Introduction to Materials Science and Engineering
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Lecture – 117
Frank-Read source

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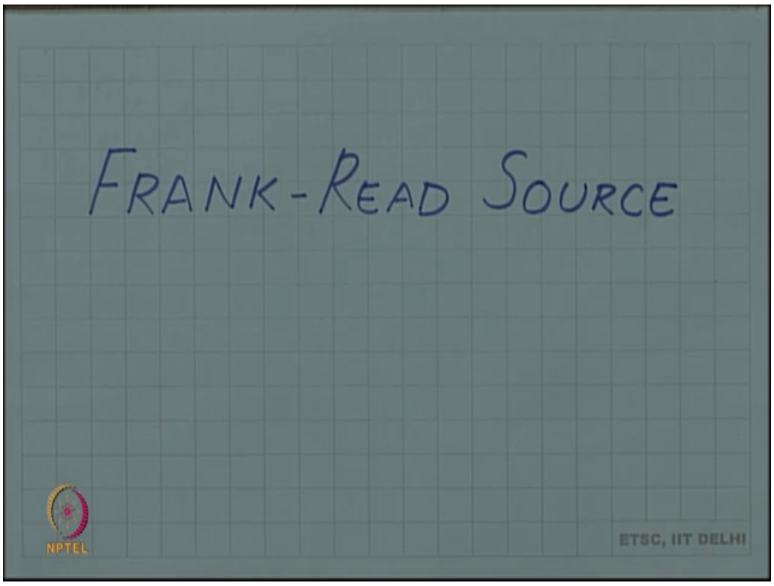

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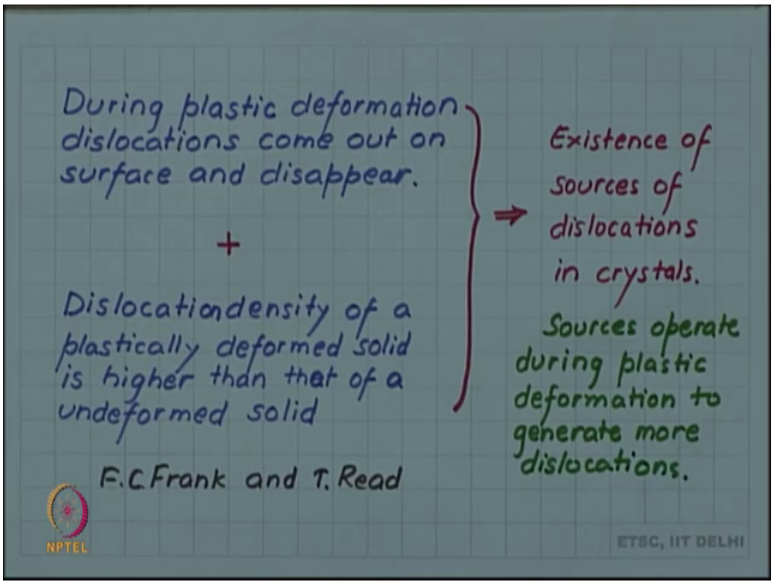

In the last video, we saw a sort of contradiction regarding the behavior of dislocation during plastic deformation; during plastic deformation, dislocation come out on the surface and disappear we saw that that when a dislocation when a single dislocation sweeps the entire slip plane and comes out of the crystal it creates a step of Burgers vector b.

Another fact which we saw that dislocation density of a plastically deformed solid is higher than that of a undeformed solid. So, on the face of it, they these are two contradictory statements that because if the dislocations are coming out on the surface and disappearing the dislocation density should come down; however, finally, we are seeing to the dislocation densities increasing.

However this contradiction is not really a contradiction and this is what was seen by two scientists Frank and Read; F C Frank and T Read. They saw that actually both of these things can be true, they are not contradictory and together, they imply that since the dislocation density dislocation is coming out and disappearing and despite that the final dislocation density is increasing. This implies that there are some sort of sources of dislocation in the crystal. So, they predicted the existence of sources of dislocations in crystals which means that there are sources which operate during the plastic deformation and generate more and more new dislocations so much.

So, that they not only counter the any decrease due to dislocations coming out, but they actually make more dislocations such that the dislocation density the final dislocation density is higher than the starting dislocation density. So, these sources operate during plastic deformation to generate more dislocations sources.

Let us see, one example of such a source that how such a source can work.

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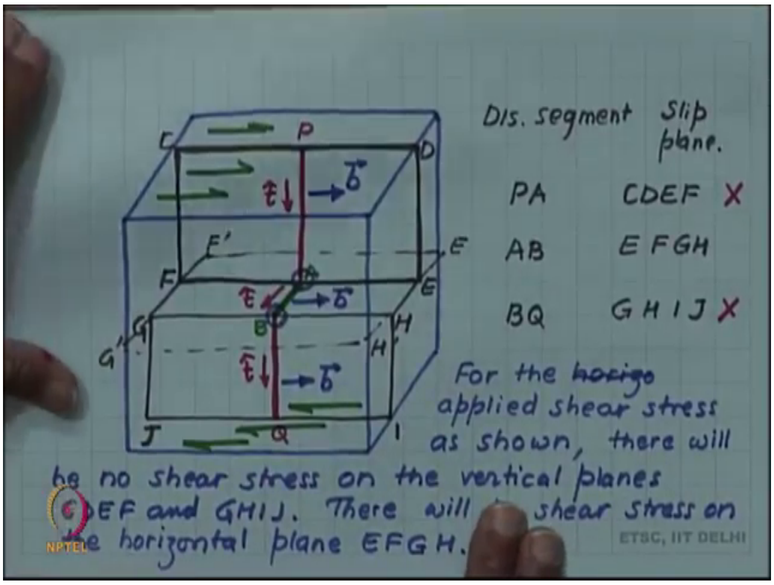

