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

Lecture – 33
Examples on Jogs + Dislocation Intersection

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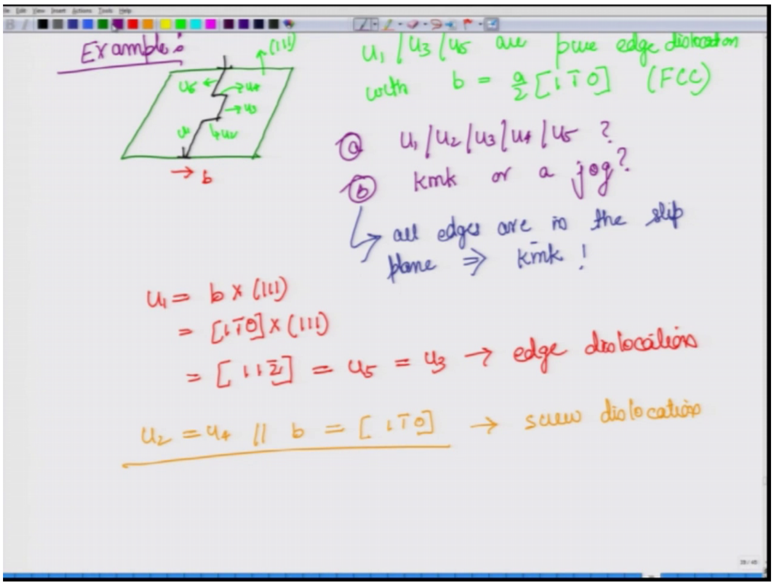

So, in previous class we went through this example. So, I drew this edge dislocation which had some step and you were to find out whether it is a kink or a jog, and next you had to find out whether the different sections u 1, u 2, u 3, u 4, u 5 what are their directions and also have their screw and edge.

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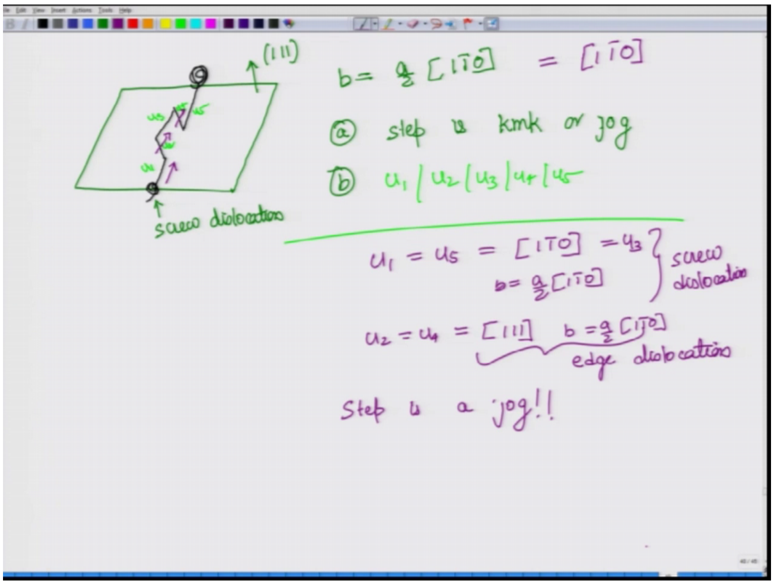

So, in this particular example we used edge dislocation. Next we will try to do the same thing with a screw dislocation. So, here the screw dislocation is given to you here this is the screw dislocation and this is coming out of plane this step then there is a section parallel to this, then again coming back. And here and this is a hole screw dislocation and it is given that this is 1 1 1 plane and the burger vector for this is given as a by 2 1 1 0.

So, first thing is to find out whether it is a kink or a jog now the way it has drawn it has been given that this is the slip plane, this 1 1 1 is the slip plane for the screw dislocation and you have to describe the characteristics of u at the various sections u 1, u 2, u 3, u 4, u 5. So, let us start and see I hope you have to given a try it on your own. If you have then, you will find it, you will be able to compare your notes with mine if not then you can go through the solution here.

So, here what we have burger vector is given as a by 2 implies, line direction for this is also equal to 1 bar 1 0. So, the line vector for this u 1 and u 5 is 1 bar 1 0. And u 3 beside is since u 2 the way it has been drawn and I have explained that u 3's parallel. So, is u 3 u 3 is also equal to 1 1 0. And for all of them burger vector is also equal to a by 2 1 bar 1 0 they are parallel. So, all u 1 u 3 u 5 are screw dislocation.

