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

Lecture - 24
Perfect Dislocation in FCC Structures

Welcome you all to this course and defects in material. Today, we will discuss about the dislocations in the FCC lattice. FCC lattice is the one in which most of the metallic materials crystallize; many of the structural materials which have used like steels, nickel based super-alloys all of them have got the FCC crystal structure. So, to understand the deformation behavior one should know what is the nature of the dislocation, what is the burgers vector corresponding to it, what are the types of burgers vectors dislocations can have, and what is the slip plane in which this dislocation will move, all this information is very much necessary.

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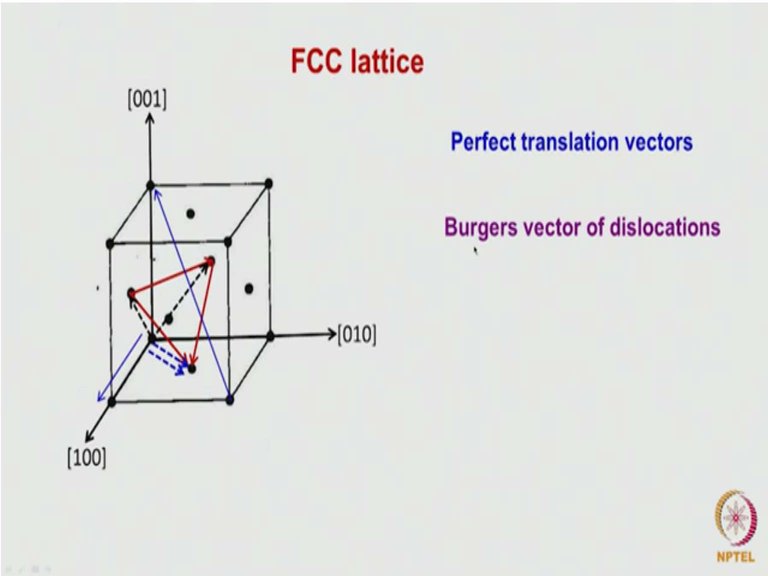

So, let us just look at the crystal structure of FCC structure. In the FCC structure when we look at it the vectors which we can have that is the lattice translation vectors which we can have or the lattice parameter r a by 2 1 1 0, r a 1 1 1 that is these are all the perfect lattice translation vectors. What we should know to define a perfect dislocation is that the perfect dislocation have got a burgers vector which is the lattice translation vector that means, that when the perfect dislocation passes through the slip plane, the atom we are both that plane or below that plane is shifted by a lattice translation vector. That means, that it is moved from one lattice point to an another lattice point.

So, here what are the vectors which we can have this is one vector which we can have; here we can notice it that this is a by 2 1 1 0 will be the lattice translation vector. This is an another vector which we can have a 1 0 0 and this is another vector which we can have which is a 1 1 1.

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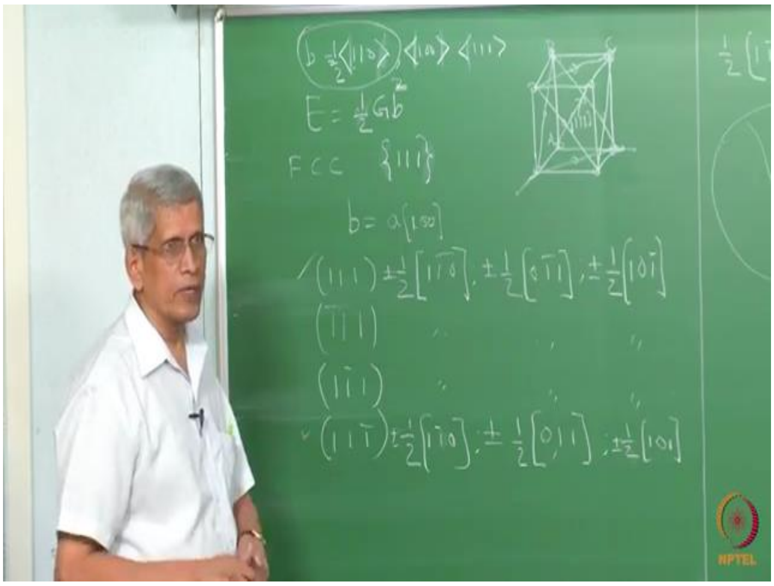

So, in FCC increasing order of the magnitude of the translation vector if you consider you can have b equals 1 1 0, 1 0 0.