So, in this drawing, I have drawn by the blue line, you can imagine a cubical solid cubical crystal and within that crystal by this PA BQ line, I have drawn a dislocation line. So, this is a segmented dislocation line, it has two horizontal segments, it has two vertical segments PA and BQ and a horizontal segment AB.

Let us say the dislocation has a burgers vector which is perpendicular to the dislocation line everywhere. So, it is in this direction; as we know disloca the burgers vector for a given continuous dislocation line should be same. So, although I have drawn it at three places, these are all the same burgers vector.

The t vector follows the dislocation line. So, let me choose t vector going down. So, t vector is horizontal here and then it again goes down. So, this means that this dislocation line now has a slip plane which is segmented slip plane. So, for the PA part the slip plane is this vertical plane let me label it CDEF. So, CDEF is a vertical slip plane for the segment PA and then GHIJ and the GHIJ is another vertical slip plane for the segment BQ, but the segment QB lies in the horizontal plane and has a slip plane EFGH. So, let me write down dislocation segment the slip plane.

So, the for the dislocation segment PA the slip plane is CDEF for the dislocation segment AB, the slip plane is EFGH and for the segment BQ, the slip plane is GHIJ, if I notice that the slip plane has to be the plane containing the dislocation line and the burgers vector.

Now, in this crystal, suppose we apply a horizontal shear stress acting on the top phase of the crystal in this direction is the shear stress applied on the top and the bottom phases. So, we are trying to deform the crystal using this shear stress notice that this horizontal shear will be felt on the slip plane EFGH so, but it will not be felt on the slip plane CDEF and GHIJ which are vertical. So, there will be no for the horizontal shear stress shown for the applied shear stress as shown, there will be no shear stress on the vertical planes CDEF and GHIJ these planes will show C no shear stress.

But they will be shear stress on the horizontal plane EFGH. This means this will have an interesting consequence, there is no shear stress on CDEF. So, there will be no tendency for the dislocation line segment PA to move. So, PA will not move, similarly, EQ, sorry, BQ will not move. So, PA and BQ will be immobile, but the dislocation segment AB we will feel a stress in its own slip plane and so, it will like to move according to that stress

So, effectively; what will happen is that this dislocation line segment A AB will be pinned at A and B because segment AB PA is not trying to move and BQ is also not trying to move. So, A and B will act as spinning points on its slip plane, but the rest of the dislocation will try to move according to the applied stress. So, that situation let us picture now. So, now, I am drawing imagine. So, let me draw that so let me draw an expanded view of the EFGH slip plane.

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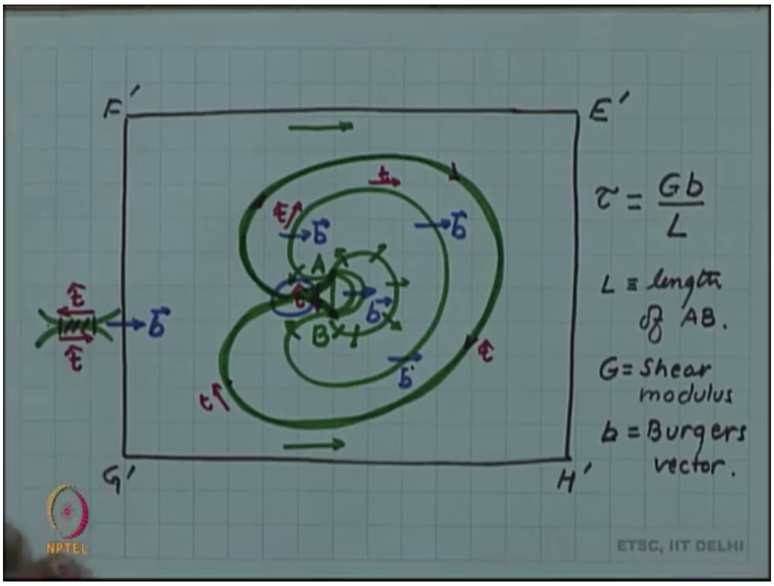

So, now I am drawing only this EFGH in the in last form and on this EFGH plane, this segment AB is lying actually really, what I am drawing is a larger plane in the crystal not just the EFGH strip, but let me call that E prime, F prime, G prime and H prime. So, on which the EFGH is a part of that and the dislocation segment AB is lying . So, if I am drawing that plane E prime, F prime, G prime, H prime and on this dislocation line segment AB is lying when A and B being the pinned points, the dislocation burgers vector; we had decided to be in this direction and the line vector was parallel to the dislocation line pointing from A to B .

