Introduction to Materials Science and Engineering
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Lecture – 64
Small angle symmetric tilt boundary

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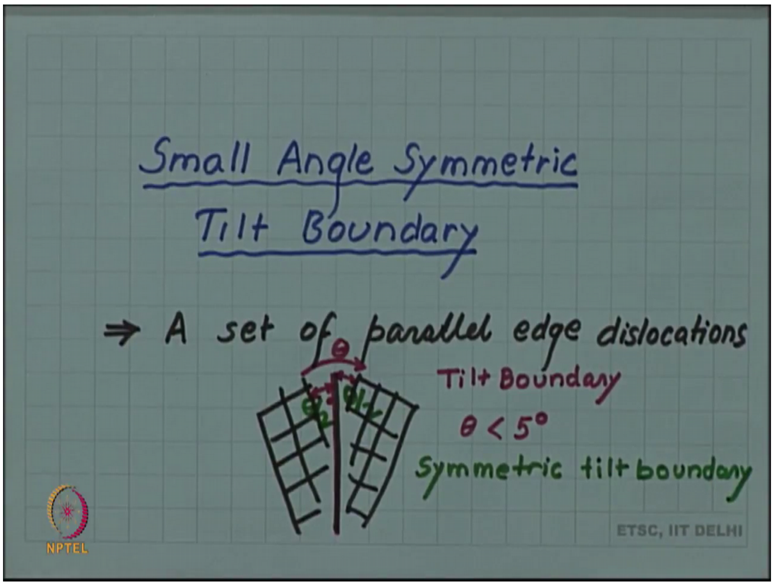

So let us discuss, a Small Angle Tilt Boundary and particularly Small Angle Symmetric Tilt Boundary. We will discuss and we will show that this can be described as a series of a set of parallel edge dislocations. So, what we mean by, remember this when we said is small angle tilt boundary, when we said tilt boundary we meant a boundary plane such that the grains on either side rotated with respect to each other such that the rotation axis lies in the boundary plane. So, you have an orientation something like this.

So, the rotation you can see, the rotation is like this. The rotation axis is perpendicular to the plane of the paper and the boundary axis is also lying perpendicular to the plane of the paper. So, they 2 lie in each other or parallel to each other. So, it is a Tilt Boundary. So, this is a Tilt Boundary. And if this angle is less, if this rotation angle theta is a small, I said theta less than 5 degree; some author may like to even restrict theta to even a smaller angle like 3 degree or 2 degrees, I am being little less restrictive by considering theta is equal to 5 degree.

Now, so this angle is small and now that you can see that the 2 crystals can be thought of independently rotated about the boundary plane on each side. So, when we say symmetric tilt boundary, we mean that the each of the rotation, independent rotations are equal to each other and half of the total rotation. So, if both of this is theta by 2, this is also theta by 2 and this is also theta by 2, then we say symmetric tilt boundary.

So, let me show you a model of such a symmetric tilt boundary.

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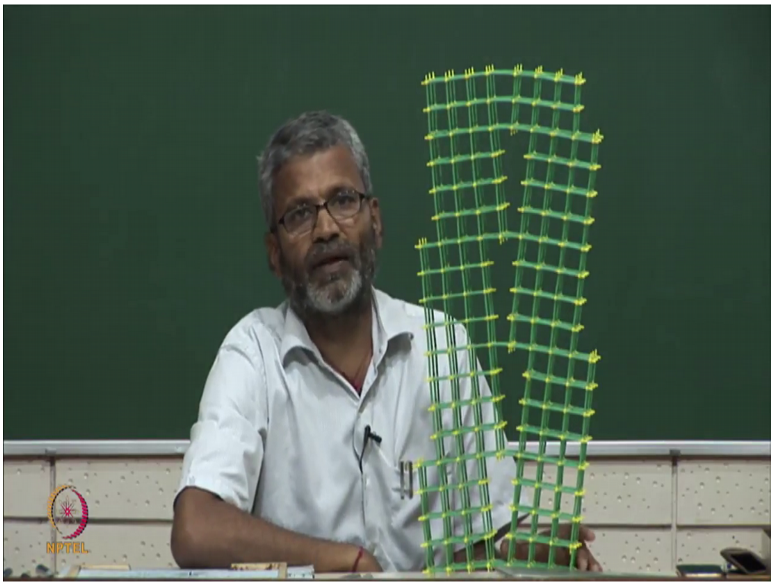

So, this is a model of low angle symmetric tilt boundary. You can imagine the vertical plane; you can imagine the vertical plane going here in the middle. So, there is there is a boundary which is normal to this front surface of the crystal and is vertical. So, that separates, you can see there are 2 grains here, one on the left and one on the right. So, there is 2 sides of the crystal which are separated by this vertical boundary. And you can see that there is a rotation, there is a bump up in this crystal here is rotated to get into this orientation and you can imagine what will be the rotation axis.

So, the rotation axis in this case will be horizontal rotation axis like this. About this, if I rotate this crystal from this orientation, I can get into this orientation. So, this horizontal axis is lying in the vertical plane. So, this is a tilt boundary and about the tilt axis the 2 grains are equally tilted. So, this is a symmetric tilt boundary. The tilt angle is not very small here, but still you can see the configurations which you are getting close to the boundary.

So, if you look at this plane, if you look at this plane; this plane comes and abruptly ends here, but the neighboring plane this one and this one continues. So locally, here you have an arrangement like a edge dislocation because this plane abruptly ended, this plane abruptly ended and the neighboring plane continued; neighboring planes are continuing and going down. So, this is a like an extra half plane.

