Defects in Crystalline Solids (Part-I)

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Lecture - 37
Dislocations in FCC + Partial dislocations

So, in the last class I showed you the topics that we have already covered.

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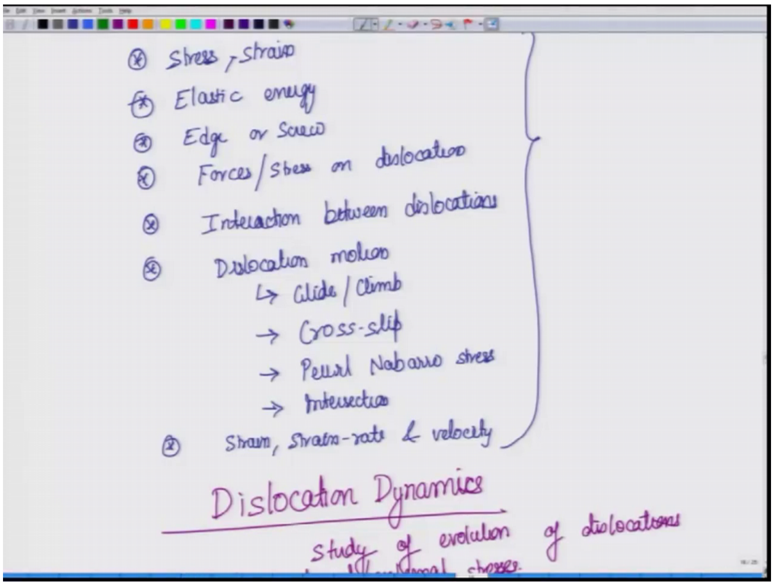

So, if you take a dislocation as a individual entity we looked at stress strain elastic energy, types of dislocation edge and screw forces stress interaction, their motion stress strain rate velocity and in the end we also took a look at dislocation dynamics, meaning where you can based on these understanding predict the evolution of dislocations. So, now we have covered all the fundamental aspects and now it is time that we move on to real dislocations meaning in a more usual system and one of the simplest in this one would be FCC.

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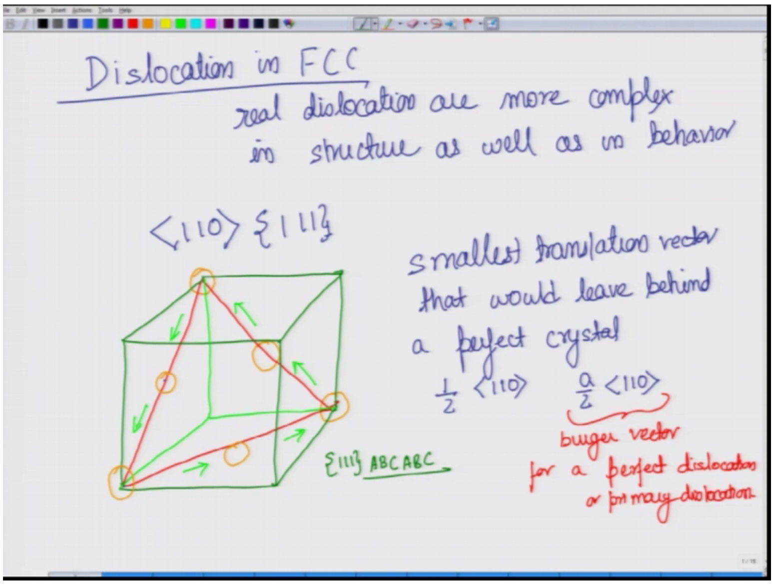

So, we with now our topic would be to understand dislocations in FCC and very soon you would realize that the simple model that we have been discussing is very different or the real dislocations in FCC are very different from the dislocations that we have been discussing. So, the real dislocations are as you would aspect real dislocations are more complex in structure as well as in their behavior ok. So, first thing we know about FCC dislocations the slip system is 1 1 0 direction and the slip planes are 1 1 1 ok. So, this is direction but now let us look at FCC system and let us draw it over here.

So, this is the cube we are drawing a FCC cube and we will put atoms right, now we will put only atoms for the 1 1 1 plane because you are interested in looking at this. So, let me draw one of the 1 1 planes there can be several, but let me draw just draw this one and then let me connect it to show that this is a plane. So, first thing that I have been emphasizing earlier from the very beginning that when we say plane, you see that this is not plane as a floor or a roof it is a made out in imaginary plane composed out of atoms ok. So, now let us look at this one so this is the 1 1 1 plane and here where are the 1 1 0 directions. So, this is 1 1 0 direction, this is 1 1 0 direction this is 1 1 0 direction this is 1 1 0 this is 1 1 0 direction.

