that it happens of one layer of atom it is like a carpet sitting on another layer of atom. By means of for having a dislocation, just moving that step to move on at a time or breaking of bond and joining of bond, we can make the whole layer to move. This is how a dislocation moves that is way the energy which is required is extremely small also when a dislocation is present.

So, when this dislocation moves like this, if you look at it initially we started and you can see that there are some steps which are created on the sample surface on that cross section, which was otherwise when the dislocations were inside the material; it looks like a perfect cube. Now after the dislocations have come of it shape has changed if dislocations are randomly distributed within that sample and they come out on both the directions a shape deformation takes place. That is how plastic deformation of a material. We now correlate it to the moment of dislocations and they can bring about shape change.

The same if we consider it. Here what happens is that in this when we show a dislocation with this sign, especially this is valid only for a edge dislocation.

(Refer Slide Time: 61:42)



This sign represents when we put this is an extra plane on the top. If you put it like this we mean that extra plane at the bottom, these only valid for an edge dislocation. Generally, for screw dislocation also as a general symbol for a dislocation we will use it like this. That is just to say that it is a dislocation, but now we cannot say that the screw dislocation there is any extra plane, but this symbol is often used.

Now, if you look here if an edge dislocation is there, with respect to this diagram. When the dislocation line from here to here, moves like this, the step is also created in the same direction right; that means, that here if you see when the dislocation moves what is the direction which step is created? In the direction in which that dislocation is moving, that is perpendicular to the dislocation line direction, in the same direction as the dislocation, when the direction of movement of dislocation is in this direction the step is created perpendicular to it.

This is what it happens. In the case of a prismatic loop, what will happen here you can see that these are the burgers vector is in this direction, slip plane is a cylinder. So, finally, if this dislocation comes out of the sample surface it will be creating a this sort of a.

Student: It will always come to surface.

Which one? If or it has to go to a grain boundary if it considers single crystal this has to come to a surface only. If it moves, correct? And similarly we can control a shear loop. In this when the loop moves, the shear loop if you consider it here, loop like this the burgers vector is always in the direction, but the line direction is always the line direction moves in the same direction there sense it has to be continuous.

So, here the dislocation will have an edge character will have a screw character here the line direction and the burgers vector perpendicular. It will be an edge character in these regions it will have a mixed character.

Student: It need to some time to move the dislocation.

That takes finite thing. What we are talking about it is not about the intermediate step, when the dislocation has completely moved and come out of the sample surface, what will be the shape change which will be seeing it. Suppose the dislocation moves in a sample from this region to this region, no external shape change will take place. The external shape change will take place only when this dislocation is moved this dislocation is moved and come out of the sample surface. Then this sample will look like a step which might have been created shape changes happen.

We assume there was only one dislocation which was there it has just come out of it. That dislocation has created a step with that it is job is over, because the dislocation is vanished from the sample also.

Student: What we see.

So dislocations are generated they come out of the sample surface and generate some shape change to the sample. So, if the dislocations do not come out of the sample surface, no shape change will occur. But when they move inside the sample surface the stress and strains at different regions will change within that sample. That is what it will happen. This we will talk about it later.