Introduction to Materials Science and Engineering
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Lecture – 119
Dislocation interaction leading to strain hardening l

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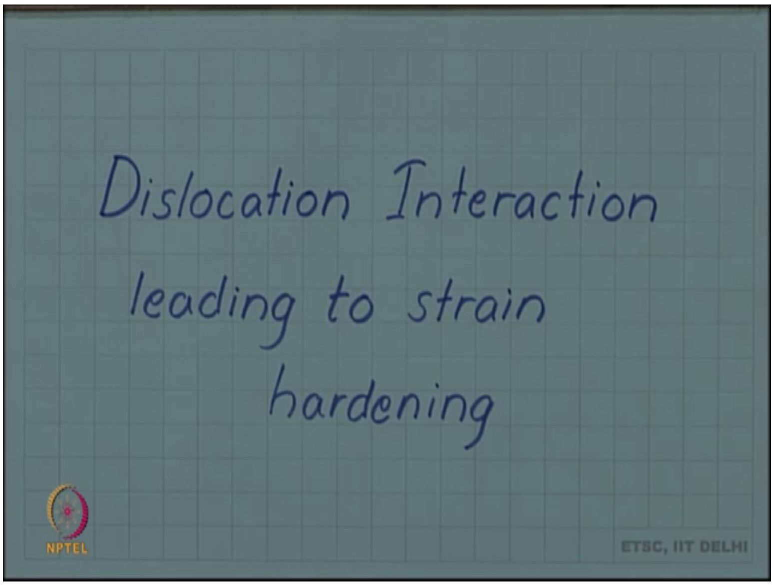

In the last video, we mentioned the dislocation-dislocation interaction, which lead to interference between the motion of two dislocations and that leads to strain hardening. So, let us look at in a specific example to make this idea clear.

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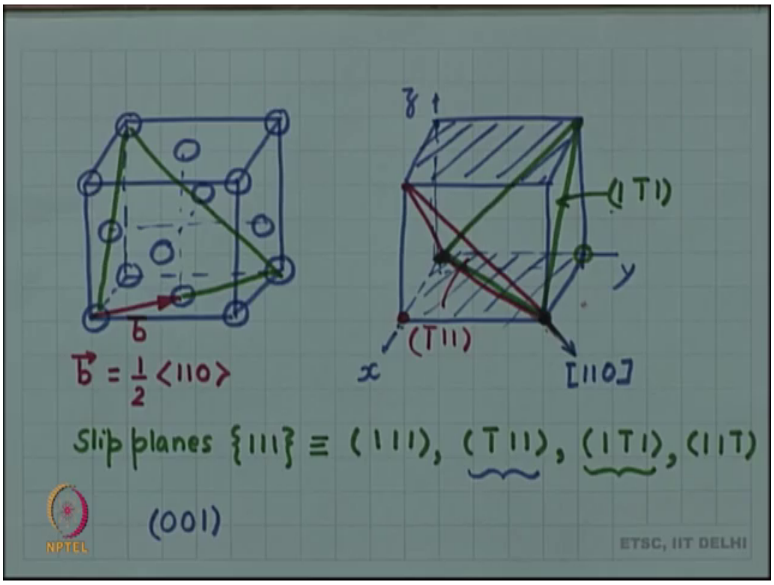

So, let us take as an example face centered cubic material. So, you remember face centered cubic material and in the face centered cubic material atoms are at the corners and all the face centers.

Now, we have seen that in the face centered cubic material the Burgers vector is half the face diagonal; the burgers vector is vector like this. So, b is of the form half 1 1 0. We have also seen the slip plane in the face centered cubic material are of the 1 1 1 type. So, this will be one of the slip planes 1 1 1, but remember one this 1 1 1 family of planes actually means six different planes, sorry four different planes and they are 1 1 1 bar 1 1 1 it may be useful to refresh your crystallographic videos, if you are having difficulty in recalling these. So, four such planes are there.

So, let us consider again let me draw a unit cell. So, let me draw two of these planes. Let me take bar 1, so let me use this as x, y, and z and let me draw bar 1 1 1 plane. So, I need to go negative in the y axis for negative in the x axis, positive in the y and positive in the z. So, this may be a suitable choice of origin for that purpose; so let me select this origin minus 1 in the x axis. So, one intersection is there; 1 in the y axis and 1 in the z axis. So, I have a plane I have a plane like this.

Now, let me draw another plane which is 1 bar 1 1. So, for 1 bar 1 1, I need to go negative in the y, but positive in x and z. So, this will be a suitable choice of origin for that. So, I I go 1 on the x axis, so there is 1 point there, minus 1 on y axis, so there is a point here and plus on the z axis, so there is third point there. So, my this other plane is like this. So, you can immediately see that the two planes are intersecting in a common line, which is the bottom face diagonal along this and this direction you can index using miller indices, because I can take one step along x and one step along y to generate this vector, so this direction is 1 1 0.

