Defects in Crystalline Solids (Part- II)

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Lecture – 02
Partial Dislocation in FCC

So, now, let us come back and look at a little bit of accurate geometry of the orientation of these partial burger vectors or full dislocation burger vectors. And how they will form the or and see whether they are energetically favorable or not ok. So, let us look at the orientation.

So, this is the original burger vector b naught which we are taking the bottom line that there are 3 possibilities for each plan. We are taking just one of these and it will be possible for all the 3. We will come back to find out how to identify all the 3, but for now we are just sticking with one particular burger vector.

So, this is the burger vector that we are looking at the one, one of the possible one of the 3 possible on the 1 1 1 plain. So, b naught equal to a by 2 bar 1 and 0 1. And if you look at the other possibility other burger vectors, then we know that all of them are lie in a triangle which is a equilateral triangle. So, it was something like this, I am not drawing it on here this is just for getting a reference frame for the two other dislocations that I am about the partial vectors that we un about to draw. So, now, the two other vectors we know that they form something like this.

So, this is one partial vector we will call it b 1, this is another we will call it b 2 and looking at this geometry, you can clearly identify that this will be 30 degrees. This is the total is 60 degrees and this has to be half of this. So, this will come out to be 30 degrees and therefore, we can say that this b 1 and yeah, another thing was that this b naught breaks into b 1 which is equal to a by 6 plus b 2. Now let us compare their energy the first thing is are they energetic, is this reaction. So, that is the first question we need to answer. So, we will take the energy is proportional to b square relation. So, we will take b square and so, this will become.

So, this is the energy for this. For this one it will be 2 square plus 1 square plus 1 square is equal to 6. So, this becomes 6. Similarly here we will get a square by 36 into 6. So, on the left hand side we have a square by 2 and we are comparing it with a square by 6 plus a square 6 which is equal to a square by 3. Now clearly which one is smaller? So, this is a square by 2 is greater or a square by 3 is smaller. So, this means this is this reaction is energetically favorable ok.

So, this is something that we assumed in our previous when we were looking at the PPT when we were trying to understand whether this can actually form or not. So, yes energetically this is favorable, now we have not yet gone to the issue of stacking fault that will be created which will add another energy.

But for now we are just looking at these two partials getting formed. So, here as far as these partials getting formed are, the question arises for these two partials, it is completely possible and again I am not showing here the exact geometry or I am now trying to derive the geometry.

But you can clearly find out that if this is a by 2 bar 1 0 1 then b 1 and b 2 will be of this form and there is very you can say ready to go model available which is called Thomson Spectridal model well it will come later on, which describes these in a very easy way or where you have all these in a very easy competent. So, this is possible, now let us look at what else will happen when we have a geometry like this.

$$F_{repulsion} = \frac{Gb^2cos^2 30}{4\Pi(1-\upsilon)d}$$

$$F_{attraction} = \frac{-Gb^2 sin^2 30}{4\Pi d}$$

Other thing we said was that there may be a repulsion taking place. Now does that repulsion take place that is the question that we want to answer now. So, this is our original burger vector and these are the partial burger vectors. Now this has some component along this line and we assume that this is edge. So, there will be 1 and this is b 1 this is b naught this is b 2. So, there will be a component of b 1, which will be parallel and there will be a component of b 1 which will be perpendicular to b b naught. So, b 2 so this is this 1 will be like this b 2 perpendicular and b 2 will also have a parallel component.

So, we that we can dissociate or we can look on b 1 and b 2 as if they had 2 components one parallel to b naught and the other perpendicular to b naught and the reason is that we then we will be able to dissociate them into edge dislocation and screw dislocation. In this case we know that b naught the burger vector b naught where that we have taken is as you mean a edge dislocation we will we will clearly expressively mention that original dislocation is edge in character ok.

So, in the original is a edge in character then b 1 and b 2 will also b 1 parallel and b 2 parallel will also be edge in character. And since the dislocation line it means that the dislocation line is like this and therefore, the perpendicular once by default become screw dislocation.

So, b 1 parallel and b 2 parallel are edge dislocations and b 1 perpendicular and b 2 perpendiculars are screw dislocation another thing is that b 1 parallel and b 2 parallel are in the same direction while b 1 perpendicular and b 2 perpendicular are in opposite direction. And if you remember from the first part that whenever there is dislocations of this kind as your screw of the opposite kind are together they will attract and when the same kind are there they will repel.

So, opposites attract, this is something underiving from our earlier part one lecture and similar repel. So, there will be repulsion between these two part and attraction between these two parts. Now before that lets see what will be the burger vector for this. So, the b 1 parallel and perpendicular which means b 1 parallel and this time I am meaning the magnitude wise will be equal to b 2.

So, if this is 30 degrees that we have already here mentioned and this is b 1. So, this will be thirty cos 30 degrees the parallel once and again we are talking about magnitude b 1 times cos 30 which will be equal to b 2 cos 30. On the other hand when we take b 1 perpendicular magnitude, it will be equal to b 2 perpendicular magnitude which will be equal to b 1 sin 30 because we will be taking this one and again we are taking just the magnitude and it will be equal to b 2 sin 30.