Now, what is the smallest translation vector over here? Smallest translation vector that will leave behind; so, if you displace by the whole thing then it would leave behind a perfect crystal that would leave behind a perfect crystal, so as you would see this atom when moves to this position is a smallest lattice vector. If you move the whole thing from here to here you will not find that any change in the crystal system after that, if you are doing the doing it for everything above it. So, this is the smallest vector and what is the magnitude of this and you would say 1 by 2 1 1 0 or to be more precise you can say a by 2 1 1 0 and over here you can see this is a by 2 1 1 0 all these are even in the opposite direction you will get a by 2 1 1 0, so this is called the Burger vector.

So, this so for we had only look at direction, now this is the actual vector because this leaves behind this is the smallest translation vector that will leave behind a perfect crystal. And this is also called the Burger vector for a perfect dislocation or why perfect because, we also have imperfect dislocations or what are known as partial dislocations and we also have something called as secondary dislocations. So, this is perfect dislocation or primary dislocation, so a by 2 1 1 0 is our vector.

Now, let us try to understand some this so concept or this plane in a little bit more detail. So, for this now I will draw 1 1 1 plane so the here what you seen I have drawn it more like a point in reality you know that these atoms are touching, so the atoms are much larger and they will be touching each other. So, now let me draw it with that respect to be able to see on that particular plane, so I will now just draw one plane and on that particular plane I will show you the 1 1 0 vector and some more intricacies related to FCC.

Another thing to understand is that when you have a 1 1 1 plane it is it has a stacking particular sequence that appears and which is called ABC ABC stacking and it will come more clear when we look at this second diagram which is over here.

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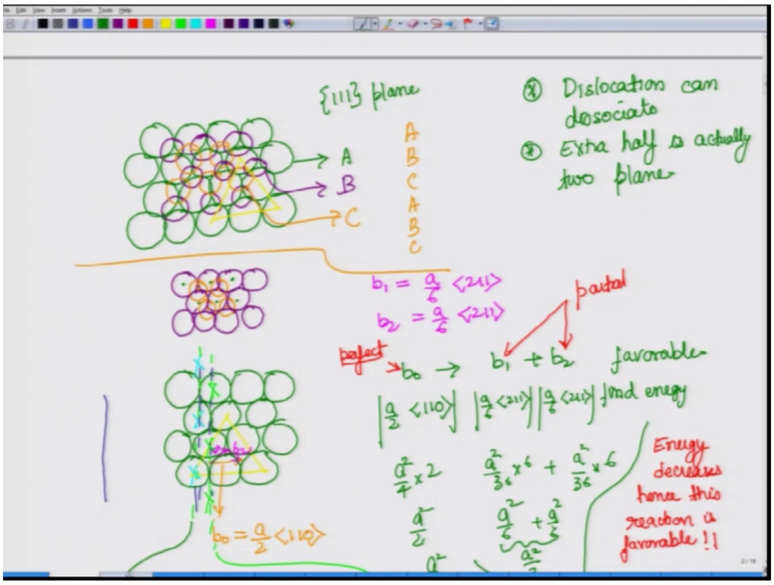

So, now let us draw it with respect to atoms where atoms are really touching ok. So, we draw those cube just to be able to explain concepts related to directions, but in reality you would you should realize that atoms are touching ore like this and although my drawing, in my drawing it may seem like some of the atoms are large some are small. You should also realize that will not be the case all the atoms would be equal in size.

So, this what I have drawn here is a 1 1 1 plane and if you want to compare with this triangle that is showed you over here, so let me draw in yellow just a light shade to show that there is indeed that kind of plane. So, there is 3 atom 3 atom 3 atom just like that we see over here. So, this is the plane that I have drawn over here and here as I said that these 3 atoms must touch and here you can see that these 3 atoms touch. So, this is the 1 1 1 triangle that you see in the cube, but the plane when we draw would look like this.

Now, here the first thing that you must realize is that this is one layer where will the where will the next layer set. So, there are particular positions where this next layer sits and I am again drawing smaller circles to emphasize that there are 2 different kind of point. So, you see there are triangular regions where the atoms can sit and I and out of this only 50 percent has are been used and the other 50 percent would be used in a next layer. So, if you now form this if I were to draw it in a bigger circles, now I will draw this next layer. So, you were here which are the locations where the our green layer is sitting, it is if we look at this then the green layer is sitting over here, it is sitting over here the green this corners I am talking about the corners green corners are over here and the once which were left open or over here in between these 3.

