Mechanical Behavior of Materials-1

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Lecture - 21
Dislocation Motion Glide

Welcome back students. So far what we have seen are the static dislocation, characteristics of a static dislocation. Now that we have understood well dislocation in isolation and in a static form it is now time for us to understand the motion of dislocations. And in this context you would get to know there are two primary types of motion of the dislocations, glide which is in the plane, climb which is out of the plane.

And then there is also something called as cross-slip which is type of a glide, but is possible only for screw dislocations. And then talking about the motion of the dislocation as you would also get to realize that there are certain planes on which the dislocations can move and only the certain Burger vectors are allowed, which we already know and together they form what is called a slip system. So let us begin.

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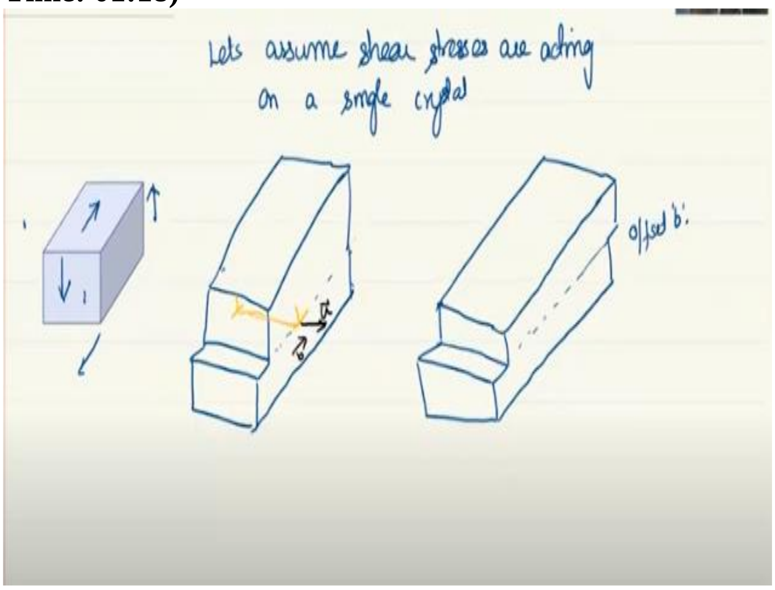

So let us say there is a material which is given to you like this. It is a single crystal and we are talking at a very small length scale, so that we can look at individual dislocations. So let us say we are applying a stress, shear stress like this. So there is shear stress on the top surface like this, which means there is a shear stress on the bottom like this, which also means that there is a shear stress acting on this surface.

And I will draw it a little far from here because okay, I will have to draw it here anyways and the other one would be on this surface. So these are shear stresses. Keep in mind that these are shear stresses, because we have already mentioned that at the atomic level the deformation is taking place only because of shear stresses, okay. So keep that in mind and hence, at the atomic level again dislocations also move because of the shear stresses.

So these are the shear stresses. Of course, we can apply a normal force which will get translated to shear stresses or in terms of dislocation itself we can come to what is called as force on the dislocation, but these are conceptual forces. So coming back to this, the point we have to keep in mind is that it is the shear stresses that act on the material, which lead to the motion of the dislocation.

So these are the shear stresses that is acting on this plane and to counterbalance in the perpendicular direction you will have this. So these are shear stresses. Let me write it here. Shear stresses are acting on a single crystal. Therefore, let us say a dislocation gets generated. So I will have to move it a little bit to the bottom so that it does not interfere with my writing over there.

So this was the shear stress, this was the shear stress and this is the shear stress and let us say a dislocation gets generated. And there are two ways the dislocation can get generated and which will lead to two opposite direction of motion of the dislocations because they have opposite sense. So because this dislocation is generated there is a step created. And in this case let us say that this is the edge dislocation.

So it is this plane on which the edge dislocation is generated and from it led to the generation of step here and it has already moved over here, and over time, it will move from here to even further over here. And eventually it will go all the way to the other end. And then we will have a step over there too. So this is the initial step and this is the final step.

