Defects in Crystalline Solids (Part-I)
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Lecture - 32
Climbs + Jogs

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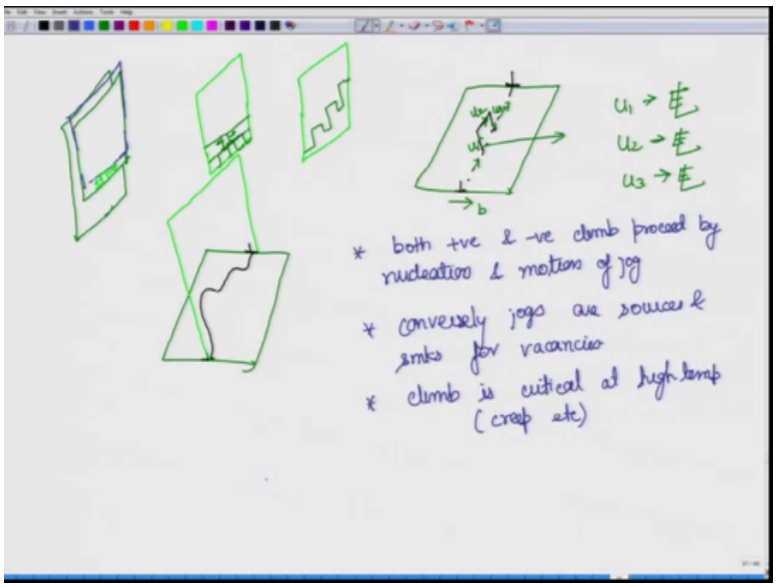

So, here we have extra half plane and a jog can form over here, and this can move. So, if I had to visualize it, this is how it would look like. So, here one jog has formed, then this jog moves like this and eventually it forms like this. Again another jog would form somewhere else, it would move like this, and it will keep moving. So, it will ensure that this dislocation line overall moves up. So, we are not even talking about once whole slip plane moving simultaneously, only small jog or a small step in it is actually getting formed and that then spreads apart to allow the dislocation line to move.

And again this is, if you remember again from our discussion for glide, where kinks were formed this need not be just one step by one step, there is nothing that will govern that it will have to be one line at a time. It can actually be more like something like this. So, there will be jogs at some places which will keep moving up and there will be some side dislocations which whose character will see in a moment. And they will keep moving in the other sides.

Another view to look at it would be like this. So, let us draw it on the plane. So, let us say this is one dislocation line that has to move, and it may form a jog like this, where does the burger vector for this, if you remember the burger vector for this is the edge dislocations burger vector is like this. Here the line vector is like this here the line vector is like this. So, this is the line vector, this is the line vector, this is the line vector.

So, in this particular case, what do we see when a jog is formed on a screw sorry on a edge dislocation, what will be the characteristics for this one. So, let us say this is u 1, u 2, u 3. So, what is the characteristics of u 1, u 1 is still edge dislocation because the burger vector is perpendicular to it. So, this is the edge dislocation. What about u 2, u 2 is over here also it is the burger vector is perpendicular, so it is a edge dislocation. What about u 3, this is also a edge dislocation.

Now, if you remember edge dislocation as higher energy than a screw dislocation. So, again having a mixed character would ensure that the energy is minimized. So, in reality what you would get is something like this a rounded character. So, this is how the extra half plane would look like. And to ensure that you visualize it properly. Let me draw the other part of it. So, this is the extra half plane and somewhere over here there are different layers where jog has found. So, somewhere the same what I was trying to show over here, but only now that we are doing it with rounded edges meaning these are mixed character ok.

So, now that we have understood so much about climb, let us note down some important understanding that we get here. What we understand here is that, both positive and negative climb proceed by nucleation and motion of jog. So, somewhere a jog must be created and whence that, jog has been created that jog will spread apart or move apart and it will lead to dislocation climbing. So for example, if you look at this particular, these are edge dislocations. So, which will be the movement of edge dislocations they will move along this direction and once and when they move it will move like this they will cause the dislocation to climb up.