Student: 1 1 1.

1 1 1 and in fact I should write it as the set up direction all these directions are equivalent in a cubic system. These are all the burgers vectors, which the dislocation can have. Then all are possible which is the one the system will try to have added as the burgers vector for the dislocation that is decided by which dislocation will have the lowest self-energy. That means that if we take this to be the burgers vector, we can try to calculate the self-energy because we know that the self-energy equals half G into b square. So, if you take this b squared value then we will immediately notice that the one with this burgers vector is the one which is going to have the lowest self-energy.

So, with a burgers vector b equals half 1 1 0 is the one which will have the lowest burgers vector that also we can make out from here that this is the closed pack direction in FCC other directions are not as close packed as this direction. So, now we have considered which is a vector, this the multiplicity if we see we can have 6 type of vectors can be there correct, distinct ones and both positive and negative direction if we can take, 12 burger types of burgers vectors which the dislocations can have.

Now, the next question comes is that what is the direction line direction which the dislocation will choose. The burgers vector we talked that though all any perfect lattice translation vectors could be a burgers vector potential burgers vector for the dislocation, but the material choose the one which has got the smallest self-energy; that means, the one which has got the smallest translation vector that in FCC, it turns out to be half 1 1 0. Now, what is the line direction which the dislocation will try to have, it can choose any direction, it can take.

Then the next question also which comes is that which is the plane in which the dislocation will move that plane is decided in any crystal by the fact that has the dislocation moves the resistance which the dislocation faces to its moment has to be minimum or the lattice frictional stress is small. That also in any crystal structure if we consider that just looking at the geometry of the crystal we can tell that the one which has got the highest packing density the plane which has got the highest packing density, in that plane the frictional stress will be less. On that basis, if you look at it in FCC structure 1 1 1.

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Will be the.

Student: (Refer Time: 06:53).

Slip plane, and this plane is called as the slip plane or the glide plane; this is a plane in which the dislocation can move.

Student: So, 1 1 1 can be (Refer Time: 07:09).

Is the slip plane.

Student: And 1 1 0, half 1 1 0 is a burgers vector.

Is A burgers vector of the dislocation.

Student: (Refer Time: 07:21) highest.

No slip plane the density - atom packing density should be as highest possible in that plane which because that other plane this is something like equivalent one which we can consider it is that you think of a road, where the road, if it is being gravel and the gravel is put at distances which are very farther apart or if the distance are gravely put the same size of gravel kept close together. If a vehicle has to move, the energy which has to spend is more in the one where the gravel distance is large, or the packing density is least that is a perfect example. So, then another type of a translation vector which is being used to define dislocations which are called as partial dislocations, these we will talk about it in future not at present, but I just wanted to introduce the term that that is a partial translation vector also is used in the case of dislocation theory.

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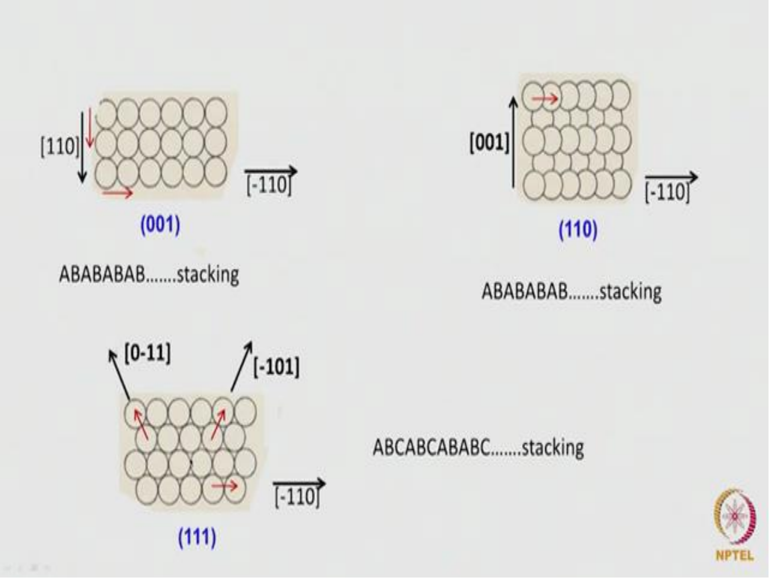