So, this is what we I meant when I told that boundary, a vertical boundary like this which is boundary between symmetric tilt boundary can be considered as a series of edge dislocation, a set of parallel edge dislocation lying in the boundary plane. So, and a simple relationship can be found between the tilt axis and the burgers vector of these edge dislocation. So, that I will show you now.

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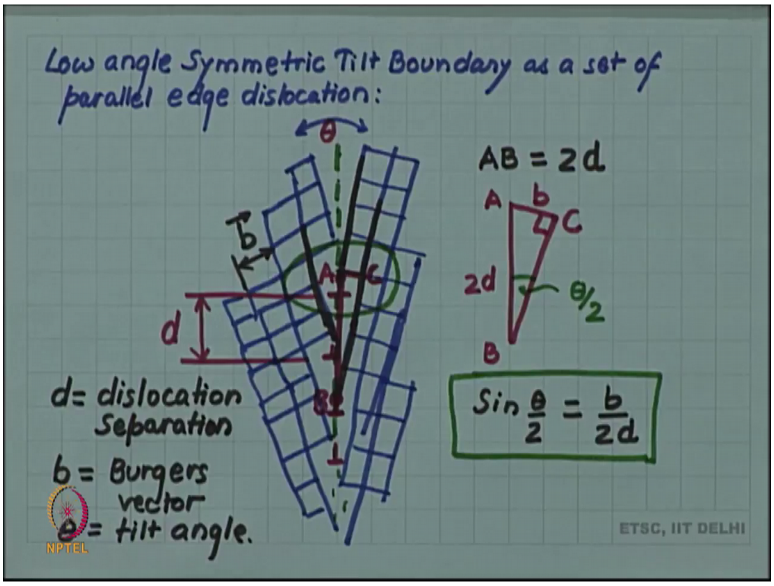

So, let me try to show you this by a drawing as a set of parallel edge dislocation. So, I will try to draw what we saw in the model.

So, we had a boundary plane a vertical boundary plane dividing 2 sides of a crystal and the way the crystal planes were coming, they were ending at the boundary. And from other side also the planes will come and they will also end at the boundary. So, this is the kind of model which you saw. So you can of course, extend the crystal on either side. I am not drawing too many unit cells, but then, you can see that you have now 2 crystals which are separated by this boundary and there is a tilt between them and this tilt is of an angle theta; this tilt is of an angle theta. And the tilt axis is perpendicular to the plane of the paper.

Now, what I was trying to show you in the model also and now I will show you it in this drawing, that if I think of this plane then I find that this plane in the crystal suddenly abruptly ends here whereas the neighboring plane this plane and this plane continues. So, locally this is what I was trying to tell you that locally in this region, in this region, this abrupt ending of this plane acts like an edge dislocation. So, I will say that an edge dislocation is present here. But then, the plane which was continuing the plane which was continuing here also abruptly ended later on down there. So, I have another edge dislocation there and then I have yet another edge dislocation here.

So, you can see that the entire boundary in the boundary plane, I will have a series of parallel edge dislocations. Now a relationship can be found by thinking of the spacing, relating the spacing of the dislocation lines with the burgers vector of these dislocation. Now the burgess vector of these dislocations will be this inter planar spacing and that is b. And the spacing between the dislocation line, let us call that, a spacing between the dislocation line as d.

So, now I will select a triangle, I will take start from here let us say and I can see that if I go from one dislocation to the next dislocation, they are coming from the alternate crystals. So, this one is coming from the right crystal, this half plane is coming from the right crystal, but then this half plane is coming from the left crystal. So, I would like to keep myself in a single crystal on one side. So, I will go to the alternate dislocation. So, the next dislocation which I will select is this and I will form a triangle.

So, let me call this a dislocation A and let me call this dislocation B. I have jumped and I have left one dislocation here and join this. So, this distance AB will be 2d. So, the distance AB will be 2 times the dislocation spacing because I am looking at alternate dislocations because I want to keep myself on the same side of the for given crystal. And then, if I join this let me call the C. So, I have made a triangle. Now where AB was, AB was 2d and then A to C is nothing but the inter planar spacing which is what is our burgers vector. So, A to C is b and this is the right angle.

Now, you can see what this angle will be. Since AB is in the boundary plane, if BC is the tilted plane on one side; the corresponding tilted plane on the other side will also be there and it is the angle between those 2 tilted planes which is the total angle theta. And since it is a symmetric tilt boundary, the boundary plane divides this entire angle theta into 2 equal parts. So, this angle what you are seeing here will be theta by 2. Then we have a nice simple relationship, you can easily write because you have a right angle triangle with the angles and the distances defined. So, I can see that I can write sin theta by 2 as b by 2d.

So, this simple relationship between the grain bound the dislocation separation, let me write it out; d is dislocation separation and b is magnitude of the Burgers vector and theta is the tilt angle. And these 3 variables are connected by the simple relationship which we just derived. In fact, such parallel series of dislocations have been seen experimentally in the and, it was one of the earlier verifications of the dislocation theory because one could connect the tilt angle and the dislocation distance observed in their experiments with the Burgers vector of the dislocation in the crystal. So, this relationship, the derivation of this relationship as well as the experimental verification of this in the observation was one of the early confirmation of the dislocation model of such boundaries.