Conversely we can say jogs are we said earlier also sources and sinks for vacancies and since vacancies are involved then this becomes a thermal process. And therefore, climb is critical at high temperature. So, processes like creep etcetera involve climb or a climb is more critical in understanding the process of process like creep etcetera.

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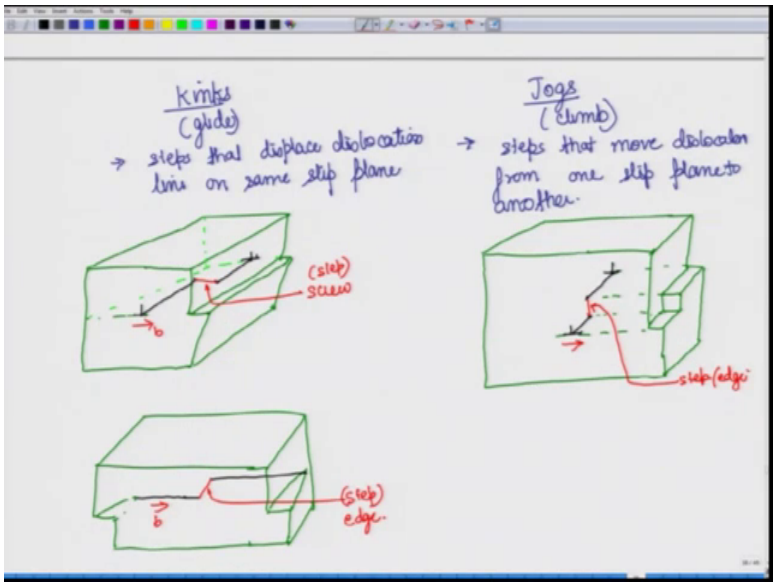

So, now we have two components or two different steps, two different things that we have looked at one is kinks, the other are jogs. Kinks help in glide, jogs help in climb or in other words, kinks are a steps that displace dislocation line on same slip plane ok, so that is the more critical differentiation. On the other hand, jogs are also steps that move dislocation from one slip plane to another ok.

So, now let us understand let us do the comparison also by some diagram with the help of some figures. So, let us say we have so we are trying to draw step formed on one side which leads to the formation of edge dislocation, and now that edge dislocation has a step which is the kink. So, let us say this is the edge dislocation that we are looking at from one side, and this is the plane.

Now, over here, this will be the so there is a step here and over here. So, this is the region or let me draw it with a different colors, so that the difference is; so this is the step that we have over here. And in this particular case if you remember, this is the burger vector would be along this direction, and this line vector is also in this direction. So, the character of this is should be the burger vector and line vector are in the same direction, so it should this character of the kink should be screw.

Now, let us look at the kink that is formed due to a screw due to a screw dislocation. So, let us what I am trying to show here is the step that has been formed, because of the presence of a screw dislocation, and there is also a step involved here, step in the screw

dislocation. So, we can see that there is a ledge on this side, a ledge on this side, there must be a screw dislocation. But, at the same time, this ledge is larger, this ledge is smaller, so there must be also a step and in the slip plane.

So, we will try to draw this which is the screw dislocation; and the step I will draw in the red color. So, here so let me write that this is step is which is red, you screw here the step what will be the character of this. So, for that first we need to know the burger vector, the burger vector was originally like this. And this is 90 degrees perpendicular to it, therefore this step must be edge in character. So, we have seen that this is a originally it is a edge dislocation, and the step here is screw. Originally it is a screw dislocation, and the step here is edge.