And here I am not showing a dislocation, because the dislocation has moved out from the crystal from this end, which has created offset of b. So offset b is created over here and similarly offset b is created over here. Now what is the line vector of this dislocation if I ask you? Then obviously, the line vector and here we have kept things simple so that this is a straight dislocation.

Therefore, the line vector is like this. And this is the line vector. Now the question is where is the Burgers vector? So looking at this we know that the Burgers vector would be in this direction and given that the slip is acting in that direction, so this will be the Burgers vector. And now, this is the dislocation with this Burger vector and with this line vector. And which direction is the dislocation moving?

So this particular dislocation is moving in that direction and hence it has, and because of the nature of the shear stress, we see that an offset has been created like this first on this side and when eventually the dislocation which led to the generation of dislocation and when the dislocation is released on the other end it creates offset on the other side. We could also have had a dislocation of opposite nature.

So edge location, but this time with so if this is b then it would be opposite of this b. So we will call it b prime which will be equal to negative b. Basically this time the edge dislocation would be introduced from the other end. So this is also something that I missed.

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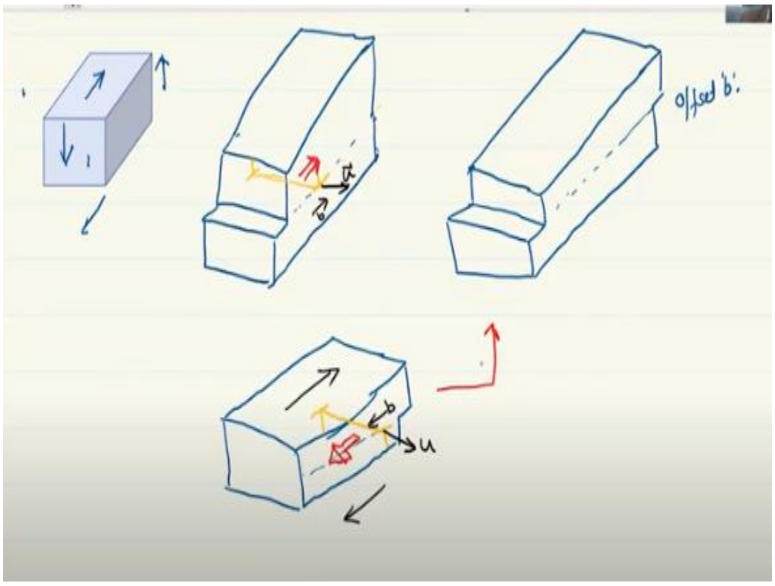

Because it is opposite in sense it will be generated from the opposite side. So a dislocation is generated from here and it is like this. So it generates and leads to the offset b. This is opposite sense dislocation and when it keeps moving, so we are applying a stress like this and because of the application of shear stress like this, so there is a shear stress in this direction and in this direction.

And because of this, dislocation keeps moving in this particular direction. So if the dislocation here was moving like this this particular dislocation is moving in this direction. And the eventual shape of this block would also be like this. So I will not draw it again because as you would have realized that this is not so easy to draw on the surface.

And therefore, but you can see that in both the cases the eventual offset or the eventual configuration would look like this. In this case positive edge dislocation was created, in this negative edge dislocation was created. So here the Burger vector is in this direction and the line vector is in this direction or you can say the other way around. You can say the line vector is in that direction and the Burger vector is still, Burgers vector is still in this direction.

So what do we see that this same shear stress can create either a positive edge dislocation moving in this direction or a negative edge dislocation moving in this direction. And in both the cases the final configuration would look like this because the shear stress is like this. So it will want to create steps over here like that. Now this is not all in fact the same shear stress.