Let us just for example, we talked about the different types of planes. Let us look at this 0 0 1 plane in cubic system. This is 1 1 bar 0 direction, this is a 1 bar 1 0 direction, and this is the lattice translation vector here by to 1 1 0, this is the lattice translation vector. In this hard sphere model, you can make out that these balls or the atoms are touching each other here correct. So, in this plane there are two closed pack directions are there;

both of them could be the possible burgers vector of the dislocation. And if we take 1 1 0 plane, these are all the atoms are 1 1 0 plane, this is a closed pack direction, and this is 0 1 0 direction which is not closed pack and this layer of atoms which is being shown actually the layer which is behind this. So, only one closed pack plane is there. So, suppose in this plane the dislocation has to move then it will be 1 1 0 plane, but the burgers vector will be 1 bar 1 0 that is the possibility.

Let us take the case of 1 1 1 plane here one can make out that the atoms are packed much better than even in 0 0 1 plane. And here three closed pack directions are there half 1 bar 1 0, 1 bar 0 1 and 0 1 1 bar all that three planes. So, in this particular plane, we can have three types of dislocations with burgers vectors corresponding to any one of this direction and another thing also which you should notice it is that here the stacking sequence is A B A B type of a stacking sequence. And in this 1 1 0 also ABAB type of a stacking sequence here it is an ABCABC type of a stacking sequence.

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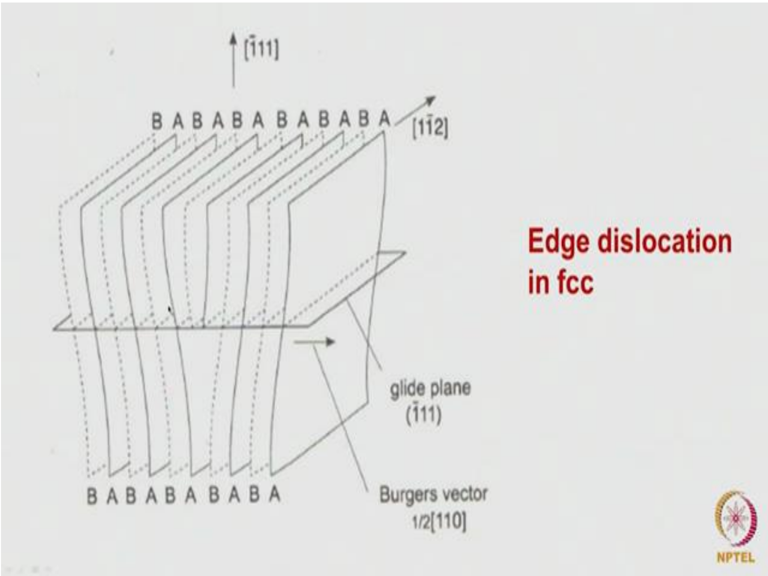

This stacking sequence has something to do with the actually the structure of edge dislocation for example, if you look at an edge dislocation which we look at it. So, far when we have drawn the dislocation, all of them have been drawn for a simple cubic structure. So, in a simple cubic structure, if you look at the burgers vector is equal to essentially it is a 1 0 0, it is essentially a moment of an atom from one direction to the another direction. Here what happens is that if you look at the stacking sequence in half 1

1 0 corresponding to the specific case, it is a stacking sequence in ABAB type of a stacking sequence.

When the shacking sequence is in ABAB type of a stacking sequence, if we add an extra plane or remove an extra plane, the translation symmetry has to be maintained. So, if you add any extra plane to it, we have to add by adding a B plane if we do it then we will find that A B, B will come. So, the structure is getting changed, so that is not acceptable. So, if we add two layers like here B A two layers have been added then one extra layer which has been added. So, one can maintain the translational symmetry in the top as well as the bottom, to maintain the translational symmetry minimum two layers have to be added this one should keep it in mind for in edge dislocation in FCC.

