Defects in Crystalline Solids (Part-II)
Prof. Shashank Shekhar
Department of Material Science and Engineering
Indian Institute of Technology, Kanpur

Lecture - 06
Dislocation Structure in BCC

So, last week we looked at Dislocations in FCC in much greater detail. This week, we will start from dislocations in BCC. As you remember in part-1, we have already touched up on some of the aspects of dislocations in BCC. We will briefly touch upon them again, and continue where we left. And, then we will move onto some other systems to look at dislocations ok. So, we will go ahead with dislocations in BCC.

Now, when we talk about BCC, what is the first thing that is different in BCC as compared to FCC? First thing that comes to mind that is different for BCC is that this is not a close packed structure. What do I mean? So, if you compare the packing fraction of FCC, it is the highest that is possible which is equal to 0.74. On the other hand, if you look at BCC, this is much lower than that equal to 0.68; meaning this is not a close packed structure, it is open structure relatively with respect to FCC.

And, what is the implication on dislocations. So, basically the hard-sphere model that we have been looking at, when we talked about FCC is not very accurate, when talking about BCC ok. So, that with that premises will start now what is the plane on sorry the burger vector on which for the BCC. And, from the pearl Navarro stress equation that will look that again in the previous part, the part-1 of it. We know that the burger vector has to be the shortest translation vector.

And, for we also showed that for BCC that will come out to a by 2 in the direction 111 because if you look at the cubic cell; then it is along the 111 direction that the atoms are actually touching upon each other. Now, what is the what is the plane on which the slip takes place, the plane again we can derive from the pearl Navarro relation, which says that the planes which are farthest spaced out or the ones which will give you the smallest tau or the shear stress for movement of dislocation. And, for 111 for sorry for the BCC that turns out to be 110 type of planes.

Now, when we say 110 type of plane, and each of this 111 direction, this also we have in 3 110 plane ok. So, this is about the 110 in 1 111 direction itself is contained on three different planes, know more about it. So, the 110 plane that we are talking about this is usually most active at low temperature.

And, also because of the fact that we said that this particular model the hard-sphere model is not very successful (Refer Time: 04:47) BCC, there are also some other possible planes for BCC. And what are those planes, so these 112 and 123 type of planes. And, again like we set each of the 111 direction is contained in 3 110 plane. Similarly, if you look at 112, then there will again 3 112 planes. And if you look at 123, there are actually 6 123 planes. So, if you look at one each of this 111 direction, it is contained in 6 plus 3 plus 3, 12 different possible planes.

Now, the edge dislocation does not leave the plane, but screw dislocation we know can leave the plane. And therefore, if you are talking about a screw dislocation, so let me talk a little bit about the screw dislocation. So, from what we saw just now, we can say that a screw dislocation. What should be the burger vector, it should be equal to a by 2 111 type burger vector has 12 possible planes to slip on slip or actually cross slip I should say, because it can leave this one plane and go on to the other plane.

And so it can so a screw dislocation, you can see is so much more you can say versatile in a BCC system compared to FCC system, and that is where you get what we call as easy glide. So, if you look at macroscopically, it may seem like the system is or the dislocations will leave a trail as if they are moving randomly, there is no fixed path. But, why is that happening that is happening, because there are so many possible planes with that it can almost at least macroscopically, it will look like it is a continuously varying direction of movement of the dislocation. So, this is only because it has 12 different possible planes.

And, this kind of motion gives at a distinctive different deformation behaviour as compared to FCC. Now, since you are talking about screw dislocation, let us also say put couple of things important facts about it which we will see again, when we talk about particularly about the planes.

And, one important fact is that these screw dislocations do not disassociate you remember in FCC, we have both the edge screw dislocation as well as the screw dislocation, which can dissociate into partial. Although, we showed that assuming certain value of gamma and certain ratio you will see that only edge dislocations will dissociate, and not the screw dislocations.

However, in here from the very beginning we are letting you know that screw dislocations do not disassociate. And, later on you will see that given the stacking fault energy, even the edge dislocation cannot dissociate. And, why does the reason for screw dislocation to do not dissociate is that they do not have a planar core. So, if the core is not spread or is not you can say laid out on a particular plane. And, because of that this dislocation cannot dissociate onto a plane ok. So, this is about the screw dislocations, but even before we move on to about more about the dislocations in BCC.