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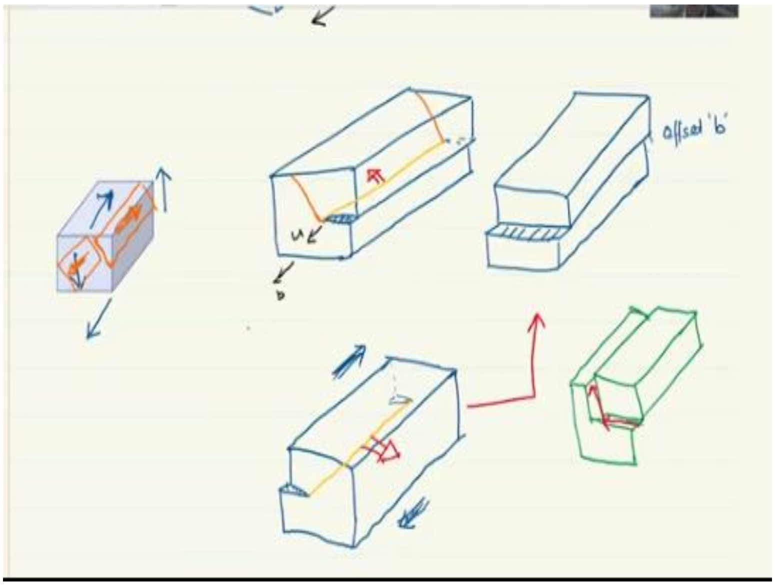

So let us say we have the same shear stress. Edge dislocation is not the only possibility. We can also have screw dislocations getting generated. And bear with me again here because the drawing of this one will be a little bit more complicated. So here again we can have two types of dislocations getting created. So a dislocation has been generated. Because of this, you would get a screw type of structure in the material.

And it would look like this. So this has come out better than what I expected and here is a step, partial step and your screw dislocation is all the way from here to here. This is the screw dislocation line and as we know that for screw dislocation this is the line vector and this is also the Burgers vector. So both of them are along this line and you are applying a stress like this. So what will happen to the motion of the screw dislocation?

Screw dislocation, this screw dislocation would keep moving in this direction. And eventually this would also form a step just like the above. Because you are applying shear stress like this, so it will always lead to this kind of step. The other possibility is getting a step created because there is also a shear stress in the other two planes. So you can also get steps in this way.

These are the only two possibilities. But for the other possibility you would need accommodating dislocations. Right now the dislocations that we have shown can only accommodate the stresses along this direction. We will understand this, we will be in a position to understand this better in couple of, after a couple of lectures. So this is the final configuration.

Although I have drawn a line over here it should not be over here, but you can ignore that line. And then this is the step over here and this is the step here. So this is again offset b which has been created because of the motion of the screw dislocations. The other configuration, other possibility in this particular case is to again have a dislocation which would be. We are not in a position to see exactly the shape here.

So I will draw it in dotted lines and the screw dislocation would look like this. Now you can clearly see that the handedness of this screw dislocation is different from this one or the both of these are opposite to each other. And clearly this one if you keep applying the stresses like we were applying earlier, which is shear stresses acting like this, then the slip wants to take place, slip wants to move, the upper block towards the right and bring the lower block towards the left.

And in the process this screw dislocation will have to move to the right. So again what do we see that the screw dislocation of opposite sign has to move in opposite direction and it will also eventually lead to this final configuration. Now here, there is one more thing which will be very interesting. And it is to assume that the shear stress that we were applying, for example in this particular case.

Let us say that this particular shear stress was not being applied on this plane but on a different tilted plane. So let us say, so let us say we have this two planes and the shear stresses were acting on these two. The question is, can they cause any motion? If we are applying a shear stress like this would it cause any motion? So the answer is that it will.

In this particular case, where we have a edge dislocation, we see that this particular plane where this is moving is not the same as the shear stress on which we are applying the, is not same as the glide plane where the dislocation is moving. So it is very different from this one. But then, we also have to see that there is, whether or not there is a component of this shear stress in this particular plane.

As long as there is a particular component of this shear stress in this plane, then what will happen is that this dislocation can keep moving. Only this time the force acting on it would be a little lower, which would be just a component which is acting on this. And that this particular dislocation would still have to move in this plane, it cannot move out of this plane.

This is, for the edge dislocation, this particular plane is uniquely defined. It is defined by the Burger vectors and the line vector. So you can see both of them are perpendicular which means there is one and only one unique plane where this dislocation can glide. However, the things become very different when we have screw dislocation. So let us say we were applying similarly over here.