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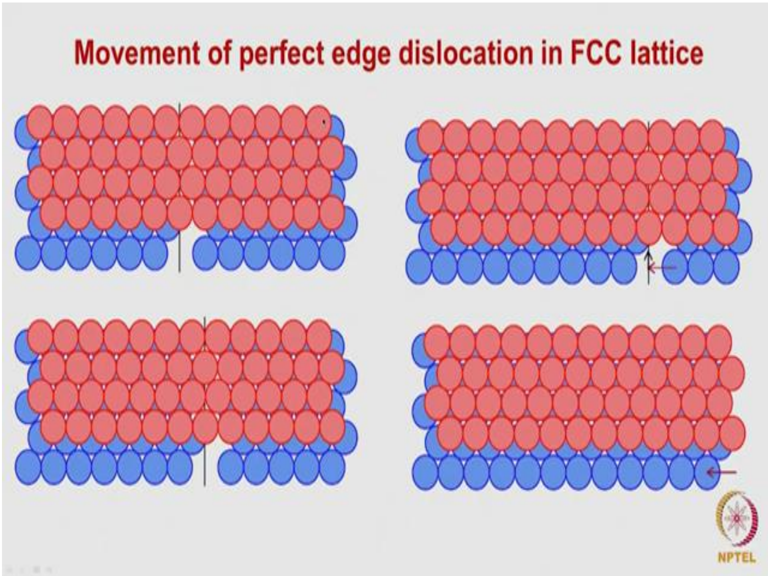

The same thing I had the shown when an edge dislocation moves, how the moment takes place. Here one can immediate make out this orange colored ones or the atoms are on the top and the blue colored on the atoms at the bottom. If you can remember one layer of an atom which has been removed from this that is equivalent to say that one extra layer has been added here this is where the defect is being present. Assume that extra layer is on top bottom there is one layer is missing. If this dislocation moves from here to this point, then an atom from here has to move from here to this place that is exactly what is being shown. When that atom moves from here to here, it is equivalent to this line has now shifted and come to this position.

But another thing which is interesting to see also that here when we look at it one and two layers actually two layers which are up to moved here which one can make out that there are missing of two atomic layers are there. Though atom is only one which is being removed from every this direction, but if we considered as an atomic layer which is perpendicular to it, there is a two layer which is missing here. This way by moving atoms from here to this direction, we can see that the dislocation line is moving towards right hand side, and finally, this dislocation can come out of the sample surface.

Now, if we look at it with respect to the top layer, the bottom layer was actually at some particular position. Now, in this picture, if you see the top layer remains at the same position, the bottom layer has been shifted towards the right by the burgers vector. Now, in this context, I wanted to make one point which is very clear is that one should understand the clear difference between the translation vector and the number of planes which are going to be in between.

Because if you take this will be an 1 1 1 vector from here to here, in the case of a FCC lattice. But if you consider the number of planes which are involved, this is from A layer before we reach this layer there is this one layer is there, then there is going to be an another layer A, B this is the C layer then the A layer repeats itself. So, between two vectors are between any vector there can be many planes which can be there that is what essentially is here this vector is B, but between these if we see there are actually two planes are there.

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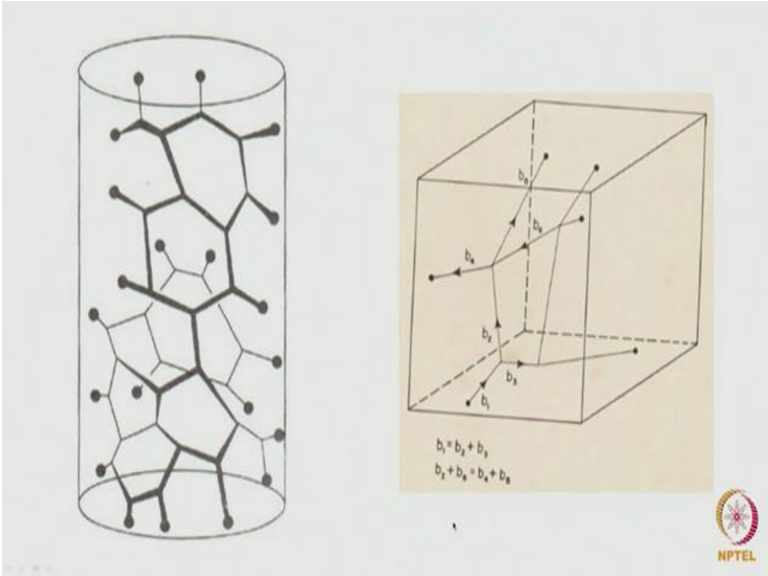

We have studied about another property of the dislocation that when the dislocation forms in the material, the dislocation cannot end within the material that means, that the dislocation should be interconnected that is what essentially is being shown in this picture. That the dislocations are interconnected and the dislocation ends can come out of the sample surface at many points. And another important property which we have studied is that as the dislocations come and join at any junction if you see it at that point if you take the some of the burgers vectors they have to be equal to 0 all the burgers vector which are there around that point. This has to be always kept in mind as far as the dislocations are concerned.