Now, let us look at jog, how will they be different. So, let us draw the jogs. So, again here we have step that has to be form, but the step will also be climbing at certain position, there would be a climb in the step. So, let me try to draw this climb in the step. So, here I have drawn a step. So, this as you can see, since there is a ledge, there must be edge dislocation sorry as screw dislocation involved, but at the same time sorry this is the edge dislocation involved. But, at the same time, there is a step rising, which means that this edge dislocation must be climbing up at certain partition. So, we will show that with this. So, there is a edge dislocation, which is moving like this, and this is like this, and which then but there is discontinuity, and hence there is a step involved.

Now, for this step what is the burger vector or for the hole first, let us describe the burger vector for the whole thing. Now, remember keep that in mind always that burger vector will not change for a dislocation, whether we are talking about steps or a continuous loop of a dislocation. So, the burger vector for the dislocation would also describe the burger vector of the step. So, here the burger vector is like this, line vector is like this. Therefore what should be the character? The character for this should be edge. So, what we have here is a edge dislocation. Now, what we want. So, this is a jog. Remember that on the left side, we have all the kinks; on the right side, what we are drawing is the jogs. So, in the jogs for edge dislocation is also edge dislocation.

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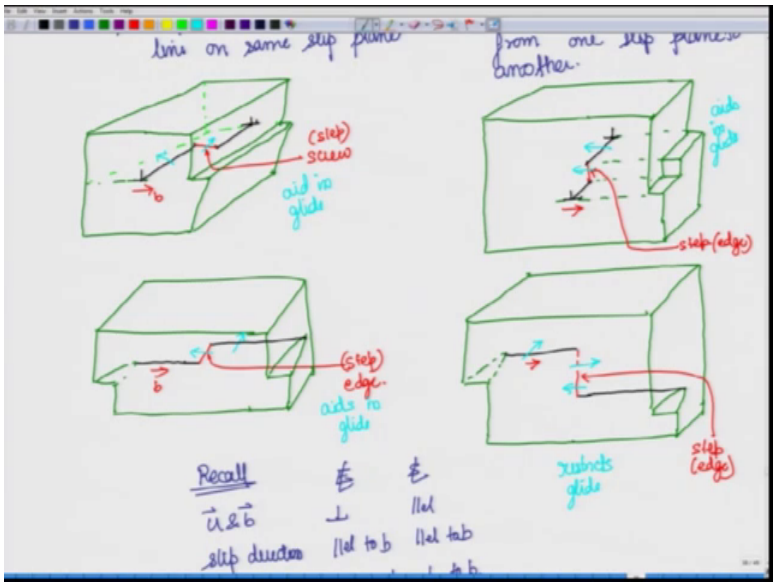

Next, we want to draw the jog for a screw dislocation. So, again we have to draw ledge which is like screw in character. So, this is the ledge, which is screw in character. And but this ledges are not on the same plane, which means that this has been moved up or down from its plane, depending on whether you start it from the bottom side or whether you start it from the so, here is a ledge.

And let me now draw the line for the screw dislocation. So, the screw dislocation line would go like this, screw dislocation line would go like this, and there is a mismatch over here which is a step. Although, this in this particular drawing it has come out to be much larger, but the steps would not be so large usually. And what is the original burger vectors, since it is a screw dislocation, the burger vector is like this. And what is the line vector for this, this is parallel to this. Therefore, what is the character, this character of the step is edge. So, in three of the cases, we are getting step as a edge step has a edge character. And only in one particular case, the step has a screw character.

Now, there are few more things to look at, when you have up when I have drawn it something like this. Now, let us try to understand it with respect to their motion. So, the dislocations were trying to move in this particular direction, so because the slip has taken place over here, so it will move out over here, creating a step over here. Similarly, in this particular case, all of them they will lead to a formation of a step like this step on this

side with a negative step on the other side that is the final stage. Now, in that particular case, let us see the steps that have formed are going to help or not.

Usually you can imagine that for glide, we get kink; and the kink is helping in glide. So, in that particular case, glide would be enhanced when there is a kink formation, but jogs are formed for climb. What we are looking at is glide motion of the dislocation. So, the jogs would not really always help. In some cases, it may help, but not always help in the glide of the dislocation that what that is what we will see here, but before that it will be it will be good.