So here we are applying again at some particular angle and not in the same plane. But then this dislocation line, this dislocation line is not uniquely confined to one glide plane. This particular dislocation line, if we just take Burgers vector and the line vector, it has several possibilities. And therefore, it can also move along this plane. And in which case you would get a crack which would look very different, which may be something like this.

So you can see until this point, it was moving, the screw dislocation was moving in this plane. And then when you change the direction it started moving in this direction. And therefore you get, you can get this kind of final configuration. So the screw dislocation can change its motion, but a edge dislocation has a uniquely defined glide plane. So these are some of the important messages or information that we gather from this particular understanding.

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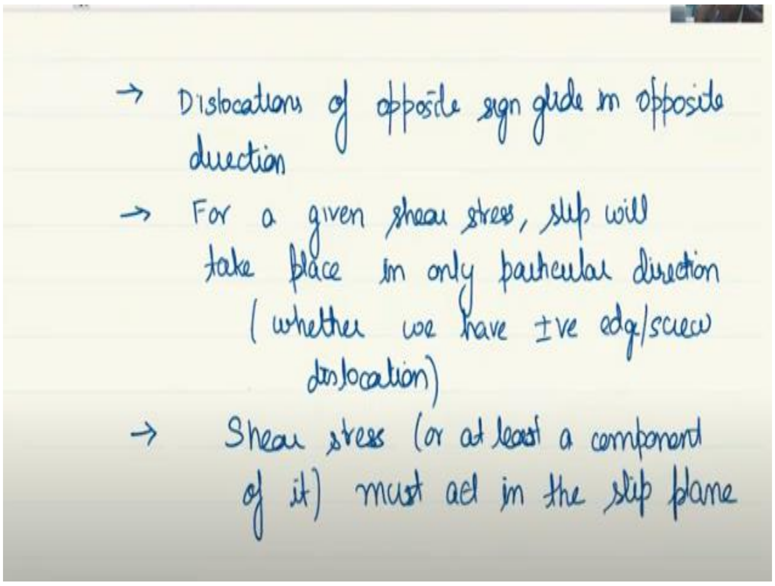

One is that dislocations of opposite sign glide in opposite direction. Second, for a given shear stress deformation or slip or offset has to take place in only particular directions. So we will say that slip will take in only particular direction. So we have seen that in this particular case shear stress was acting like this. So whether it is a screw dislocation or edge dislocation, we always get this kind of step.

And this was a different case where we change the direction of the shear stress. So as long as the shear stress is same and assuming that these are the dislocations, which are possible dislocations, then we will get only this type of final configuration. The other possibility was when we are considering this particular dislocation, sorry this particular shear stress. In that case we will get a step along this direction.

But for when we are focused on this particular shear stress then we will get only this kind of step, whether it is a edge dislocation, positive edge dislocation, negative edge dislocation, positive screw dislocation or negative screw dislocation.

The other important message that we take home from here is that shear stress or at least a component of it, we have not shown these things quantitatively, but we have clearly established this qualitatively from this thought experiment, must in the direction of the Burgers vector, okay. So that is what we mentioned that in the case of edge dislocation the shear is acting like this and you can see the Burgers vector is also like this.

So as long it is then all of the shear stress is acting on this dislocation. But if the shear stress were acting on this particular plane, then we need to find the component of shear stress which is acting on this plane. And that component will only be working towards the movement of dislocation or movement of the slip.

Similarly, in this particular case, when we have the shear stress acting like this, then the dislocation is moving like this and since it is a screw dislocation so when we change the direction of the shear stress the direction of the slip may also change. However, if for some reasons this slip plane was not possible and only this slip plane was possible then we will again here find a component of the shear stress on this plane.

And that shear component will only be acting towards the movement of the dislocation. So these are some important information or take home messages that we would learn.