Now, since this dislocation line segment is pinned at A and B, but is still is feeling a shear stress in this direction because of the applied shear stress on the top and bottom phases of the crystal. So, this dislocation segment will start bulging under that stress and at some point, it will take a semicircular shape, it can be shown we are not going to we will just accept this result it can be shown that the stress required to bow it into a semicircular shape is the shear stress Gb by L, where L is the length of the dislocation line segment AB.

G as usual is the shear modulus and b is the burgers vector length of the burgers vector and it has also being shown that after it has become semicircular no further stress increase is required, if this stress is maintained this semicircular dislocation will keep expanding into larger and larger loops. So, at any given time, each dislocation segment feels a force which is normal to the dislocation line and that is why it keeps bulging into the shapes.

Finally a moment will come because now this will keep bulging this way this will keep bulging this way. So, you can see that these two segments now are trying to come together and when a stage will come when they finally, touch as soon as they touch this segment will be these two dislocation line will come close together and will interact; let us look at the nature of this interaction. So, let us blow up; let us blow up this segment. So, we have dislocation line like this and a dislocation line like this since the t vector was going from A to B; with starting from A to B, it will always start from A and go to B and follow like the current with the t vector keeps following the dislocation line.

So, in this case, the t vector starting from A will be pointing to the right, but then when it takes its entire journey along the loop when it will come back it will come back in the opposite direction. So, these two segments have opposite t vector, but what about the B vector; B vector, we had shown by this blue vector and B remains constant for a curve dislocation line, we have seen that if this dislocation has B this one here, it will keep having the same B everywhere. So, which means both these segments have the same B given by the blue vector.

So, which means the upper segment t and b of antiparallel whereas, in lower segment t and b are parallel. So, they are opposite in sign there are screw dislocations, but they are of opposite sign. So, which means that there will be annihilation of this segment of the dislocation this segment will annihilate. So, what will happen then that you will have the dislocation lines with will break into two segments, one of them will be a loop this heart shaped or kidney shaped loop and the other will be a smaller segment like this.

So, let me redraw that for clarity. So, what we are seeing that after annihilation.

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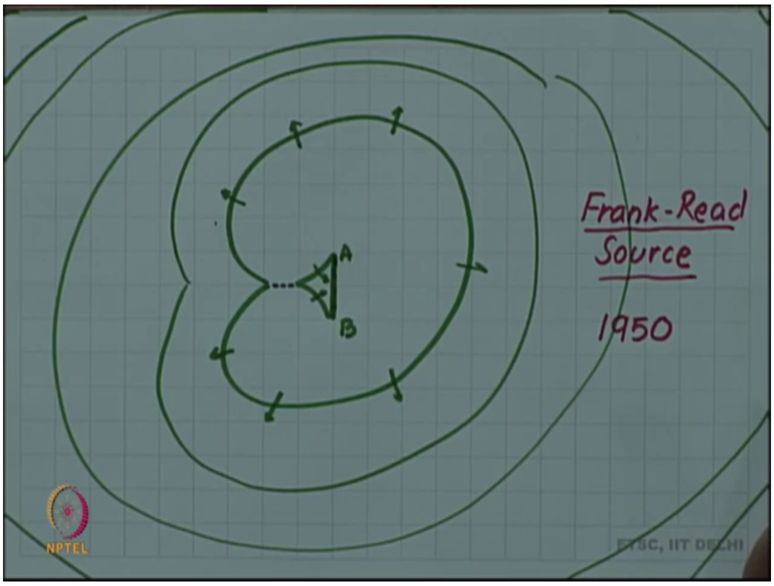

So, let me now, draw it in dashed line, this was AB the original segment, but after this annihilation process you have one segment left like this and another segment another segment like this which this part being annihilated. So, you can see now that when this will relax this segment will relax, it will come back to its original position because this will keep feeling forced like this and finally, it will come back to its original position and will be ready to generate another loop, whereas, this loop which is created, it is still feeling normal force all along its length and will keep expanding into larger and larger loop and when it will start coming out. So, let me try to simulate that on this board.

So, now you can see some part of the dislocation has gone out of the slip plane out of the crystal and finally, these segments which are left will also keep moving in that direction and will come out. So, when one loop completely sweeps out the entire slip plane you get a step of one burgers vector, but notice that although one loop has completely swept out and has disappeared there are other loops which are coming because this AB segment has been regenerated and can keep creating newer and newer dislocation loop. So, this is why it is called a dislocation source and it is a continuous source for dislocation generation and is known as the Frank read source.

Both Frank and Read independently thought of this process and then in 1950, they met in a conference and quite gentlemanly, like they agreed to have a joint publication, instead of fighting over the priority of who has thought of it, first they shook hand and published the paper jointly and this is now known as the Frank Read Source. So, it was a theoretical proposition, but later on through various experiments, it was verified and such kind of dislocation loops were actually seen in microscopy; electron microscopy and in some cases as steps in the crystal form due to this kind of movement.