For the u 2 and u 4, what you see is that the burger vector is going like this. So, here it is also like this here it is also like this. So, for these sections these it was parallel, but u two and u 4 you see it is going perpendicular. Moreover, u 2 is coming out of the plane just normal to the plane, but normal to the plane is given as 1 1 1. It means that u 2 equal to u

4 is equal to the direction should be same as the normal which is 1 1 1. And here the burger vector is equal to a by 2 1 bar 1 0, and these are perpendicular as you can see hence this must be a screw sorry; edge dislocation.

Next we want to find whether the step is kink or jog: that is the simplest part we said that kink will be in the plane of the slip while jog takes it out of the slip line. And hear it clearly coming out of the slip plane therefore this step formation step is a jog. So, that solves this problem. So now, let us summarize some of the important aspects that we have learned so far, and in the process we will also list out how these kinks and jogs are generated what are the usual mechanism?

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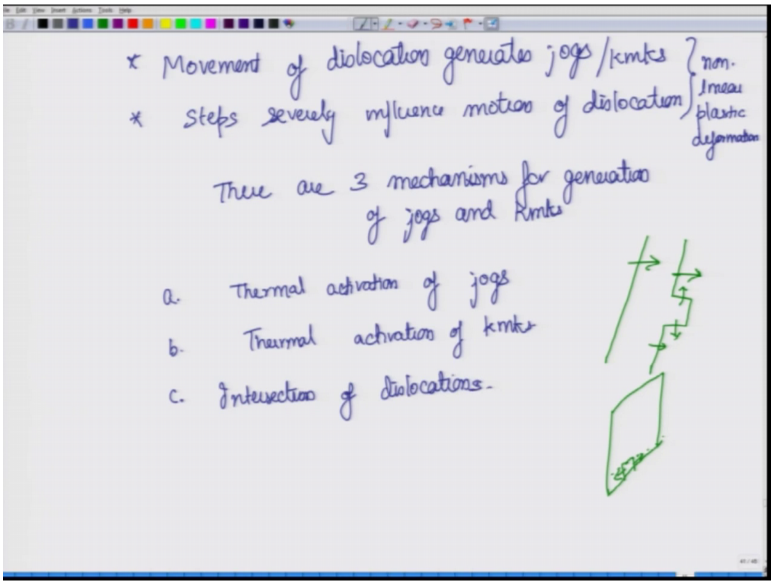

So, what are the some of the things that we have learnt today or based on the jogs and kinks that movement of dislocation generates jogs and even kinks.

In fact, this will become more clear when we come to the last point as you will see in a moment. And another thing that you would realize is that when a step is formed, somewhat sometimes they have the similar character, sometimes we have different characters. So, these steps severely influence motion of dislocation. So these two are kind of interrelated steps are severely influencing the motion of dislocation. And dislocation motion is creating these steps and this is what you can describe as non-linear plastic deformation.

So, there is not one to one relation it is there are other ways that it is getting influenced getting dampened and so on. So, this is a typical description of a non-linear plastic deformation. And that is why you cannot explain every effect in a very simple something like a Hooke's law that you that we use in elastic elongation. Now we have talked about generation of jogs and kinks which is by movement of dislocation. So now, we are if we are talking about in our generation of jogs and kinks you should you should know that there are 3 distinct mechanisms which lead to generation of these jogs and kinks; what are these?

So, there are 3 mechanisms and jogs. A, it is thermally generated, meaning because the jog is trying to study the time is trying to take place and because of that there will be thermally activated jog formation. So, there can be thermal activation of jogs and similarly there can be thermal activation of kinks. Similarly there can be thermal activation of kinks. So, these two are actually part and parcel of the same thing. So, you can imagine something like straight dislocation and because of thermal agitation there may be steps like this, when it was gliding like this and therefore, this will keep moving. So, this will move like this which in effect will lead to this direction motion of the overall dislocation. Similarly you can have extra half plane and there may be jogs formed, these jogs would move in the opposite directions leading to an effective movement of the dislocation half plane. So, this will lead to climb up.

Now the third mechanism for generation of jogs and kinks, which is very important with respect to plastic deformation is intersection of dislocations. So, because when you start deforming what happens, that certain dislocations will get generated and you keep applying the stress dislocations move and when more and more dislocations are present, then these dislocations will interact. And when they interact they will relate to formation of some steps kinks and jogs and when these kinks and jogs are found some of them will be glisile, which is they will be movable some of them will be sessile meaning they will be non movable.

And because of that the this what this leads to called as the plastic hardening or the work hardening of the material, because there are more and more dislocations they interact, they intersect, they form forest, what is called as forest dislocations, because there are some immobile dislocations. So, the overall strength of the material increases. As we showed you in one of the earlier lectures describing of a dislocation that there is two regime of dislocation one almost 0 rate dislocation where the strength is again very high, and then a very high dislocation density where again you can strength can increase to certain extent.

So, in this particular case we have our intersection or dislocation leads to increase improvement or increase in the strength because of some of them will be glisile and sessile ok. So, let us try to understand intersection of dislocation in a bit more descriptive way.