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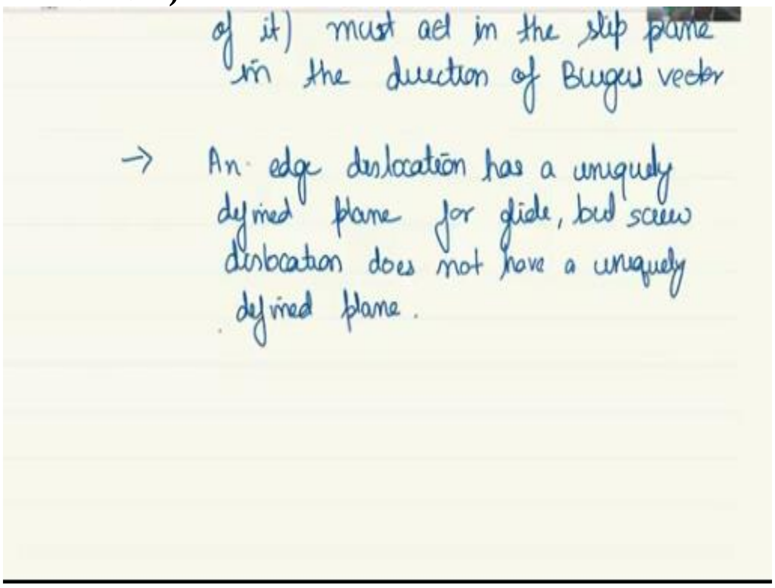

And another important message is that an edge dislocation has a uniquely defined plane for glide. But screw dislocation does not have uniquely defined plane, at least in terms of Burgers vector and line vector. So we saw that edge dislocation gets confined to the plane where Burgers vector and line vector are present. While in the case of screw dislocation, Burgers vector and line vector are parallel.

Therefore, there is no plane to be defined as such. And hence screw dislocation is not confined in any plane, okay. So these are some of the important points about the glide of the dislocations. So let me just to paraphrase about the uniqueness of the plane and not unique plane for the screw dislocation let me put it like this.

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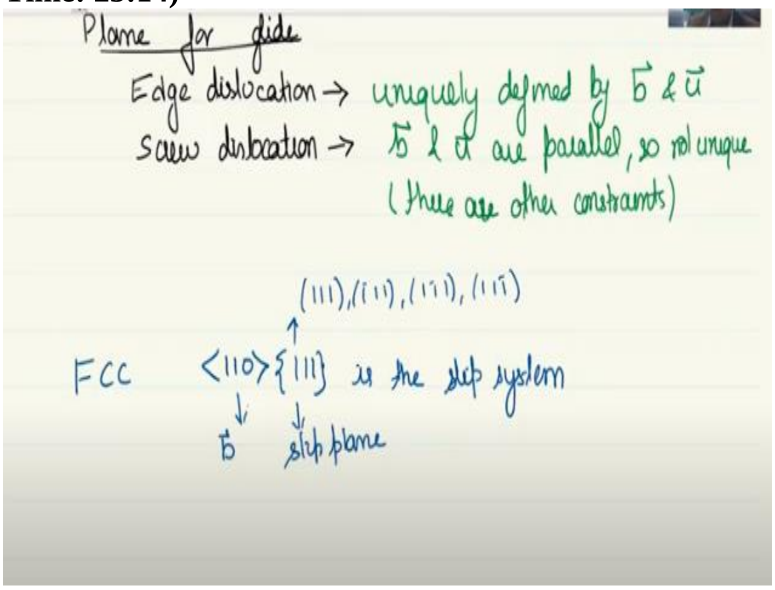

So plane for glide. Edge dislocation uniquely defined by Burgers vector b and line vector u. For screw dislocation Burgers vector and line vector are parallel. So not unique. However, like I have mentioned earlier also that screw dislocation the Burgers vector and line vectors are parallel.

It does not mean that all the infinitely possible planes, so this is a screw dislocation, so all these infinite planes are not the possible planes for slip and maybe other constraints. So there maybe or actually there are other constraints. So we will just take a quick look at what do we mean by the other constraints.

So for example, let us talk about FCC system. And I will jump ahead a little bit and I will tell you that <110> and {111} is the slip system for FCC. We will, actually we will derive this later on. And when we write it like this what it means is this is the Burgers vector and this is the slip plane. So now you can clearly see that it is that not any plane can be the glide plane, okay.