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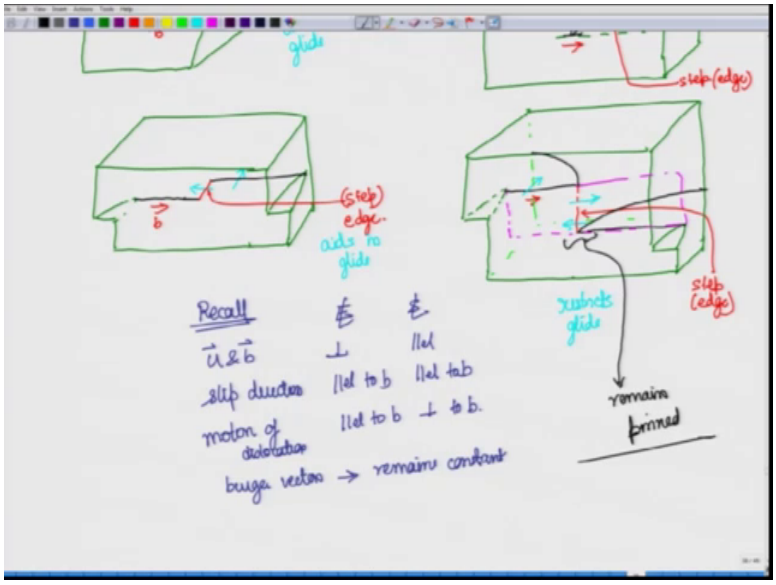

If we can recall somehow some of the things that we have discussed earlier, regarding edge dislocation and screw dislocation. So, what do we know about u and b, remember that it is perpendicular for the edge dislocation, it is parallel for a screw dislocation. What about the slip direction, slip direction is parallel to b? So, slip direction by b in other words does determine or define the slip direction. So, in both cases, it is parallel to b.

But, when it comes to motion as you know that in one of the dislocation which is edge is perpendicular to b, and screw dislocation is parallel to b. So, the motion would be different with respect to b motion of dislocation, this will be parallel to b, this will be perpendicular to b ok. So, these are some of the things that we will use when we are again looking at this diagram again. Another thing to keep in mind is that about burger

vector, remains constant. Keep these things in mind, and then you will be able to see how the motion would be helped or impeded by the presence of these steps.

Now, let us look at the step the screw dislocation over here. The screw dislocation is the burger vector for this is in this direction. And therefore the movement of dislocation would take place. Now, let me use a cyan color. So, it the dislocation good, if the right stresses are applied, this dislocation would move over there. And hence, it will lead to overall displacement of dislocation in the right direction, so it will aid in glide and this is expected. Over here, this is a edge dislocation, so it will move parallel to b. So, it will move like this, and it will cause the whole screw dislocation to advance in this direction. So, this will advance like this, which will ensure that the overall screw dislocation is moving like this. And in fact, if I were to draw this, so I would also say the overall edge dislocation is moving like this. So, here also step aids in glide.

Now, over here what we have is edge dislocation, this is the burger vector. So, it will move parallel to burger vector. So, the parallel meaning in the same direction, it can be positive or negative depending on the kind of shear stress that is being applied. So, this overall would move like this. And hence the overall edge dislocation would move like this. So, this also aids in glide.

Now, this let us look at the 4th case, where we have the screw where we have the screw dislocation, and we have a jog in this screw dislocation. So, this jog has a edge character. So, this is the burger vector is like this. So, this particular jog can only move in these two directions. So, it can either move like this or like this, but what we wanted was the screw dislocation to move like this. So, is this helping is the movement of this edge step leading or aiding in any ways to the movement of the screw dislocation, and the answer is no. In fact, it would happen something opposite of this, it will pin the dislocations. So, it enough in other words, you can say that it restricts glide.

