Defects in Crystalline Solids (Part – II)

Prof. Shashank Shekhar
Department of Materials Science and Engineering
Indian Institute of Technology, Kanpur

Dislocations in FCC
Lecture – 03
Thompsons Tetrahedron

So, now let us come to this Thompsons tetrahedron

Now, again going back to our cube this is the cube and these are the atoms, now we want to find all the possible 111 planes. So, this is one set of 111 plane, but and we are talking about types or family of 111 planes, not the same set of 111 planes. This is what we are talking is family of 111 planes. So, now, this is another 111 plane. So, this connecting all the 110, this is another 110.

So, this be forms another family of 111 plane. Now, again you connect this and you get another family of 111 plane and if you look closely this and the line behind this also forms another set of FCC planes. So, this will be become like this. So, we have four different 111 planes over here and if you recall from our earlier lecture in the part – 1 that FCC has 4 different possible 111 planes and of course, they are negative. So, we have outlined all of this here. So, that is very good thing.

Now, inside the cube we have outlined all the four possible 111 plane and we see that it forms like a tetrahedron. Now, we can take out the tetrahedron it will look like this. So, this as four triangles 1, 2 and the back and one over here and other free unique features of this tetrahedron that it is equilateral another unique feature that all the edges that you see are actually along 110. So, even the directions the edges also telling us something about the possible Burger vector, the 110 direction. And, we know that each 111 plane has three possible 110 direction. And, thankfully for us each of these are triangle. So, and all this three are representing 110, three independent 110.

So, this tetrahedron is very you can say gift for us in that we are able to see all the 111 planes and the corners of this triangle are giving us the 110 directions. So, all the possible 111 planes, all the possible 110 directions in that particular plane can be identified using this tetrahedron. The tetrahedron that I drew over here is taking the full cell, but in reality what you need to draw or because the Burger vector is equal to the closest back direction.

So, what you have to do is draw along the or join the corner items of the four nearest neighbors. So, here are the items A, B, C, D and you connect them you get the same tetrahedron, that is not no difference in the orientation etcetera, but this is more accurate representation of where we are getting the tetrahedron form. So, because the edges represent here the x equal to the Burger vector the BD length, AB length they all represent the Burger vector.

And, if you look at it from the top this is how the tetrahedron would look like. Now, you have the A, B, C, D corners and these dotted lines represent another triangle.

Now, here at this point let me introduce you to similar thing that you can draw on your own and thankfully to the internet there are several such possible tetrahedrons that possible that you can download from the internet. So, but whenever you download from the internet I request you to look at the accuracy. For example, if you are looking at the different vectors on a plane make sure that all the planes, all the vectors do lie on the planes because when I look that some of the possible Thompson tetrahedron downloaded from the internet there were some inaccuracies. So, just be careful about where you are downloading from and to cross check that everything that you have is right.

So, now, I will take this is, I will just first make it like tetrahedron. So, this is our tetrahedron like I said this as four triangles. Now, you can see 1 2 3 and the 4 and like he has shown over here I am putting it over here like this. So, you have the three, the triangles and we have when you are looking from the top you can see that the 3 triangles that you have drawn over here. So, that these 3 triangles become the three triangles over here and the base triangle is over here. So, this is the tetrahedron and like I said that there are four sides to it and it represents all the possible four 111 planes in a FCC system.

And, the edges that you see over here they are you remember along the 110 direction if you look over here, they are along the 110 direction. So, they represent the possible Burger vectors or the possible slip directions on each of these 111 planes. And, if you accurately draw the x, y, z you can find and identify what should be each of these and like I said this is also possible to download from internet. So, this is the Thompson tetrahedron that we are talking about, ok.

So, before I get back let me show you one of the possible thing that you can download from the internet. So, this as this is how it will look like. So, this is the Thompson tetrahedron and over here now I will show the on the here screen you can see this big triangle over there, there are four smaller triangles.

And, here also I am showing on a paper printed something similar that was drawn here and it has as you can see it is a big triangle and it has four small triangles and from this you can make the tetrahedron you just fold it along the smaller triangle that you see over here and when you connect it back you get the tetrahedron. So, this triangle and the tetrahedron are not different it is just the 2D version of the tetrahedron and will come to more information about it later on, but let us now come to the triangle part over here.