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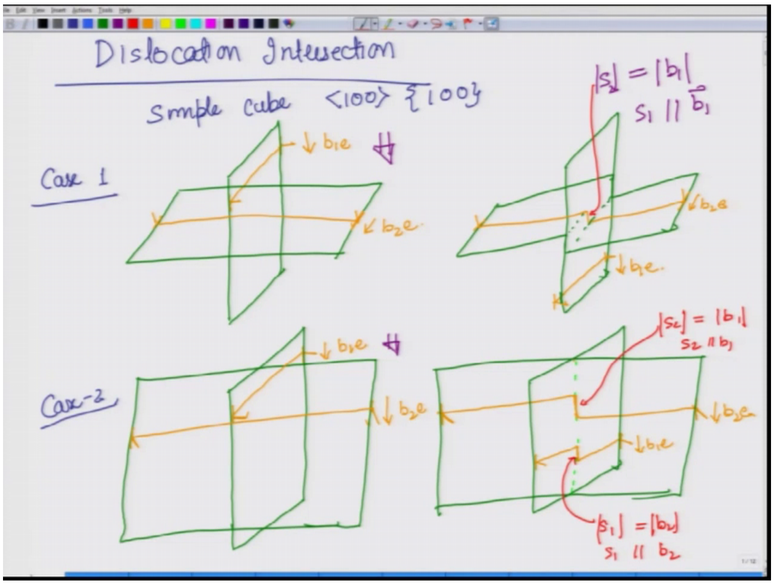

So, here we will now start the descript intersection of dislocation. So, we will our topic here is dislocation intersection. And here so far you would realize that we are focusing only on very simple description of dislocation and here we will continue that. We are not yet talked about a specific kind of dislocations inside a specific system for example, a edge dislocation and or a screw dislocation in FCC. Very rarely once a once in a while we do touch upon the topic, but we have not described this structure in so much detail. So, far we assume that one single plane can describe the extra half plane for edge dislocation, which is not really true for either FCC or BCC both of which were one of the simplest systems.

So, coming back to this we will continue our utilization of the simple description. So, in other words what we are saying is that we are assuming a simple cube, type of system, where the slip direction is 1 0 0 and the slip plane is also of 1 0 0, that is what it means when we mean that when we say. So, for this particular kind of system you will get the dislocation description the way we have described it.

So, here will describe 4 cases: so first well take 2 edge dislocation. So, this is one edge dislocation and the other one we have here is like this. So, in this particular case the burger vector for the two of them are like this. So this is the; this one let us call it dislocation 1. So, we will call it b 1 e, the burger vector is going down as you see this is one horizontal plane this is one vertical plane. So, this is a burger vector is going down as you would realize because this is a edge dislocation. And this is coming in this parallel to this edge and this will describe as b 2 e.

And let us assume that this particular dislocation is moving in this direction. So, what will be the final shape of this? Let us see, actually we need to. So, this particular dislocation that we had so, it is moving down and down and then at certain point it will intersect with this and when it intersects, this leads to a step formation here and this is how this deformation takes place at like this and like this. We will come back and describe more about the step, but for now just understand that this is the step formation in this. So, it has it was on one plane it has a part of it has now moved to another slip plane.

And what happens to this one? This one actually makes a just a small difference, which will not be really observable and which is that it moves 1 step to the left ok. We will come back and describe all these in more detail or not basically we will describe what is happening once we have looked at all the 4 cases. So, this is this was our b 2 e, this was our b 1 e.

Now let us go to case 2: here also we have 2 edge dislocations, but they are oriented differently here in this particular case you can see the two burger vectors are perpendicular to each other. But we can have same burger vector, but the dislocation line can be oriented perpendicular to each other and this is how it will be. So this is one plane, this is another plane; this is same dislocation b 1 e. So, it is burger vector is like this, but now in this particular plane. So, imagine like this one has been this particular plane that you see has been rotated by 90 degrees along this axis and so the same dislocation can be assumed to be here. Now since it has been rotated by 90 degrees. So, the burger vector here is b 2 e, now b 1 e and b 2 e are parallel as you can see here. So, this is a different case from here. So, do not get confused that both of them are edge dislocation. So, they are saying no it is not, this one is burger vectors are perpendicular here they are parallel.

And here also b 1 e is moving down. So, this one is moving on this plane and keeps moving on at certain point it will intersect this burger, this dislocation line with whose burger vectors b 2 e. So, what happens, so let us see that. So, this dislocation line has come down and what has happened to it will describe. So first let me, draw a dotted line to show which is the line of intersection and in this particular line of intersection, we had the dislocation like this and this dislocation has got in a step along this line.