So, in the three cases, the presence of steps have allowed what made this glide easier, but in the one of the cases, where there is a jog which is actually a formed by climb, it does not aid in glide. So, this is also something that we are able to understand, when we look at these diagrams. So, when I say pin the dislocation, so let me explain it in a little bit better diagram.

So, why does it get pinned? So, let us say this is the dislocation, and I will now have to use in another color. So, this particular this is the plane in which this edge dislocation can move, but the screw dislocation, because of the stress that is being applied will move in this direction. And therefore, if we let me just draw a glide line, so this screw dislocation would eventually move like this, this would move like this, and this particular region would remain pinned.

So, you can see that how this particular presence of this step is restricting the motion or the glide motion, not all the motions (Refer Time: 22:32) glide motion. If we were looking at the climb, then obviously this jog will aid in climb, but as far as glide is concerned, then this does restrict the glide motion of this particular dislocation. So, now that we have looked at glide and climb in so much detail, it is time that we solve some example with respect to this. So, let us come and solve some example.

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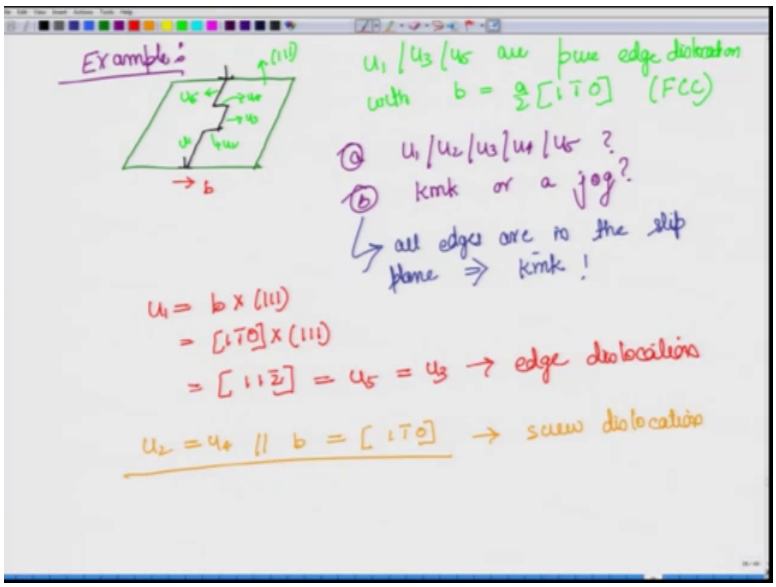

And these are simple example more or less based on what we have already discussed in one of these lectures. So, what you are given is that this is a edge dislocation and is a sharp, we will assume sharp steps over here, and again you are given that this plane is 1 1 1. You are given that this is a pure edge dislocation, from here this part and this part. So, let us say this is u 1, this is u 2, this is u 3, this is u 4, this is u 5.

So, these are the five parts, where so based on this, since it is oriented such its given that u 1, u 3, u 5 are pure edge dislocations, with burger vector it is also given that the burger

vector is a by 2. For now ignore the a by 2 part. We will come to that when we discussed more about FCC and BCC, you just imagine that we are trying to say the direction of the burger vector, which is 1 bar 1 0. So, for FCC system that should become obvious given the direction slip direction.

Now, what you have to find is what are the values of u 1, u 2, u 3, u 4, u 5? And you have to say whether what you are getting here is a kink or a jog ok? So, let us start to solve this problem. And let us solve it from part b, because part b as you would realize is very easy, we have to first find out whether it is a kink or a jog. Now if you remember, we said kink is a step formed in the slip plane. Now, if you look at this is the slip plane formed, and the way it has been drawn, all these are all edges are in the slip plane, implies this is a kink ok. So, this part has been answered. Now, let us look at how to solve u 1, u 2, u 3, u 4, u 5, etcetera.