Now, base on this we are in a position to find what will be the net force acting between these two partial dislocations. So, this is our question, does repulsion take place? So, we are trying to find the net force acting on this. So, this is like this and now we have repulsion. Repulsion between these two parallel ones which are nothing, but the edge with desolations and we have seen this is the burger vector the magnitude of this. So, we can write it like this, we will call it b 1 b 2 and b 1 b 2 over here we will translate it to just b.

So, we have b naught and now magnitude wise this will be called b just to just for our easy way of writing I have transformed b 1 b 2 to b and only the magnitude part of course, the vector part always be the as it is. Since this is edge dislocation we can write it like this and the attraction is between the screw dislocation components. So, it be minus G b square sin square 30 and there will be no n minus new term. So, this is the F attraction term.

$$F_{NET} = \frac{3Gb^2}{4\Pi d}$$

The net force acting would can be now written like G b square by 4 pi d. So, this is the net force acting and if you look at the values you can see that let us put nu equal to 0.5 and cos square 30 we can that becomes 1 by 2 and therefore, this becomes G b square by sin square 30 is 1 by 4.

So, this becomes 3 by 4 G b square 4 pi d. So, this is the net force acting and you can see this is the positive value which means that there is a net repulsion between the two partial dislocation. So, there they will keep moving on, but how far? Now that is that will be determined by how big a stacking fault region they create. Now stacking fault region will have energy now that energy would be given by, that energy is given by this is given by gamma SFE which will be in the units joule per meter square, which we can also translate as Newton per meter that is force per unit length acting which will same as the units of f net.

So, the energy per unit area that we see if affectively also the force per unit length that will be acting along the edges and therefore, we can directly relate f net to SFE that will give us the equilibrium.

$$d_{equi} = \frac{3Gb^2}{4\Pi\gamma_{SFE}}$$

When we do this we will be able to directly get the equilibrium d value. So, initially it is equal to 3 by 4 and implies and now we will switch to the red because now we have d equilibrium is equal to 3 by 4 G b square 4 pi gamma SFE. So, this will be the equilibrium width, now I gave you the values in the in last lecture of the previous module of the equilibrium. Now this using that value of d equilibrium, one can back calculate what should be gamma SFE.

So, that is infact one of the ways that the stacking fault energy of different materials are calculated, you can look at the tm images and find what is the equilibrium thickness of this stacking fault region between two partials and that will be more or less constant for a given material and why it will be constant because gamma SFE is constant. And so, from calculating this d equilibrium value you would be able to calculate d, gamma SFE value for these materials.

Now, here you would have seen that we assumed that our dislocation to begin with was a edge dislocation.

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$$F_{attraction} = \frac{-Gb^2 sin^2 30}{4\Pi d}$$

Now, next what we want to do is what if original dislocation was screw in character? The overall derivation you would see would follow similar lines, but the result would be a little bit different ok. So, begin with we will again draw the structure, the geometry of that dislocation and the partial dislocations.

So, this is our b naught and the magnitude wise this is b this is b that is of course, b 1 and b 2, but we are just let us not confuse we will call it still call it b 1 then call it b 2 and they will have again a parallel component and antiparallel component. Now this one here is screw in character and therefore, what we will have is that b 1 parallel is a still b 1 cos

30, but this is for screw dislocation and b 1 perpendicular is equal to b 1 sin 30, but this is for edge dislocation and this will be equal to b 2 cos 30 this will be equal to b 2 sin 30. And over here we will replace b 1 b 2 and the magnitude by the magnitude b. So, this becomes. So, our f repulsive is equal to G b square and that is between the parallel which is these two, these are our parallel which are now screw.

So, let me write it screw over here and these are edge. So, the repulsion is between the screw dislocations and we will write it as cos square 30. Now there will be no 1 minus neo term over here, it will only be 4 pi d and f attractive would be between the edge dislocations which will be G b square sin square 30 and remember we are taking b 1 and b 2 magnitude as b and this is edge. So, there will be 1 minus nu. So, this is attractive terms minus time ok. So, now, this f net what is f net equal to this plus this and therefore, this will be equal to G b square.

Now, again we will put in the values the usual values cos square 30 is 1 by 2, this is 1 by 4, this is one 0.5. So, this becomes 1 by 2 and what do we get? This is approximately equal to 0. So, stacking fault region unlikely for screw, this is what these equations tell us. So, we have seen so, far in this lecture that that dislocation, the partial dislocations do repel and they can create a stacking fault region.

And based on the width of the stacking fault region we can say what will be the de equilibrium we also saw that this particular derivation is true and when we use these type of equation is true only when we assume the dislocations to be edge in character. If we take the dislocations to be screw in character, then we do not get a dislocation or we do not get repulsion meaning there will be no stacking fault region created.

Now, the next part is that I have used only one particular if you go back here we have used only one particular b 1 and one particular b 2 and one particular b naught and, but I said that they are 3 other burger vectors and all of these dissociate. So, how do we find what is the different possibilities, now geometrically you can find all of these, but there is a still and geometrically only there is a another method which is possible and it is called Thompsons tetrahedrons.

Thanks.