So, the red plane is bar 1 1 1, the green plane is 1 bar 1 1 with the common direction being 1 1 0. So, let us start with this situation and these are the slip plane and dislocations will be gliding on these planes and dislocations will have Burgers vector of the type half 1 1 0.

So, let me now just draw these two planes separately and schematically.

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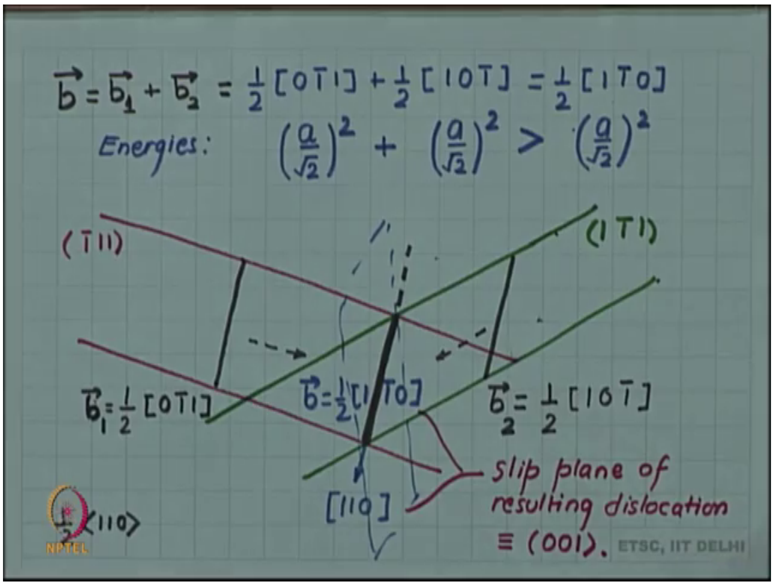

So, I draw; let me say that this is my red plane, and this is my green plane and they are intersecting as we saw on this blue line 1 1 0 is the line of intersection. So, the red plane is bar 1 1 1, the green plane is 1 bar 1 1 and they are intersecting one along the line 1 1 0.

Now, let me create a dislocation let me create a dislocation in the bar 1 1 plane parallel to the line of intersection. So the dislocation line the t vector is along 1 1 0. And let me give a burgers vector to this dislocation line as; half the burgers vector of this dislocation line let me write as half o bar 1 1. Notice; that the burgers vector has to lie in the slip plane, so I have chosen from a family our family was half 1 1 o. So, from that family I have chosen one of the Burgers vectors, which lies in this plane bar 1 1 1 plane, because the Burgers vector of any given dislocation line has to lie in a slip plane and I am creating this dislocation, such that the red plane is a slip plane for this dislocation line.

Now, let me create another dislocation line on the green plane again parallel to the line of intersection. And let me give this also a Burgers vector, half 1 0 bar 1. Again I have chosen from this family and I have chosen one vector, which satisfies the wise zone law with 1 bar 1 1 such that the burgers vector lies in this plane. So, now, I have a scenario where; there are two intersecting slip planes two intersecting slip plane bar 1 1 1 and 1 bar 1 1 in a face centered cubic crystal, and on each of those planes there is a dislocation line parallel to the line of intersection and having these Burgers vector.

Now, assume that we have a stress system such that both these dislocations move towards the line the intersection line. So, if these dislocations move towards the line and if they if they finally, meet at the line what kind of interaction will be there; so let us say that these two dislocations have come along the line to form some sort of composite dislocation. The question is that whether do they do come and form a composite dislocation or whether they will repel each other with whether they will attract each other or repel each other. So, this we can answer energetically.

First let us find the; first let us find the Burgers vector of this composite dislocation. So, we know that the burgers vector of a dislocation, which is produced by a combination of two dislocation is the sum of the two Burgers vectors. So let me call this b 1 call this b 2. So, the sum Burgers vector will be b 1 plus b 2 and if we write this then we find half o bar 1 1 plus half 1 o bar 1, if we add these two vectors you will find that the new vector is half 1 bar 1 o.

So, we see the new dislocation line this possible dislocation line in face centered cubic material, because that also belong to the same family half 1 1 0. So, it is a possible dislocation line and energy energetically we see that all these three dislocation line have the same length their length is, because they are equal to half the face diagonal; the lengths are a by root 2; we call that the Burgers vector the length is a by root 2; half the face diagonal. And energetically we know that the energy of the dislocation line is proportional to the square of the burgers vector. So, if we square these the energy of this dislocation line was a by root 2 square this dislocation line was a by root 2 square and the resulting dislocation line is also a by root 2 square.