So, you are given burger vector is equal to a by 2 1 bar 1 0. Now, if the burger vector is given and it is a pure edge dislocation, this would mean that this burger vector must be oriented like this, perpendicular to the line. Now, so the line vector u is perpendicular to burger vector, but at the same time, it is also perpendicular to the normal to the plane, which means that u 1 should be equal to cross product of burger vector, and 1 1 1, which means it should be 1 bar 1 0, and till using the notation of direction and plane. And you can do it mathematically or just by intuition, you can see that it should come out to 1 1 bar 2.

So, now you can cross check 1 1 bar 2. If you take a dot product with 1 1 1 is 0, so it lies on the 1 1 1 plane. 1 bar 1 0 dot one 1 1 bar 2, you can take a dot product, and you can see that it is 0. So, it is must be perpendicular. So, there can be only one direction, which is perpendicular to both, because we are in a 3D world, here x, y, and z. So, if it this particular plane is perpendicular to both 1 1 1, and burger vector it can define only one unique direction, so that is u 1. If this is u 1, then it would mean that it is also equal to this is parallel to u 5, and it is also equal to u 3.

So, now we know the line vector for u 1, u 5, and u 3. Now, what is remaining, what is remaining is u 2, which is parallel to u 4. So, u 2 and u 4 are same. What is it, this equal to this is a now we have already mentioned that these are sharp corners, meaning this is perpendicular to this line. And what is perpendicular to this line, it is the burger vector.

And we also know that from the earlier understanding that this must be a screw dislocation. Although, this is something we have to derive, but this is something we know that it is has to be a screw dislocation. So, if the line vector will be parallel to burger vector, so u 2 will be parallel to b, so it is equal to 1 bar 1 0. And this is a screw dislocation. And these are edge dislocation. So, we have seen that it is so easy to solve this problem.

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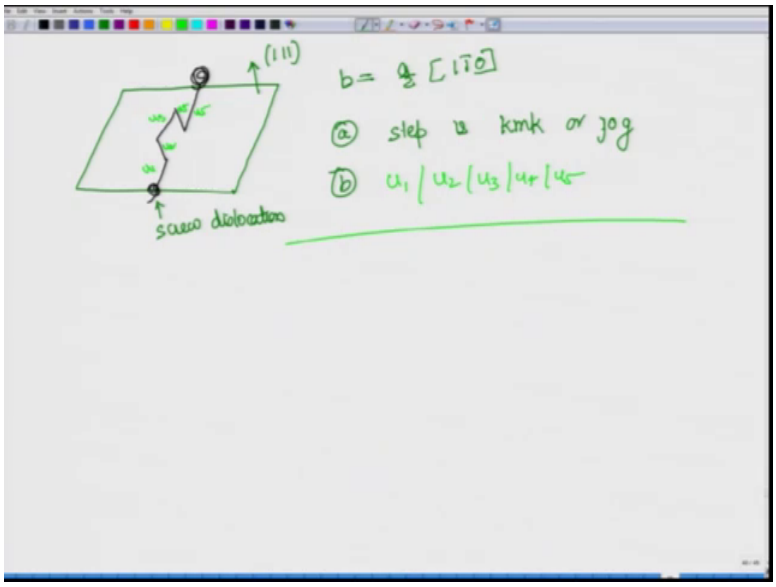

Now, there is a related problem to this. And over here to begin with what you are given is that what you are given is a screw dislocation. So, you are not starting with edge dislocation, but with a screw dislocation, and the steps are also little different to look at. So, this is a screw dislocation. And again, what is given to you is that the burger vector is a by 2 1 bar 1 0, and it is given to you that the normal of the plane is 1 1 1, and it is given to you that this is a screw dislocation.

So, the first part is whether this step is kink or jog. And second part is that you take u 1, u 2, u 3, u 4, u 5, so find u 1, u 2, u 3, u 4, u 5. So, you solve it on your own, if you are not able to do it. So we will meet again in the next class.