So, these are I will now mark it with orange colour, so this is these are the open ones. So, now what I am trying to emphasize here is that there are 2 different points or 2 different locations on the green layer of atoms and out of this one was taken by the this maroon layer and another set is still available over here that is the set that will wear the third layer of atom sets. So, the third layer of atom sets somewhere like this and if I were to draw it over here it will be sorry not this one, so like this and what do we understand from this that if you call this as the a site where the green atoms sitting let me put it in green. So, let us say the green layer is sitting in the A sites, then whereas the maroon layer sitting they are sitting in the B site and where are the orange layer sitting it is sitting in the C site.

So, we have a particular sequence A B C and this keeps continuing, so you will have layer like A B C A B C this is what happens in the 1 1 1 plane of FCC. So, now moving ahead where it will become important when we look at what happens after displacement of 1 by 2 1 1 0. So, you see that in this particular case now let I will need to redraw it the first layer, so that I can again come back and explain the translation Burger vector. So, these are now these are not come out as good as the previous one, but I hope you are still able to see what is going on over here.

Now, where is the direction 1 1 0, so if I drew this as my triangle then you can realize this is 1 1 0 direction this is 1 1 0 direction this is 1 1 0 direction and the atom just above it is sitting from here and when I move it will moving from this site to this. So, this is our Burger vector which we have defined now let me call it as b naught and you will realize why I am calling it b not, so this is the Burger vector b naught equal to a by 2 1 1 0.

Now, if you see this particular atom has to move or basically go uphill and then it will come down downhill to be able to move to this position, this is also possible via alternate route which is like this. So, it may as well go from here to over here which is not as much uphill as this one and again over here. So, you will get a Burger vector b 1 and a Burger vector b 2 and with simple geometry you would be able to show that this Burger vector b 1 is equal to a by 6 2 1 1. In fact, both of them would be of the same form, so this is another important aspect that you realize that the original Burger vector that we have can actually be dissociated into b 1 and b 2. So, the question is b naught to b 1 plus b 2 favorable and how do we find out we find energy.

So, how can we find the energy over here you can just take this Burger vector which is a by 2 1 1 0 and this is a by 6. So, will take magnitude of these so this is a square by 4 into, if you take the square 1 square plus 1 square 2 here it will be a square by 36 into 6 plus a square by 36 into 6. So, this comes out to a square by 2 and this comes out to a square by 6 plus a square by 6 this is a square by 3 this a square by 2. Now which of these where larger this is obviously larger, so if it dissociates the total energy of this system is going down and therefore this is favorable.

So, energy decreases hence this reaction is favorable, so you will always the dislocations would like to dissociate into the 2 what are called as partials. So, these are partial this locations and this is the perfect dislocation or the whole dislocation. So, this is one important aspect about FCC that the dislocations over here tend to get dissociated, will come back to this in a while.

But there is another important aspect when so we are talking about this a whole there are this is one important aspect which is that there dislocation have partial and another important aspect is that because, of these partials you get a dislocation which looks something like this. Now, I will draw try to draw it in terms of the planes so let say these are our planes.

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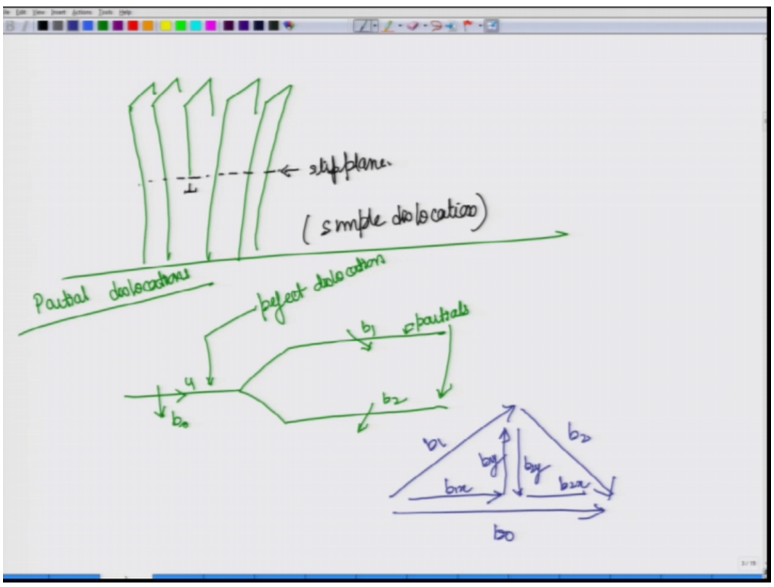

Now, for a simple dislocation this is how we have being drawing a dislocation planes. So, this is one plane this another plane this is another plane this is another plane and this is these are the different planes. So, this is the way we have been drawing the different planes, but this is now very different so this will be if that were the case then this would have been our dislocation or extra half plane and this would have been our slip plane. But again here so I will have to use this side only, so that I can make use of this drawing.

