Introduction to Materials Science and Engineering
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Lecture – 57
Dislocation cannot end abruptly in a crystal: Dislocation loop

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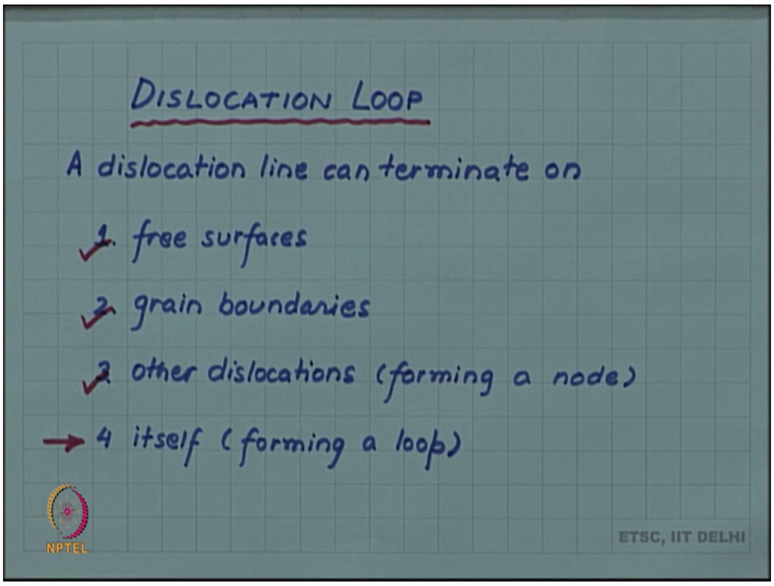

Our discussion: On what all a dislocation line, can terminate on? We have given this list previously and we have discussed the cases that, a dislocation line can terminate on free surface on grain boundaries and on other dislocations forming a node. These cases I have already been considered. We will now, in this video, consider this last case of a dislocation line terminating on itself or forming a loop so a dislocation loop, geometry of the dislocation loop, is what we will consider now.

So, let us consider this whole, a plane of the page, as the slip plane and on the slip plane let us consider that there is some sort of a closed loop which is a dislocation line.

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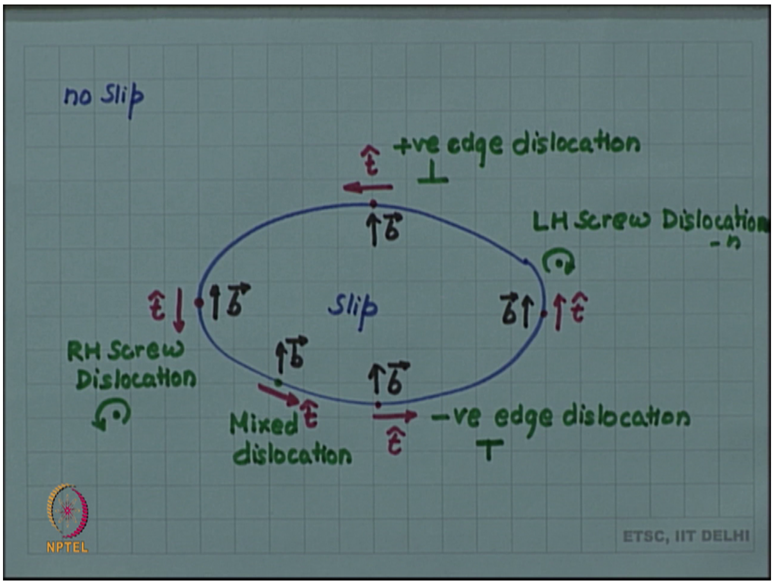

So, let me mark outside region as no slip and inside as the slip. So, this loop also qualifies the definition that is the boundary between a slipped region and an un slipped region. So, the slip is happening now inside the loop and the outside has not slipped. If we have so, this becomes a dislocation line.

Now, according to our definition of the tangent vector, if I take at any given point a tangent vector, here I had a choice, I am marking the tangent vector pointing to the right, but I could have marked a tangent vector pointing to the left also. So, initially I had a choice here, but once I have made this choice, as I told you, that, you should consider to be consistent at other points, the dislocation line, the tangent vector should appear as if current a single current is flowing.

So, we keep the sense consistent with that fact, we get a t vector here pointing to the left and a t vector here pointing to the down. So, t vector; obviously, as we have discussed in the last video also changes from point to point for a curved dislocation line. Now the question is, what the b vector is doing? If the b vector is also lying in this plane and let us say, for example, that the b vector is pointing up at this point, such that t and b are perpendicular. So, at this location we have an edge dislocation.