It is true that for Burgers vector for edge dislocation, we will still have only one particular plane, but for the screw dislocation, it may not be defined by the Burgers vector and line vector but it will still be limited to only these sets of 111. For example, the {111} planes are (111), $(\bar{1}\ 11)$, $(1\ \bar{1}\ 1)$, $(11\bar{1})$. So these are the four different (111) planes that are possible in FCC. And the screw dislocation can only take one of these.

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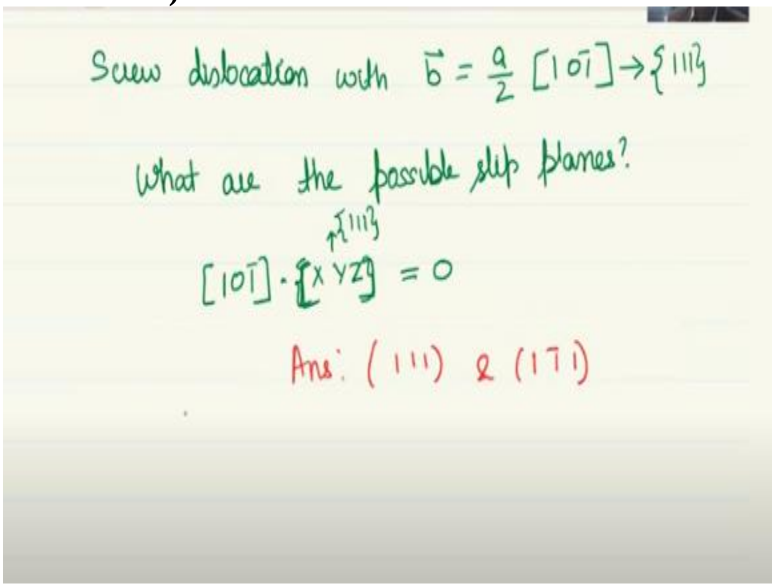

So now with this information let us say that you are given that there is a screw dislocation with Burgers vector equal to a/2 $[10\bar{1}]$. Then what are the possible slip planes, okay? So how do we find it? We know that Burgers vector is parallel to the line vector and that does not define any plane. But what we know is that the glide plane must be one of these.

And another thing we know is that if the screw dislocation is gliding on it, it means that the Burgers vector lies on it and therefore, we take the normal of the plane which is one of these and the Burgers vector then these to be perpendicular to each other. So if it is, it has to be one of the {111} then $[10\bar{1}]$ dot whatever it is x y z which is of the form of (111).

I will write it as a normal vector here. So it is x y z should be equal to 0, okay. So since you do not have to do complex mathematics to find out x y and z, we have only four different possibilities. And you can put in plug in over here and find out which are those {111}. And answer you will be able to clearly establish that the planes, and I am using this bracket because we now know the definite planes and this is for the family of planes.

So and this is for the family of directions. So now we can clearly say (111) and (1 $\bar{1}$1). So this you take the dot product 1 plus 0 plus -1. So it becomes 1 – 1 = 0. This is 1 + 0 and -1. So this is again 1 – 1 = 0. And therefore, this two are dot product 0. And it is also of the form 111. So these are the two planes. And it is clearly more than one. So the screw dislocation can indeed move on more than one plane.

It is not confined to one unique plane. That is one big thing that we can clearly see from this example. Now that we have talked about FCC system, so let us also talk about the BCC system.

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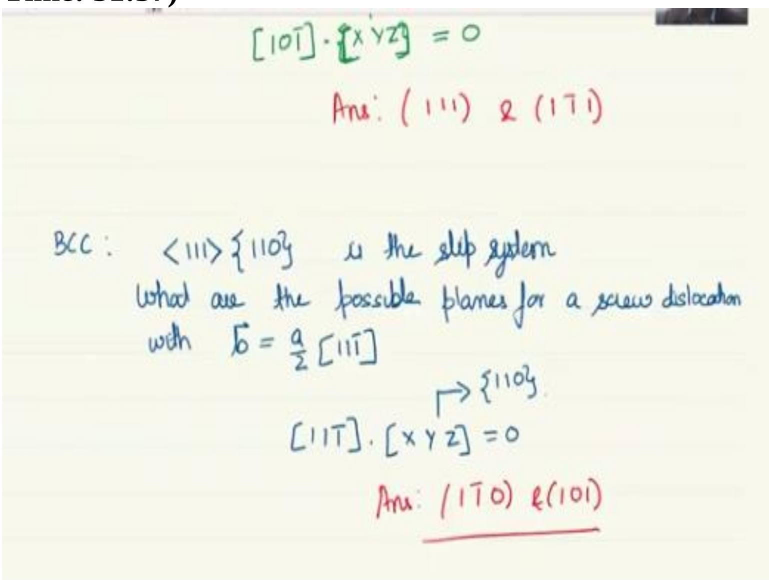

