Mechanical Behavior of Materials-1
Prof. Shashank Shekhar
Department of Materials Science and Engineering
Indian Institute of Technology-Kanpur

Lecture - 30
Partial Dislocations

Welcome back students. So in this lecture, we will look at a special type of dislocations. It is called partial dislocation. So you so far whatever dislocation we have looked at is formed when you have that smallest lattice vector, smallest translation vector and that gives to a full dislocation. But as you will see that there is also a possibility of getting partial dislocation and this partial dislocation, we will first have to see, check whether it is energetically favorable or not.

And we would also see what are the Burgers vector for this and this is most common in FCC type of material. So we will start from or we will look into the partial dislocations in FCC system. So let us look at it.

(Refer Slide Time: 01:07)

So in FCC we know the slip system is a by 2 110 and the plane is 111. Now this 111 plane for FCC has a very different kind of structure in the sense that it has ABC ABC type of packing. So this 111 has ABC ABC type of packing. What this leads to is that the extra half plane that forms is actually not just one plane, but it is a combination of two planes. Let us see how. So on the left cube is FCC shown to you and the 111 planes are marked. And you can clearly see that there are three different arrangement of atoms.

(Refer Slide Time: 02:03)

If you were to look at it the three arrangements in terms of atoms this is how it will look like. So you can see clearly these are three different arrangements, the A, B and the C. It is not that A and C are the same. So yes there are three layers ABC when we look at a 111 plane, which is shown over here. Now let us draw this 111 plane over here and we know that it has the Burgers vector a by 2 110 that we know will be on one of its edges.

So each of these are of the type 110 and the shortest translation would be a by 2 110. So when an extra half plane forms that extra half plane will have to move from this point to this point. That is what will happen when the deformation takes place and the dislocation moves. So let us keep this in mind because this one we will have to, utilize this information and this knowledge we will utilize several times in the next slides.

(Refer Slide Time: 03:00)

So here is the ABC ABC type of packing. And looking at this you will have this is your 111 plane and this would be your a by 2 110 type of translation vector. So if the dislocation were to be present here like this, it will have to move from here all the way over to here for one translation according to this Burgers vector. But we will see that there is a smaller Burgers vector possible. And that is what we will call as partial dislocation.

(Refer Slide Time: 03:46)

So let us say, we saw that this is the direction for the Burgers vector. So let us say we have a missing plane. So this extra plane has been removed, but when you look at this removed extra plane or removed half plane, so the bottom side or the one we are looking at the red and the blue layer, on that side you have the extra half plane. And on the side towards us is the missing half plane.

So what we see is that this gap, the white window that we see is actually in two parallel layers. So this is one layer and this is another layer and another one would be over here and then another one would be somewhere over here. So this is these are the two layers and which have been drawn by two lines.

So what we thought of or what we would have thought of to be just one dislocation actually happens to be two extra half planes or two missing planes depending on which side you are looking at. But is it really two half planes or is it just that it appears to be so? So let us say that one layer of atoms move to the other side. Then what do we see over here?

Or to be precise actually, we will not be moving the whole thing. We are moving just one the atoms are moving to one step, not the full step, but a partial step, let us call it partial steps. So this atom is moving partial step over here, this is moving over here, this is moving over here. So they are not moving the whole distance, but only a partial distance.

(Refer Slide Time: 05:32)

And how would it look like after this partial movement, partial movement of the atoms of one layer? This is how it would look like. So now, you can clearly see that there is a actually missing half plane over here, there is also a missing half plane over here. But to form this the atoms had not moved the full dislocation or the full translation vector, by the full translation vector.

They had moved only one step or partial displacement. They had taken one partial displacement. The other partial displacement would be this one. So it moved from here to here. And now let us say if all of these move over here, then what will happen?

(Refer Slide Time: 06:11)

Again it forms the full dislocation. So now, we can be confident or we can be, we are very convinced that this full dislocation is actually sum of two partial dislocations. And this becomes or this particular vector diagram makes the orientation, the configuration much clearer. So this is the full dislocation Burgers vector and these are the Burgers vector for the partial dislocations.

So how would this partial dislocation look like? So let us try to understand this with respect to a drawing over here.

(Refer Slide Time: 06:51)

So we said this is a 111 layer. So it looks something like this. Of course, it is not accurate, because I have drawn it by hand, but we can still get understanding. So what we looked at earlier was that this is the full dislocation vector and this is the partial one this is partial two. Now I will draw it separately. So this is full dislocation. This is these are the two partial dislocations.

So this one is of the form, this one the full dislocation has the Burger vector form of the type a by 2 110. On the other hand this one, you can show it from the geometry by calculating the angles that this one it is actually 30 degree angle, that this one is of the type a by 6 211. So both of them are symmetric. So this is also a by 6 211.

Okay, so over here it does look like dislocation can move like this. But the next and more important question is, is it energetically favorable? And how do we calculate that? Simple, we take the square of the Burgers vector and compare the sum of the partials with the full. If the sum of the partials is lower, then it means the total energy for the partials is lower.