Now, since b is constant, remember this b vector is characterizing how much this internal region has slipped with respect to the outside region and that slip is constant all along the line. So, the b vector at all the points will remain of the same magnitude and will be pointing in the same direction. So, it would be pointing up at all these locations.

As it does so, you can see, that the angle between t and b the relationship the angular relationship of t and b keeps changing, as you follow the dislocation line. So, at this point at the bottom point t and b are perpendicular. So, we have an edge dislocation. So, we have we have, a negative edge dislocation here and we can be noted by a symbol t, at this point t and b become parallel and according to our convention, this will become a left handed a screw dislocation. We can represent it by a notation like this.

Then, if we come here, t and b are again perpendicular, but the dislocation changes sign. So, this becomes a positive edge dislocation and we will denote it by an upside-down t. And when we come here t and b now have become anti parallel here the t and b were parallel and that gave us a left-handed screw dislocation here t and b are anti parallel. So, it will give a screw dislocation of opposite sign. And so, in this case, it is a right-handed screw dislocation, which we can denote by a symbol like this.

And in between, if you have location like this, you can see that the b will still be pointing up, but t will be tangent to the dislocation line. So now, the angular relationship is neither perpendicular nor parallel. So, this location, this kind of locations, will be mixed dislocation. So, dislocation line like this which is lying on it is own slip plane, remember the plane of the drawing is a slip plane of the dislocation line, we call both t and b a line in this plane.

So, such a dislocation line will have it is b vector constant, but since t vector is changing from point to point it will keep changing it is character from point to point, but it is possible to have a loop which does not change it is character, this kind of loop known as Prismatic Dislocation Loop.

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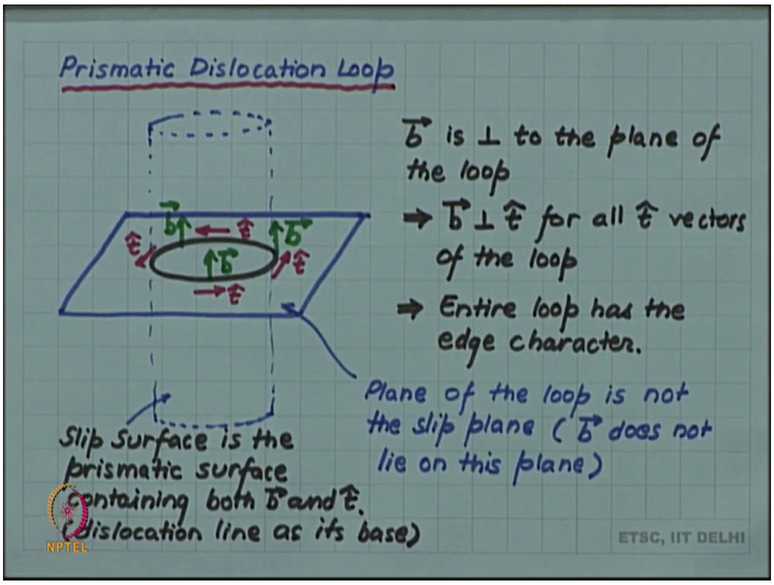

To imagine a Prismatic dislocation loop. Let us consider, a plane, and in that plane consider a loop. And Now, if I wish to let us say that, I wish to make this loop everywhere edge dislocation, unlike the previous loop which we considered which was edge at 2 locations, but where he screw at other 2 locations and was mixed everywhere else I want to make this loop lying in this plane edge everywhere. Now; obviously, it is t vector is tangent to the dislocation line and is changing. It is changing it is direction as I follow the dislocation line.

So, how can I have this dislocation line to become edge everywhere, for the edge dislocation t and b should be perpendicular? So, I should have a b and the b vector is constant along the line. So, a b vector which is everywhere constant and is everywhere perpendicular to t should only be possible if the b vector is perpendicular to the plane of the dislocation line itself. The b vector for this dislocation line should be perpendicular to the plane of the dislocation.

So, we can make a note that, b is perpendicular to the plane of the loop. So, b will be perpendicular everywhere, may for every t vector b will be perpendicular. So, loop has an edge character everywhere. So, b is perpendicular to t for all t vectors of the loop, entire loop has the edge character. Also notice that although I have drawn a plane here on which the loop is lying, but this plane is not the slip plane of the loop because, the b vector is not lying in this. So, that also let us note down: plane of the loop is not the slip plane, because b does not lie, b does not lie on this plane. Slip plane by definition should contain both b and t. So, this plane the blue plane which I have drawn here at the plane of the loop in which the black loop is lying, this plane only contains t, it does not contain b.