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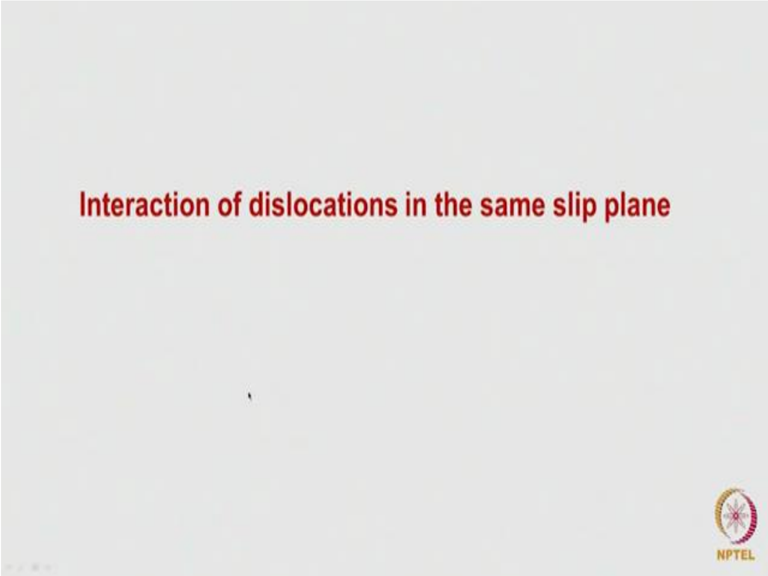

So, having this information, if you try to look at the type of slip systems which we can have in FCC lattice, we have four 1 1 1 planes are there plus minus half 1 0 1 bar. So, essentially on this one single plane we can have a dislocation with A burgers vector 1 1 bar 0 or a dislocation with a burgers vector half 0 1 bar 0 or half 1 0 1 bar, this dislocation could be either an edge or s screw dislocation correct.

If it is a screw dislocation the line direction will be the same as the burgers vector; if it is an edge dislocation the line direction will be perpendicular to both 1 1 1 the plane normal as well as the burgers vector. So, three distinct dislocations are possible. Let us consider the case interaction of dislocations, which are present in the same slip plane, it should be similar for other slip planes also. We are considering one specific case its only this case that is similarly we can write expressions to find out what is going to be the burgers vector of this I would like you people to do it as an exercise and find out the number of slip systems which will be there in FCC.

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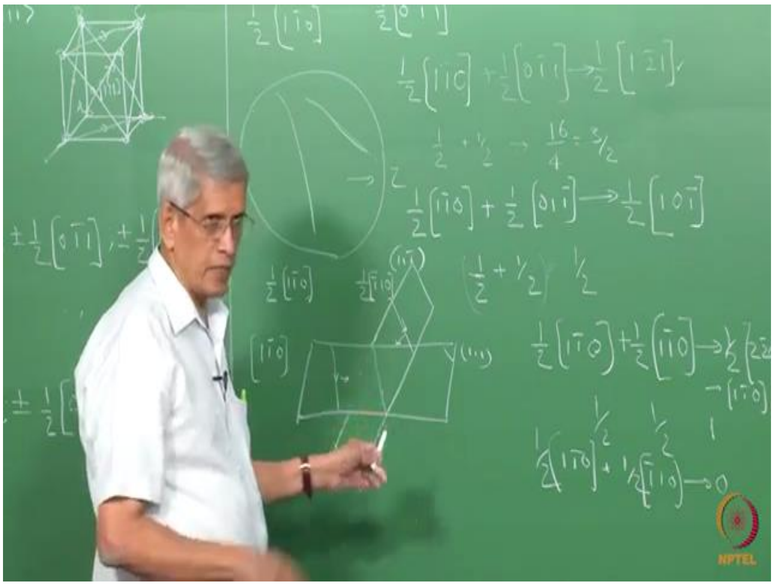