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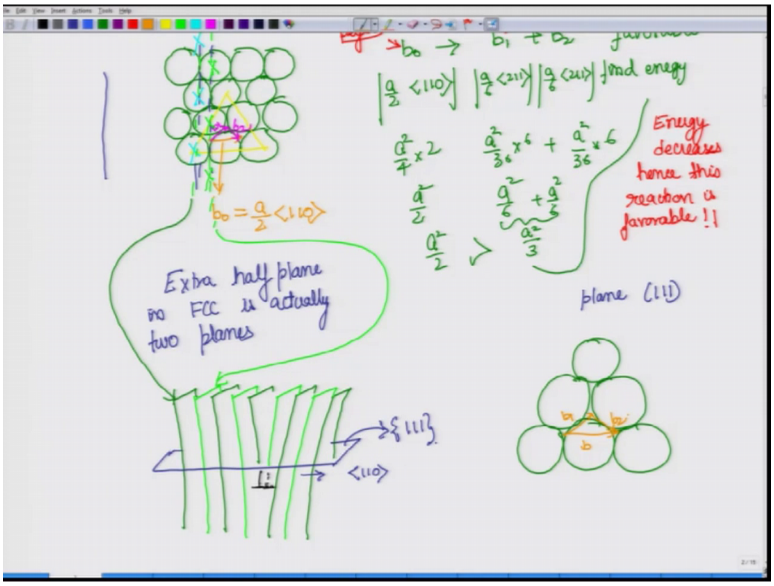

In this particular case what you will see is that our extra half plane which should lie perpendicular if it is the edge dislocation and this is the Burger vector then what is the line vector the line vector is sorry not the line vector. But where is the extra half plane the extra half plane must be like this perpendicular to this Burger vector right. So, now the extra half plane is over here, but when you look at it carefully there are actually 2 different types of layers included in here.

So, let me show you like this so this is one layer this is another layer you see these 2 atoms. So, now I will use 2 more, so this is one atom this another atom there is another atom over here and this is. So, you can see that there are 2 different layers getting found one by the sine colour one by the light green colour and these are 2 different planes. So, extra half plane in a FCC is not one single plane, so that is another important concept related to FCC extra half plane in FCC is actually 2 planes. .

So, this is one layer of atom or one layer of plane and this is another layer of plane, so that is another thing which is very distinctive about FCC and very different from what we have learnt about simple dislocations and one was this that this locations we have looked only at perfect dislocations. But we now also get partials and both of these things will combine when we look over here.

So, now I will go back and in fact I will what I should do is I should draw it over here itself, that will it will become much clear that what the 2 planes that I am drawing ok. So, here I am drawing the 2 different alternating planes that we see over here and it means that even when we are talking about extra plane when we have 2 planes like this and therefore it is this system would look something like this. Now, let me draw the plane like this and let me complete, so as you can see these are each of them are one plane and here you are seeing 2 different planes and this correspond to let me say see these 2 planes which are now been represented over here.

So, if it were just about the full plane it would not matter whether you have same type of plane or alternating planes, but it matters because here when you look at the dislocation where extra half plane here you have basically 2. So, although the symbol is still remain same I am drawing it here as a 2 dotted line here just to represent that when we say extra plane in FCC, it represents 2 extra half planes and when I look at this is the slip plane what is this slip plane. So, this slip plane is if you remember this was our 1 1 1 ok, so we are talking about this particular layer this whole layer has now been drawn over here. So, this whole layer that we see of the atoms is now being drawn like this and the atoms on top of this is what is depicted over here and where is the 1 1 0 direction over here, so the 1 1 direction it should also realize is along this like this.

Now coming back to the partial dislocations let us look at a specific example. So, let us say that my plane is 1 1 1, so here it is given that the plane is 1 1 1 and I will now draw just 6 atoms like this and what I have shown here this part I I will now try to zoom in to this part. So, this is my b naught will my b 1 this is my b 2. So, these are the partials that I talked about and before I relate I just wanted to take a look at one real example.