What you should know is that under low temperature, and high stress, BCC metals can deform by twining. And this twining is not happening on the 110 plane read, because just now I said that stacking fault energy is too high and no stacking fault energy stacking fault is formed on the 110 plane. But, if twining is happening, then some stacking fault is certainly taking place, and that is taking place on the 112 plane ok, so that is our basic understanding about the dislocations in BCC.

Now, let us look at what we mean by stacking fault, why do the stacking fault not occur on 110. And how do they occur on 1 112 plane, which we will see also leads to twining, so, stacking on 110 and 112 planes.

Now, let us look at the BCC cube, this is how the BCC cube would look like. And here you can see the this is the body centred atom, and all the three sides are equal as A, and this would be your 110 plane right. So, this is the 110 plane on to which the dislocations are supposed to be moving at lower temperature.

But, when you look at it, so let us first draw how this 110 plane will look like. And let us call it A-Layer, assuming there is more than one layer. So, this one A layer looks like this. But, if you look over here, there is a parallel plane which will contain this. And just below this atom, there is no atom over here. So, certainly there is one more layer, and how does that layer look like and so if you place it just below it, this is how it will look like.

So, the overall form of the layer is similar, you have a rectangle and atom at the centre, here also have a rectangle and atom at the centre. I have drawn two of these; there is nothing to do with the number of atoms. It is just that how they this second layer is oriented with respect to the first one.

So, this in this second layer this two atoms are approximately oriented or not a proximity oriented just along the line of this central atom. Is there any 3rd layer? So, let us go back, so if you look at this is the one layer, this is another layer, the third layer is this one.

Now, we are looking from this direction, we are looking at the normal to this 110 plane direction. So, basically what we are looking at is in this direction. So, this is A layer, this is what we have called as B layer. And, if is this the third layer possible no, this is also B layer. So, there are only two possible layers B A B or A and B layers. And how are they stack or now when you are looking from this directions, so like I said we are looking from this direction. As if the this is a eye of a person trying to look into this direction.

So, how would they find the two layers, this is how it will look like. So, as you can see that there are the blue atoms are representing one layer, and the brownies or the reddish type of atoms are representing other layer. And, their overall structure or the distribution configuration is similar, just that they are misplaced are displaced by half of this length.

Now, here again I have drawn the 110 plane layers, what I have drawn over here. So, I am just taking it, and drawing lot more atoms not just those many. So, if you look carefully, what you would see is that this is a 110 direction, this you remember this is the base of the 110 direction; this is along the 100 direction. Now, over here again this bluish type of atoms are forming B layer, reddish type of atoms are forming the sorry one of them is B the blue is B layer, and reddish is the A layer.

So, what we have is a ABAB type of packing. Now, let us say if there was a possibility of stacking fault. So, from ABAB what would you go to, so if this was AB AB type of packing any stacking fault here would mean that you either take away this or you bring an another layer. So, if I take away this what I get is ABBA.

Now, what do you see over here or the other possibility which is ABA, and let us insert A, because we have already seen BB. So, this is ABA BBA. So, this is one of the two possible ways to get a stacking fault here. And what we see here is two similar layers coming close to each other not basically just next to each other.

So, here we have BB type of interaction taking place, here we have AA type of interaction taking place. What does that mean that stacking fault energy would be very high, implies this is unstable? So, in 110, we have seen that there is no possibility of stacking fault, and that is the reason that you do not even get partial dislocations on the 110 plane. But, then we also talked about the other type of plane, which is the 112 plane where there is a possibility where there again your 111 type of dislocations can move.

Now, where is that 112 plane, let us look at it. So, here it is mark in the green plane. So, this is representing a 112 plane, but this is just one stacking are there other possible stackings, so I have made a lot of these layers. And, when you look at it from normal to 112, how it would look like are these sorry. So, right now what we are looking at is the along the 110 planes.

Now, if you rotate it like this, then what you get is the 112 112 type of stacking. So, this is so this is one layer of 112, this is another layer of 112, this is another layer of 112, so let us call it some layer A, B, C, D, E, F. Now, again if I will not go and mark it G, why because if you look closely, what you would see is that this atom is now just let me use a so this layer is same as this layer.

And, it is not very drawn very properly, but this is so this layer is again sorry we have only one atom to show right now in this plane. So, this beyond this F layer, what we are getting is similar layer.