So, here each of these triangle you can mark a center. So, for the triangle just opposite to the A side A corner the center is marked as alpha, the corner the center just oppose lying opposite to the C corner is marked actually should be gamma and the center just opposite to B should be marked beta.

So, before I upload so that you do not get confused let me correct it here and now so, this is how it should be. Since it is opposite to C the center should be marked as gamma and opposite to A alpha, opposite to B it is beta and opposite D which is just in the center there will be on the top of this is the corner D and the bottom is that delta. So, this forms tetrahedron and these are some important points that will talk about and will continue on this in a moment.

So, coming back to our Thompson tetrahedron; so, this is the tetrahedron and like I said that there are four triangles and the center of these triangles are marked by Greek letter or alpha, beta, gamma, delta and these are unique located at a unique position do not assume that alpha can be anywhere. Alpha will be just opposite to the point we have marked A, similarly beta will be marked as just opposite to the point we have marked B, gamma will be just opposite to C and so on.

Now, let us look at it over here. So, again you can see that A, B, C are over here the way this has been folded or the way this has been drawn is that D would like, when you fold along this AB, BC and CA then D will all the 3D points will come at come together into one point. So, that becomes D. Now, you see this is the A point. So, the just opposite to this, this will lie this triangle and a center of this will be marked as alpha. Now, this is B, so, just opposite to this is beta, this is D overall the corners. So, the delta is in the center of this triangle and saw the C this is the gamma.

So, now these are important points AB, BC, CD, DA and alpha, beta, gamma, delta. Now, what is the importance? The importance is that the full dislocations over here, the full dislocations can be represented which is the Burger vector equal to like we said way this is these are the edges. So, in terms of AB, BC we can write it has AB, BC, CA, DA, DB, DC. So, these 6 represent the Burger vector for a full dislocation.

On the other hand partial dislocations which have the Burger vector of the type a by 6 112 are basically line from corner to center of that particular plane. So, is this is the corner then to the center this line represents the Burger vector of a partial dislocation and for each these you can see there will be 3 different and unique partial Burger vectors.

So, if we are talking about the A corner then A corner can have from for A, A gamma, A delta, A beta. So, this will be A beta, A gamma, A delta. For B, B alpha, B beta will not exist B gamma will exists and B delta. For C, C alpha, C beta, and C gamma will not exists C delta will exists. So, of all the four possible combinations for each of this corners one is missing.

Now, you have to see what is the patterned. It is not very difficult to recognize. So, what is you see is that here A alpha is missing, here B beta is missing, here C gamma is missing and here D delta is missing and when you look at it these 4 vectors are actually very different in magnitude compare to these 3, these 9 that we have over here. The twelve over we have.

So, these are or different set of vectors will come to that in a moment and these are a different set of vectors which we have described here and these are nothing, but the partial, like we said partial dislocations and they have the vector of the kind a by 6, 112.

Now, using this notation there is still another advantage, let me show you that, that we you can describe the dissociation of a full dislocation in n to the partials using this notation. Now, what is that notation let us see. So, if you are the full dislocation let me use a different color again. If we have a full like we said AB will represent a full dislocation.

Now, this AB can dissociate into now this you can see this is AB now if we dissociate it will either dissociate on this plane or this plane. So, there are two possibilities and for each full dislocation it lies on two planes and similarly it can dissociate on to two planes. Here AB can be dissociate in ABD plane or it can dissociate into ABC plane. We will assume that we are dissociating into ABC plane. Now, what are possible Burger vectors for the partial dislocation A delta and delta B. So, this becomes A delta plus delta B and this represents the dissociation of a full dislocation in two partial and this is happening on ABC.

Now, similarly it could dissociate the same Burger vector or the same slipped vector, could have dissociated on a ABD vector ABD plane and in the ABD plane this is your one partial Burger vector, this is another partial Burger vector. So, here AB would have dissociated as A gamma plus gamma B. Therefore, and this is on the ABD plane. So, this is another advantage of using these notations and whenever you are using these notions you have to be also careful when I write it A gamma and gamma B. So, A gamma is a vector like this and gamma B is the vector like this.