And in the BCC system it is known that <111> {110} is the slip system. So now you are given and again this means this is the Burgers vector, so direction, a family of directions and here it is the family of planes. So {110} are the type of planes where this dislocation can move. Actually there are more than one planes in different BCC systems, but this is the most common set of planes.

And we will also show theoretically why this is the most favored slip plane. Now the question is what are the possible planes for screw dislocation with Burgers vector equal to a by 2 [11$\bar{1}$] okay. So the Burgers vector we do not need to go to the magnitude of it, so we can just focus on this part. And therefore, it is given that it is of this type [11$\bar{1}$].

And now you have to find out on which particular plane this screw dislocation lies. So we know that [11$\bar{1}$] and the slip plane is of the type [110]. So we do not know which one is 0. We will write again [x y x] = 0. But then we know that this is from the family of {110}. And again there are not infinite number of {110}.

So instead of trying to set up a simultaneous equation, we can just directly plug in all the possible {110} and take a dot product and find out which one does not give a dot, which of these give a dot product of 0. And you would see that the answers are, so here so for it is for this one that we get (1$\bar{1}$ 0) and (101). And this is the answer for BCC.

So keep in mind this is the correct answer for FCC and this is the correct answer for BCC. So with that, we will close our session for this glide of dislocations and I will leave you with a thought, what will happen if there is a dislocation.

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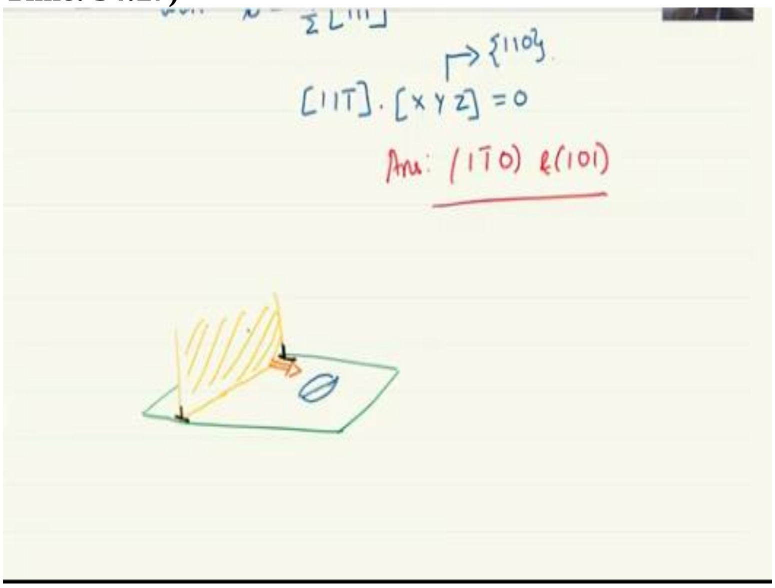

So let us say this is a dislocation which is like extra half plane. And let us say this is the glide plane. So let us say this is moving in this direction. Because of some external applied stress or because of some internal stresses this dislocation which is edge dislocation is moving if this is the edge dislocation. And it is very good all well and good. But what happens if there is some let us say some precipitate lying over here.

And it is a precipitate. So which cannot be cut or sheared through. This precipitate made to disappear in any way. So this particular precipitate will remain here. What will happen? How will this extra half plane move? Okay so with that thought in your mind, I will end this session and we will continue our discussion about motion of dislocation of other or for example how to take care of this kind of problem. Thank you.