But initially there were two dislocation lines; so you had some of these two energy, which is greater than the final energy, which is the energy of a single dislocation line, so which means that this reaction is actually favorable these two dislocations are actually attracted to each other and they will like to combine. And they have combined and formed a new dislocation line of burgers vector half 1 bar 1 0. So, this dislocation line as a Burgers vector half 1 bar 1 0, what will be the slip plane of such a dislocation line.

So, you have to find a slip plane, which contains this dislocation line; let me draw that slip plane somewhere, which contains this 1 1 bar 0 vector and 1 1 0 vector. So, using wise zone law you can find the common plane for these two. So, slip plane of this dislocation line resulting dislocation is o o 1, but that is disturbing o o 1 is not the slip plane family for FCC. So, in this case the o o 1; so let us find out the o o 1 here. So, o o 1 will have will be parallel to the x axis, parallel to the y axis and will intersect the z axis at 1.

So, it is this kind of plane which is the o o 1; the face of the cube. Now face of the cube is not the slip plane. So, in particular this drawing it will be this face will be will become the new slip plane of the resulting dislocation line, but this is not a slip plane required by the face centered cubic or in other words if the dislocation wants to slip on this plane the required critical resolved shear stress will be much much higher.

So, which means this dislocation is now no more able to move, what we call is a sessile dislocation let us write down these results.

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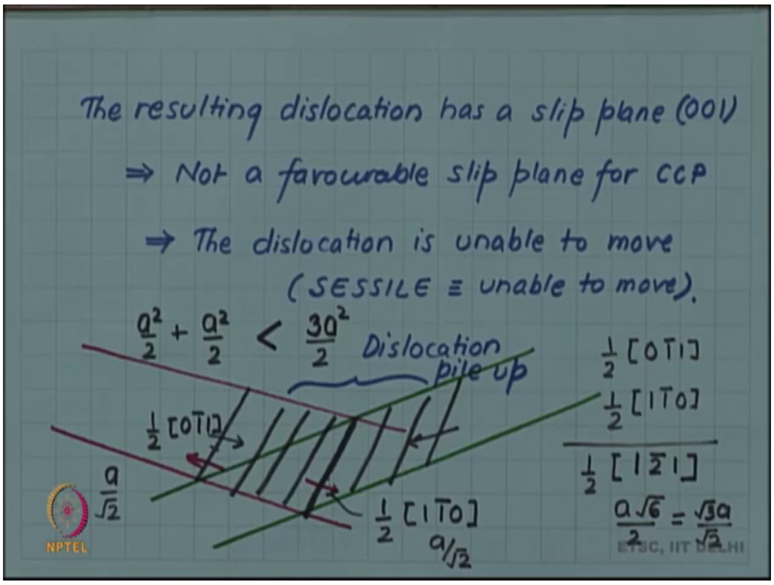

That the resulting dislocation as a slip plane o o 1, this is not a favorable slip plane for CCP crystals, which is what we are considering and that is why; the dislocation is unable to move; in other words sometimes dislocation which are unable to move we call them SESSILE; SESSILE unable to move. So, the resulting dislocation is a SESSILE dislocation.

So, now you can think of this red plane and the green plane as two highways, on which this SESSILE dislocation; now is a traffic jam it is a breakdown; which has created now a traffic jam why so? Because now the new dislocations other dislocations, which will be moving in this direction will be repelled by this SESSILE dislocation, because let us consider the next dislocation again like we had considered here of half o o bar 1 1.

So, another dislocation with the same Burgers vector around let us say suppose this is moving in this direction, but this dislocation has a Burgers vector half 1 bar 1 0, if we combine these two; if we add these two 0 bar 1 1 and 1 bar 1 0 we get half 1 2 bar 1. Now, this is a much longer burgers vector these vectors were half length a by root 2 in a by root 2 whereas; this will be of the length a root 6 by 2 or root 3 a by root 2.

So, this is root 3 times longer vector. So, if we take the energies now; we will find a square by 2 plus a square by 2 before and 3 a square by 2 after. So, the initial energy is less than the final energy. So, this dislocation now will not like to combine with this dislocation or in other words these dislocations feel repulsion. So, this dislocation will not like to move towards this SESSILE dislocation and get combined. So, not only the SESSILE dislocation is unable to move it will start stopping the other dislocations which are coming on the same slip plane towards it; so there will be what is called a dislocation pile up.

Another name for a traffic jam of dislocations dislocation. So, we have seen one example one a specific example of how dislocation-dislocation interaction can create such a SESSILE dislocation and in the result; where due to the formation of SESSILE dislocation a traffic jam of dislocation takes place dislocation movement becomes difficult and thus finally, you will have a more harder material, you will have harder material, because plastic deformation is becoming more difficult and this is what is a strain hardening?