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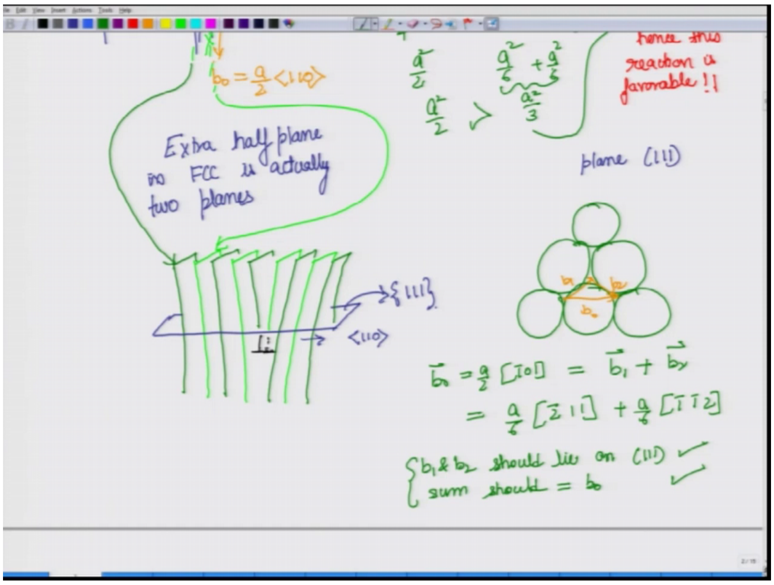

So, this is our b naught so b naught if it is the 1 1 1 plane what will what are the possible b not, so the b naught can be we can say that in this particular case it is equal to a by 2 bar 1 0 1. Now, look at the possibility what are the how do we see that it is a possible Burger vector for this plane or not just take a dot product and it should come out to 0, it cannot be any k by 2 1 1 0 type of direction. It has to be only those directions which lies on the 1 1 1 plane and that you can find by taking a dot product and when the dot product is 0, so you will know that it lies on that plane.

So, b naught is equal to a by 2 1 1 0 1 and in fact there can be 3 different Burger vectors, but we have selected this one, so this is equal to b 1 plus b 2 and in this particular case you would be able to show that this b 1 is actually equal to bar 2 1 1 plus a by 6 bar 1 bar 1 2. Now here one for this one particular example it is not very difficult to find out what will be the Burger partial Burger vectors, what are the 2 things we have to check you have to check that b 1 and b 2 should lie on 1 1 1 I meaning again you have to take dot product and so you can take a dot product bar 2 1 1 with 1 1 1 and you know that it is 0. So, it lies on 1 1 1 bar 1 bar 1 2 with 1 1 1 and you know that this dot product is 0 so it lies on 1 1 1.

So, this part is and the other part is that the sum of these 2 you have to make sure it comes out to be b naught. So, here you can see that so the sum should equal to b naught. So, bar here you just take bar 2 and here it is bar 1, so bar 2 and bar 1 are minus 3 this is minus 1 and 1. So, this is 0 2 plus 1 3 and therefore it becomes 3 0 3 and but it is a by 6 so you can divide by 6 and it becomes a by 2 bar 1 0 1. So, this becomes a by 2 bar 0 1 so this is also take, so these are the 2 way 2 things that you need to cross verify to find out whether the partials that you are looking at or actually the partials for this Burger vector and it lies on this particular plane.

So, now we have looked at the different dislocations the so, 2 different aspects so let us let me just emphasize it once again, the 2 important aspects for the dislocations in FCC are the one an important aspect is that here the dislocations can split or can become partial. Actually I should use the word dissociate, can dissociate extra half plane is not just sum of 2 plane. So, structure wise there are these are 2 different things that happen or that take place in the FCC system.

So, now coming back to what I drew over here this is the slip plane for a simple the dislocation the type of dislocation that we have been using so it is for a. But in our case we saw how it happens there are alternate layers and when there are alternate layers and it will move what will it do, so let us say that I have not come to that part. So, first let me tell you so here I have a dislocation and it gets dissociated so this gets dissociated, so now coming back to our partial dislocations ok. So, here let say I have dislocation and so here the Burger vector is like this the line vector is like this and the Burger vector is also ok. So, I will take it as a edge dislocation so the Burger vector is like this and I will take it as b naught and this is b 1 now this is b 2, so these are the partials and this is the perfect dislocation.

Now, let me draw it vectorially; so vectorially how it would look like that we have drawn it earlier also, so this is b naught this is b 1 this is b 2. Now you can see that b 1 is at an angle which means we can resolve b 1 along b naught and perpendicular to b naught so this is b naught. So, this is along the b and let us say if this is x direction this is b 1 x this becomes b 1 y, if this is b 2 this becomes b 2 y this becomes b 2 x. So, now what happens to the dislocations? What kind of interaction that takes place among them? So think over it and will come back in the next lecture because, there are now partials which have some components. So, one of the components is parallel, so if this was the edge this is also edge this is this becomes screw what happens.

So, think about it and we will come back next class.