And therefore, it is favorable for the full dislocation to dissociate into partials. So let us take the values a by 2 110 on one side. On the other side, we have a by 6 211 and into 2 times. So we will take the square of this because energy is proportional to Burgers vector square, a square by 4 and 1 square plus 1 square is equal to 2. And on this side two from two different dislocations.

And a square by 36 and 2 square plus 1 square plus 1 square is equal to six. So this becomes a square by 6. And this whole thing is a square by 3 and this whole thing is a square by 2. So clearly, this quantity is smaller, which means that this is energetically favorable. And it would also mean that full dislocation would like to dissociate into partials. So this is just one, this is a overall generalization of the various vectors and now I will give you one specific example.

So the full dislocation, a by 2 bar 1 01 can break down into a by 6 bar 2 11 plus a by 6 bar 1 bar 1 2. Now when you are trying to find the partials from a full distribution, you have to keep couple of things in mind. One that the sum of these must come back to this that is vectorial sum. So vectorial sum is something that you have to keep in mind. Second is that the glide plane must be same.

So here we are assuming it is a 111 type of plane on which this Burgers vector is there. Therefore, the dot product of a 111 with this is 0. And so should be the dot product of these two. So let us take 111 dot product and yes this is indeed 0 111 dot product and yes indeed this is 0. So these two things you have to keep in mind when trying to find out what would or what would be the partials for a given Burgers vector of a FCC.

(Refer Slide Time: 12:06)

And for this, we can again take the help of our old friend Thompson's tetrahedron. So you can see this is a bar 1 bar 1 1 plane and this is your 0 111 vector. And the Burgers vector would be a by 2. So when this one breaks or dissociates, then the two vectors that would form from this are a by 6 112 and negative of this, meaning a by 6 bar 1 2 1. And why did I say negative?

Because this one is showing you which direction it is going. So if this is going in this direction, then this one plus this one. So this one you have to take negative or you can take the negative of the other two, sorry negative of this one. So either one you will have to take the negative. So that is how it is drawn. But the important thing is that you are able to obtain the partial dislocation Burgers vector also from this Thompson tetrahedron.

Not only the planes and right planes and the possible Burgers full dislocation Burgers vector but also the partial dislocation Burgers vector can be obtained from Thompson's tetrahedron. So that is the beauty of Thompson's tetrahedron. Now before I move on, I would like to show you another perspective or another view of the dislocations like what we are calling as extra, two extra planes or in the FCC system which form the partial dislocations.

(Refer Slide Time: 13:46)

So let us say we have, I draw the two with two different colors. So these are the two different layers. So these are alternate layers. Basically what we have over here is the 111 plane. So this is your 111 plane and these are the various atom layers that we saw over here in the earlier picture. So these are there are always two or they are always in pair. So when we have the extra half plane also then there are two, there are pair of it.

And this is your 110 direction. And here if we were to draw it, this is how it would look like, partial dislocation one, partial dislocation two so that the whole thing is actually one full dislocation. So this is usual way of representing these partial dislocations and this is the full dislocation.

And we have now looked at what would be the Burgers vector for these and how to obtain the Burgers vector. And the easiest method is to find the Burgers vector by Thompson's tetrahedron, using the Thompson's tetrahedron.

(Refer Slide Time: 16:10)

Now the last thing that we want to understand here or we would like to touch upon here is that now that we have seen here that there are two partial dislocations, so these are two partial dislocations.

Now there would also be interaction between these two dislocations, because these are two different dislocations and therefore, what would happen is that, there would be a force, a repulsive force, net repulsive actually there will be screw component and an edge component and based on that you can calculate the net repulsive. But we will not get into that detail.

We would just know that, we know that there is a partial dislocation one, partial dislocation two and therefore there will be a net repulsive force. So by this logic it should keep moving out, but that is not the case. When these dislocations move out you see that there is a stacking fault created. You see that ideally there should not have been any gap after ABC layers. But here we see this gap.

Why because here there is a stacking fault. It is no more ABC ABC but it is AB AB kind of packing in between. And therefore, this stacking fault will have some energy associated with it. So the farther the partials go, the larger would be the stacking fault. And therefore, that energy would like to minimize which would mean that it would like the two partials to come together.

So there is this repulsive force which wants to push the partials away and the energy of the stacking fault which wants to bring the two partials together. And therefore, in the end what you will have is a equilibrium, equilibrium width of partials. What are the two counteracting forces? One is the repulsion of partials versus energy of stacking fault that has been created.

So together they will find some equilibrium condition, let us say it is d. So then you will reach some d and you can actually calculate the value of d. It is usually of the order of 2 to 3 lattice parameter, 2 to 3 times the b. So this lecture has given us the introduction to partial dislocations and in particularly in FCC system. So what we had seen so far were full or complete dislocations.

But in real systems, the dislocations are a little bit more complicated. And we saw that in FCC, there is something called as partial dislocations and it also happens to be energetically favorable. And we were also able to obtain the Burgers vector for these two. So we will stop our lecture over here. Thank you.