So, then what is the slip plane of this dislocation? So, the plane containing both b and t will be? Since b is perpendicular to t and b is constant. So, b is everywhere perpendicular to the dislocation line. So, the slip plane, the plane containing and infact, it is no more a plane now the surface the curved surface which is containing both b and t will be the surface of the cylinder, which in general, will be surface of a prism based on the dislocation line.

So, slip surface instead of slip plane now, I am deliberately using the term slip surface because, it is no more flat now, it is a curved surface. The slip surface is the prismatic surface containing both b and t. So, whatever the shape of dislocation line may be, it will be a surface, a prismatic surface based on that dislocation line as base. And it is because of this, because of this prismatic surface, as it is slip surface the name prismatic dislocation loop is used.

Let us look at a physical situation where such a dislocation loop can occur. One situation where this can occur is a vacancy loop in close packed structures.

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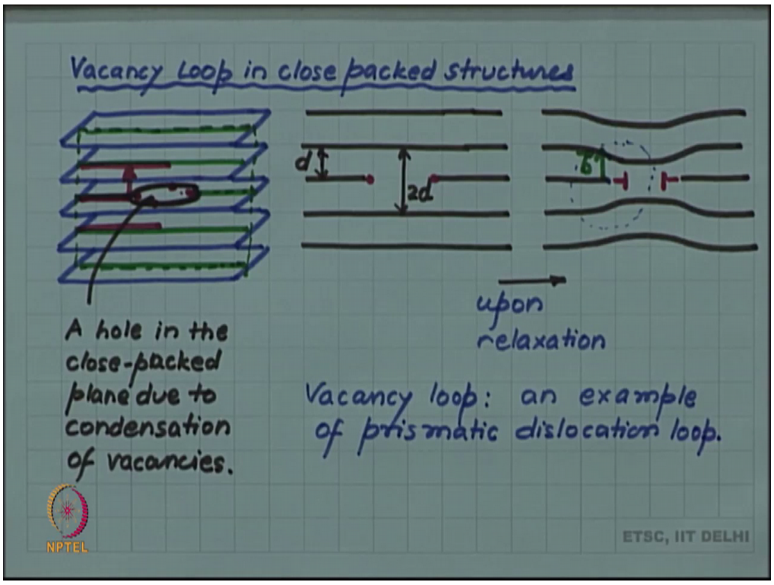

Suppose we have closed pack planes, I am drawing parallel closed packed planes, let us say in a closed packed structure, cubic close packed or hexagonal closed packed. And in one of the planes, let us say that several vacancies condense. So, that so many atoms are lost from this and you have a hole there. So, in one of the planes a hole has been punched out. So, this is not one vacancy, several vacancy we will condense out so this region or this area of that plane is devoid of atoms.

So now, we have this hole and we have the boundary of this hole, what we are going to show that the boundary of this hole, will exactly behave like a prismatic dislocation loop which we introduced in the last slide. So, if we now look at, let us look at the section on this mid plane. So, if I now represent the view, in this section so, I draw my planes. So, you can see. So, I am drawing these sections. So, I get this line and then this line, this line will be having the hole in between and then this line and then this line in this vertical green plane.

So, you can see now, that the spacing, the plane is spacing which was d here has suddenly become 2D through the hole. Now crystal will; obviously, not like this. So, these planes will relax towards each other and the configuration the final equilibrium configuration which will come, will be something the nearby planes will collapse towards the hole. Due to relaxation we will have this configuration.

You can now quickly see, the local configuration here, is nothing but like a dislocation line because this plane is continuing, but suddenly abrupt here, but abruptly ends here the adjacent plane continue. So, this is exactly like a half plane. So, what essentially I am showing you that if I am following this line as soon as I hit this hole this plane abruptly ends, but the adjacent plane will continue. So, the local configuration there is just like a dislocation. So, I have a dislocation there. Similarly, the local configuration here is like a dislocation.

So, essentially, we are showing that these 2 end points of the hole are edge dislocation line. But this was when we cut into this green plane. So, then we showed that these 2 points or edge dislocation line. You can imagine that, if I cut this hole through other vertical planes all the points can be shown as the dislocation line in the same similar kind of picture because the geometry of this loop is cylindrical is symmetrical about this axis. So, the entire loop is an edge dislocation and the burgers vector of this dislocation line if you find, will be in this diagram vertical. Because the edge dislocation line is going in at this location so the Burgers vector will be pointing into the plane and will be going up. So, the burgess vector here also will be perpendicular.

This kind of situation occurs in metals which are quenched from higher temperature. So, at higher temperature there is lot of vacancies in the crystal and when suddenly they are quenched, these extra vacancies are available and the crystal wants to get rid of them and one way of trying to get rid of them is to condense them into such vacancy loops. So, vacancy loop is an example of prismatic dislocation loop.