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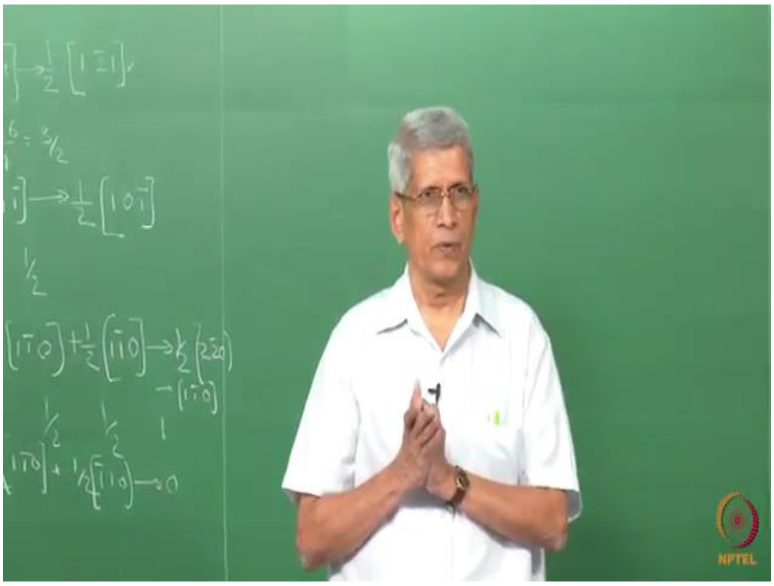

So, suppose we assume that in to 1 1 1 plane that is a dislocation with burgers vector half 1 1 bar 0, there is an another dislocation with half 0 1 bar 1. And we assume that that is the samples this is a plane in which one dislocation is there, another dislocation is there under the action of a stress which is being update, this dislocations are moving. What sort of interaction, which will take place. To find out that we should find out if this reaction takes place whether there will be a reduction in energy or not correct that we can immediately find out whether there will be a reduction in energy or not by taking the b squared value that will be here it will be half plus let us take 0 1. So, what does this reaction will first need to a dislocation which is 1 2 bar 1 correct

So, the b squared will be here half the value of b squared will be half here, here what it will happen.

Student: (Refer Time: 21:14).

Should be 1 by 4, if this will be equal to 3 by 2 that means, that the energy the self-energy of the dislocation which has formed is higher than that of the dislocations which are trying to come together; that means, that this reaction is not possible. So, if a dislocation of this type is present with the burgers vector, they will repel each other.

Let us consider the case where the burgers vector of one dislocation is half 1 1 bar 0, and the other one is half 0 1 1 bar. If this is the burgers vector of the dislocation then these two reactions if we this reaction if you consider, if this dislocations are moving whether they will attract or not, we will be decide. We can look at the dislocation reaction this will give rise to half 1 0 1 bar that means, that here the burgers that if you take the b squared value to find out the self-energy of the dislocation or the frank criterion that is what we are trying to find out. This is half plus half, and this side is going to be half correct so; that means that when these two dislocations join together and form an another dislocation, this dislocation also will be lying in the same slip plane. These two join together and vanish and new dislocation has formed, but that dislocation has got a burgers vector half 1 0 1 bar that means, that there is a reduction in energy this reaction will take place it correct.

So, this is a natural attraction this reaction is possible, here the dislocations will always the stress field will be such that they will be repelling each other. But under the action of a force this dislocation can be made to move and cut across each other. But definitely when these two dislocations are there when they move one dislocation is like this and another is like this when they try to move they will cut across, but they will never joint together to form another dislocation that will not happen. This part of it will come a little bit later. You understood this part of it.

Here what we have considered is dislocations, which are being present in the same slip plane. So, if you consider an FCC, when the dislocations are moving in the same slip plane for a perfect dislocation, this is the only type of a reaction which can happen either the two dislocations can attract each other and form an another perfect dislocation or the two dislocations can repel each other correct.

What is the other type of a reaction, which can takes place when a material is being deformed. Dislocations are moving in one plane and in another plane also the dislocations are moving then these dislocations can try to interact. So, it could be any plane in which the dislocation which is being, which is lying or which is moving in that plane can interact with dislocation which is moving in an another plane. Let us take that case. If these two case we have considered, then we have considered the various types of interaction between dislocations lying in different slip planes for perfect dislocation, all cases may come in considered.