Now, if you have already given the vector like this which is 1 bar 2 bar 1 it means it is going in this direction. So, when I dissociate AB then I must write the negative of this which will be; so, if I want to if I want to describe this then it will become bar 110, I will have to take negative. So, this is A by 2 and this will dissociate into a by 6. This is along the direction, right directions. So, I will take it as it is. So, this become bar 2 1 bar 1 plus I have to take negative of this again because it showing in this direction plus a by 6 bar 1 bar 2 sorry not bar 2 that is 2 1.

So, this is the same reaction as this one. Now, using the vector notation, now here using just a delta notation or the ABCD notation. So, now, first few things let us look at it this, is lying on a one bar 1 bar 1 1 plane. So, if you take the dot product of any of these three vectors you would see that it indeed comes to 0, which means that all these three are lying on bar 1 bar 1 1 plane that is one thing. Second, when you add these you must get on to the left hand side. For example, if you add this is bar 2 bar 1. So, it is just becomes minus 3, this becomes 2 plus 1, 3 this is minus 1 and plus 1 0. So, this becomes bar 330 and this is a by 6. So, 3 and 6 cancels out.

So, it becomes a by 2 bar 110 and this is what we have on left hand side. So, this again does indeed break into the way we have expected this becomes this is the sum of these two and it should be because that is how these have been drawn. But if you had taken it as it is without changing the sign of this vector then it would have been erroneous and you may have ended up getting wrong results. So, once you have the Thompson tetrahedron you have to select the direction carefully and appropriately used in our dissociation reactions.

Now, to that we are talking about the partial dislocations. Let me also add another type of partial reaction or the partial dislocations which is called Frank partial dislocation. Now, this is also edge particular only the edge type of dislocation; and how are their Burger vectors? now here is where will come back to our original notation of using partial dislocation vectors and where we excluded just four of those possibilities A alpha, B beta, C gamma, D delta.

Now, these Burger vector if you look carefully they have the Burger vector of the order a by 3 111 not; you remember for the usual partial dislocation that we talked about which move away and create the staking fault region that is of the type a by 6 112, but this is not one a by 6 112. So, this is completely different in magnitude and that is why we have not included it here. But, we include it in or this is the different type of partial Burger vector and it is called Frank partial dislocation. Why it is different will come to that in a moment.

But, for now this is possible in four different configurations or there are four different vectors which have this type of Burger vectors and these are, you guessed it right A alpha, B beta, C gamma, and D delta. So, if you look at the Burger vectors ok, let us get back to here and you have alpha here and A over here. So, there will be in the shape of a triangle or if I go back even further.

So, if I go back to here D delta is a line going from the top of this tetrahedron to the center of this triangle. Similarly, A alpha is the center from here to over here. So, this is a line lying somewhere in between the tetrahedron, this is what is called the Frank partial dislocation. So, A alpha, B beta, C gamma, D delta or the Burger vectors of this kind.

Now, another thing is that you will not that is does not, I will say called it b F to differentiate b F does not lie in 111, ok. So, this is direction 111. So, it will always be normal to one of the 111 planes and the 111 planes normal do not lie on the 111 any of the 111 planes and therefore, b F also does not lie on any of the 111 planes. But, for dislocation to glide we know that it must lie 111 plane. Therefore, what does it imply? Hence this cannot glide, implies sessile, ok. In dislocation terms whenever dislocation cannot glide we call it sessile dislocation. Sessile is nothing, but it means that it cannot glide.

Now, coming back to here the other dislocation that we talked about, they can be described they were described this is Frank partial dislocation. The others that we described earlier were Shockley dislocations; Shockley partials like the ones that we said these are Shockley partials and these are glissile; meaning this can easily glide because you know the remember they are on the 111 plane.

However, keep one thing in mind that Frank partials although they cannot glide, but they can certainly climb; meaning climb is possible for even the Frank partial, I am not saying these will not climb. These will also climb. So, can also climb, but of course, the glide is the more easy phenomena, so, it will prefer to glide unless it is facing some obstruction.

So, these are the important points with respect to the partial dislocations. Now, the next topic that will touch in the next class is about a dislocation lock that can form because of the interaction of dislocations on different planes and this kind of lock can also form where even if the dislocations dissociate into partials. So, we will come back and meet in the next class.

Thanks.