So, this 7th layer is nothing but A, so again it starts A, B, C, D, E, F. Meaning here we have not AB AB not ABC type of packing that we saw in a FCC, but even more you can say complex in some sense six layers, six different types. So, this is 7 1, 2, 3, 4, 5, 6 and 7th layer, 1st and 7th layer are similar over here. And, I have drawn this red line to show that this lies just above it, and we have also another line you can see compare this one also. So, this is C layer, and is also C layer. And this is the straight line drawn here you can see that it lies right on top of it.

So, we are looking still in the 110 normal direction, but what we are looking at are the traces of the 112 plane stackings. And, we can see that there are six different layers, and the seventh layers has similar configuration as the first. So, there are six different stacking A, B, C, D, E, F for the 112 plane.

Now, that becomes very interesting, let us look. So, here I have drawn the same A, B, C, D, E, F, and then another A, B, C, D, E. So, there are right now drawn 11 layers. So, this is one layer, this is another layer, and so on. These are the different layers that have been drawn.

Now, if I want a stacking fault, then what I have to do is displace 1 layer, let us say I displace this A layer. So, it is marked by marked over here. So, I am saying that let us displace this layer A layer. And, how much will be translate it or how much will be displace it by we will displace it, so that it moves from A to another layer like E. So, this is the whole thing will move.

If, we are just displacing this layer, it means everything it above it will also gets displaced. And, how much you are displacing that will imply a by 6 bar 111 ok. So, now we have a by 6 bar 111 movement of this whole layer. And, what we get is that now this has this is no more, so you can see this is changed this has earlier it was A, now it has become E.

So, now we have F layer, and beyond that we should have expected A layer, but now because we have caused stacking fault by shifting the whole thing by a by 6 bar 111, this has become E. And beyond this it continues E, F, A, B, C, thereafter because the stacking remains similar. Now, this type of stacking is possible in the BCC system in the 112 on the 112 planes. And, here what you see is, what is the closest neighbour? The closest neighbour is separated by one layer of atom. So, here the stacking fault energy would not be very high ok. So, this is one possibility.

Now, and other things like we did in the twins for the FCC, we remember we moved each layer by that amount of stacking fault. So, here also we will shift all of these layer above it by the same amount a by 6 bar 111.

So, what does that what has happened, we get a structure like this. Now, what do we see here, this now the colour of the atoms are not in the order in which it was earlier, it is it has been maintained just to show where they are after the displacement.

And, what you can clearly see are that there is some symmetry over here, which is shown by. So, this now leads to what twin formation. So, you have A, B, C, D, E, F and this F layer is common to the both the sides. Here also you will see that the stacking has inverted, because we have caused stacking on all the layers. So, the stacking has inverted, now it has become F, E, D, C, B, A. So, it has it is as if your coming from this direction, and also coming from this direction and F common to you from both sides.

So, what is this, this is a twin. So, a twin can be formed, and it is stable. Now, one thing that I miss telling you earlier is that if you go back, and look at just one layer, which is formed over here. Although, the stacking fault is not very high, but it has been found that it is not stable; meaning whatever small energy is raised because of this stacking that much energy is also not causing it to be unstable, and leading to reversion of this stacking fault. So, it is not stable. But, when you come to twin, this twin is formed and it is stable.

So, there are few things that we learn from here, (Refer Time: 24:11) let us note down those important key points that we have just learned. Stacking fault on 110 is not possible, and the reason was because what you will get is AA or BB type, which has very high energy. Stacking fault on 112 plane is possible, but not stable. Although it does not have very high energy, but still it is found to be not stable.

However, when you have several stacking fault on consecutive 112 planes, what you get is a twin, and this twin is are stable. Now, you saw that I shifted five different plane on top of it ok. So, it will be like a twin over here, and then at the end of it again you will have another twin twin boundary, so over so that was a twin layer or lamella of five atomic thickness, five atomic planes.

And, people have found that twin lamella as thin as 3 layers are also stable. One layers twin lamella would mean that the same stacking fault that we were talking about, which is obviously we know by now is not stable even two layer is not stable. But, when you get three layers up to three layers, people have found to be that this can be stable. So, these are some of the important points that we have learned about the dislocations stacking fault, and that twinning that is possible in the BCC. Now, next part is we will move on, and well talk about screw dislocation. So, we will come again for that, and we will talk more about the screw dislocations in BCC system.