So, suppose we take this is one plane. The other plane is 1 1 bar 1 this plane will be inclined with respect to this particular plane. In this particular case, what all the burgers vector which is can have one half 1 1 bar 0 this is one correct plus minus and here plus minus half 1 1; the third case is. These are all the type of burgers vectors the dislocation lying in this plane will have. Let us assume the case that the dislocation is there in this plane, which has got a burgers vector half 1 1 bar 0. Another dislocation is there in this plane which is moving in this plane which has also got a burgers vector half 1 1 bar 0 that is essentially what we are trying to do is this is one slip plane. That is our dislocation, which is moving in this plane. There is a dislocation which is moving in this plane and a dislocation in this plane is also moving in this direction we assume that. If they are moving like this, and the burgers vector of a dislocation is half 1 1 bar 0 in both the planes and you assume that this is 1 1 1 plane this is 1 1 1 bar plane.

Now, what will happen is that if they are moving and another has got a burgers vector. So, this will be plus half these are dislocations with the same type of a burgers vector, this will give rise to half 2 2 bar 0 that is essentially 1 1 bar 0 that means, that this reaction if you see it is half half.

Student: (Refer Time: 27:43).

This will be 1. So, in general the sort of reaction does not occur. Suppose, the dislocation which is going to be there on this plane has got a burgers vector half 1 bar 1 0, and the line direction is also either the same or the line direction could be different. You assume the case where the line direction is the same as the burgers vector; that means, these are both screw dislocations. And these screw dislocations if we look at it these two when they intersect the common direction which is common between these two planes is 1 1 bar 0 direction. So, when they reach there they will just annihilate. This reaction if you consider half 1 1 bar 0 plus half 1 bar 1 0, this will give raise to burgers vector will be 0 so that means, that these dislocations attracted each other and annihilate.

Suppose, these dislocations are edge dislocations, which are moving as they come here and then they join meet here at this point. Since, the common direction is 1 1 bar 0, these dislocations will have to change the character from when they come and meet and join together the character has to change, and it has to become a screw character, then only we can have them join together at this point. So, this is the second case which we consider it. So, if they have the same burgers vector, they repel; if they have a burgers vector which are different then they attract.

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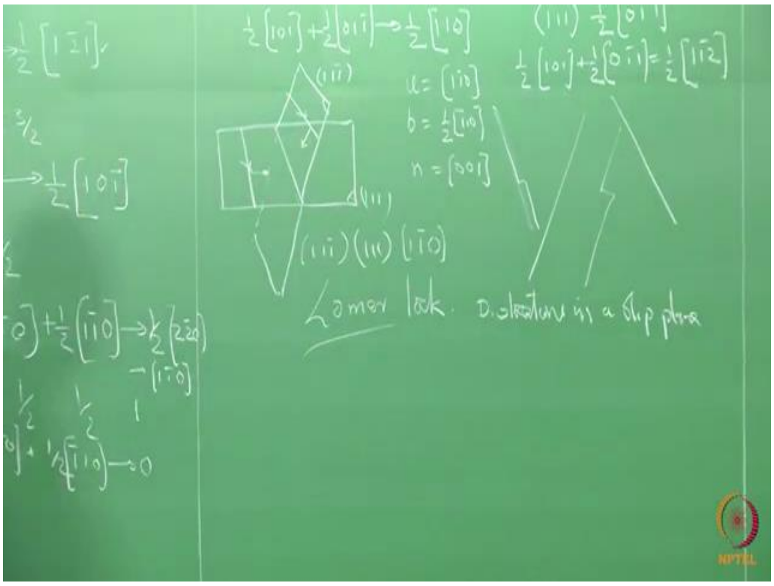

Let us look at the case where the burgers vector of the dislocations are different because here why we have considered is that between this plane and this plane, one burgers vector this locate in the burgers vector is common to both of them. Now, let us consider the case where this has a burgers vector that is in the plane 1 1 1 bar that is location as a burgers vector half 1 0 1 and that is location which is under plane 1 1 1 has a burgers vector which is half 0 1 1 bar.

Let us look at this reaction 1 0 1 plus half 0 1 1 bar, this will give raise to dislocation correct this is what the dislocation that means that in this reaction there is a reduction energy. That means, like in this case one dislocation is moving in this and another dislocation is moving in this slip plane, suppose this is 1 1 1 bar and this corresponds to 1 1 1. This dislocation is the line direction this dislocation is moving in this direction this dislocation is moving in this direction that is a chance that they will attract each other; and at this particular point they can join together, and they can have the burgers vector half 1 1 0 because this is an attractive interaction. So, this type of a reaction is allowed because the energy gets lowered when these two dislocations come together and join

Student: They always try to minimize the energy.

They always try to minimize the energy. In this case, now let us look at what will be the line direction, which this dislocation will have. The line direction when they come and join together that should correspond to this line direction where they meet. So, for a plane 1 1 bar and 1 1 1 that line direction which will be common to both of them what will be the direction 1 1 bar 0 correct so that means that when these dislocation interact and form a dislocation at this junction, the line direction of the dislocation is 1 1 bar 0. This is the burgers vector so that means, that the new dislocation which forms has u equals 1 1 bar 0, b equals half 1 1 0 and then taking u cross b, we will be able to find out the plane normal

So, what will be the slip plane the slip plane will be turning out to be the n here it will be turning out to be 0 0 1 that means, that for this dislocation its slip plane since the line direction is.

Student: 1.

Perpendicular to this next to dislocation and the slip plane turns out to be 0 0 1 plane that means, that that plane is not a close packed plane in FCC. So, this dislocation will find very hard to move. So, this sort of reaction leads to dislocations which are called as sessile dislocation. Sessile means the this dislocation is not able to move and these reactions this is also called the set Lomer lock that is when a dislocation is when different types of dislocations are moving an interaction of this step will generate a Lomer lock.

And this dislocation since it is not able to move for other dislocations which are coming in other slip planes, now it has to overcome this dislocations because this is what it contributes to when we deform a material we call it as a forest dislocation. Of many dislocations which are generated by this sort of a dislocation reaction, we find that many of the glissile dislocations dislocations which can easily move in the slip plane some of them have transformed into lets sessile dislocation with just will not move. So, those dislocations act as obstacle to moment of glissile dislocations this is one way this is the only way in which for a perfect dislocation like sessile dislocation could be generated.

We can consider here, and another case in this reaction and this plane 1 1 1 bar, we have a half 1 0 1 on this plane, 1 1 1 plane we assume that we have a dislocation with a burgers vector one bar 1. In this reaction, if you consider it, it will be half 1 0 1 this will lead to correct this will be the burgers vector of the reaction when they interact that means, that the self-energy of the dislocation increases. So, these dislocations will repel each other. When these dislocations repel each other under thermal conditions they will not come and join together because they do not attract or even if you apply a force high lot of force has to be applied because when we deform a material you are giving an external energy to it. So, the reactions which are not favorable under thermal equilibrium conditions, we can make those reactions occur in the material.

But when these sort of dislocation are there, since there what is the only type of an interaction which we can have in these sort of cases. Suppose, one dislocation is present, another dislocation is coming from this region in the same slip plane only way they can interact is that this dislocation can pass through and come to this side by cutting this dislocation. One dislocation is there, another dislocation comes through it, cuts through the dislocation when it cut through this dislocation there will be some small step will be generated in most of this cases. These steps are called either kinks or jogs that we will be talking about it later.

But for the present we should understand that this sort of reaction the dislocations will never interact. But when we are applying a force, they try to cut through that and when it comes so this dislocation will be there with maybe with the stuff like this, this dislocation might have come out with a small step which has been generated in this sort of. By this process also, we can make out that the length of the dislocation has also increased, this is one way in which the length of the dislocation increases in the material.

So, far what we have considered is different types of reactions that is first dislocations in a slip plane. And this all are perfect dislocations what is the interaction between these dislocations we have considered attractive as well as repulsive interaction. The same thing like what we have talked about it, this can happen whether the dislocations are moving in the same slip plane or in dislocation moving two different slip planes the same thing can happen. So, essentially these are all the only types of reaction which can happen that is if the dislocations are moving in the same slip plane then they can produce the third dislocation which is also glissile by interaction of them, but if the dislocations are moving in two different slip planes if it is attractive.

Student: (Refer Time: 40:02).

In one case the Lomer lock could be generated. In another case if they have the same burgers vector in both the slip planes not by just opposite burgers vectors then they will annihilate. If they have the same burgers vectors they will try to repel each other, so these are all the type of reactions which can happen for a perfect dislocation in any material. An ideal example, which we can consider is aluminum. Aluminum is one sample where the stacking fault energy is very high, so all dislocations are perfect dislocations. So, these are all the type of reactions by which dislocations can interact also dislocations can generate forest dislocations in the material.