So, this is what happens to b 1 e. And what happens to b 2 e? Which is over here, this also gets a step along this line. So, this is the line which is the common line for these two planes and both of them have got in a step along this line which is common to this. So, they have received a step they have obtained a step. And as you can see in these two cases clearly, that there are step getting formed because of intersection of dislocations.

So, these are 2 cases now let us move on to the case 3.

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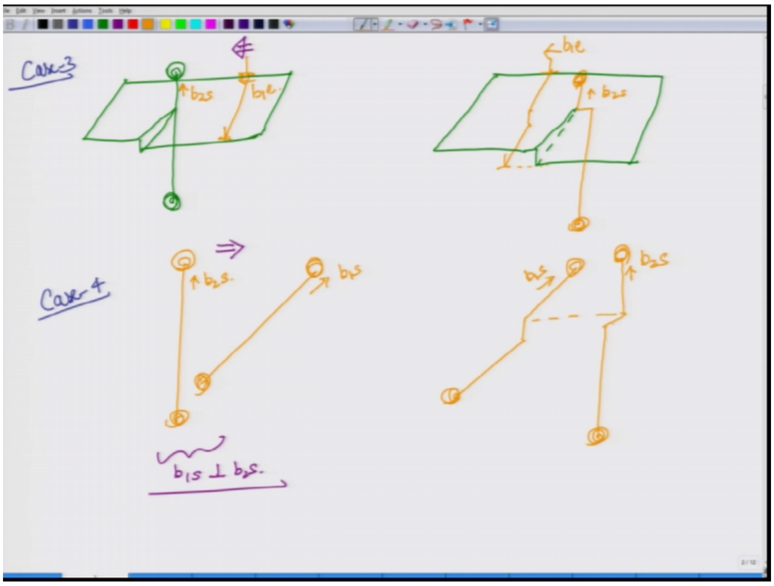

Now here we will have one screw dislocation involved, we will not be able to show the plane for the screw dislocation for the slip plane, but we will try to show the plane for the edge dislocation. So, let us say the screw dislocation is like this. So, this is the plane and in on this particular plane we will have the edge dislocation. So, the edge dislocation is like this and we will say it is b 1 e, while this is the screw dislocation whose burger vector so, this burger vector is like this and for this the burger vector is like this b. So, this is screw dislocation. So, we will call it b 2 s. So, as you can imagine because of this screw dislocation there is this ledge getting formed, which in effect also describes it is slip plane ok. So now, this will become the slip plane.

Now, this was arbitrarily defined slip plane right now, it could have been any other direction. So, whatever we describe were next with respect to kink and jog would be assuming that this is the slip plane. If it were different will we may get different result, but that will not be the case for other cases that we are describing, where we are only talking about edge dislocation the slip plane will get defined by the motion in the direction in which it is moving. And the final result will also not change as long as you assume that constraints that the burger vectors are perpendicular in the first case and parallel in the second case.

So, coming back to this we will describe that this particular edge dislocation is moving like this. So, what is the final scenario in this particular case what we get is. So, the edge dislocation comes over here and it gets a step. And now it is in a different plane, which is in the lower ledge. So, this edge dislocation has again received a step and so, will the screw dislocation which was over, here it will receive as edge disloc it will also receive step. And this is the step over here and here we had b 1 e and remember the burger vector does not change, some these are some of the fundamental rules that you must remember when you are trying to solve problems related to dislocation.

So, the burger vector here is still b 1 e and it will remain same for the steps or the whole dislocation here also the burger vector will remain the same way that is for the edge dislocation or the screw dislocation. So, that is the case 3 and here also we see steps getting formed by the movement of dislocation. Now let us look at case 4, case 4 is when we have two screw dislocations intersecting. So like I said that, it is not possible or to describe easily the plane. So, you would see we I will just draw the screw dislocation line and here the other one is almost perpendicular to it all not almost, but it is in a perpendicular plane and so, we will say this is b 1 s and this is b 2 s. You have to imagine that these two are perpendicular. So, let us write it down somewhere here. And over here we will assumed that this dislocation is moving or you can imagine that this one is moving along this direction.

So, what is the final step that you will get or final configuration that you will get? You will get this dislocation will also get a step. So, here again we have steps getting formed over here. Now do you see a pattern to what is how the steps are getting formed? The pattern here if so, let us go back and look this is moving and it forms a step in this direction, what is this direction? It is same as the direction for the burger vector, where is the step forming, it is moving in this direction it is which is parallel to the burger vector in this direction. When you have something like this in both of this the burger vector is the same direction and therefore, the step you see is also getting formed in the same direction.

What happens here? So, the burger vector screw dislocation is like this and therefore, it leads to the step in the edge dislocation in this direction. The burger vector for the edge dislocation is like this, which will mean that the screw dislocation will get a step in that direction. So, here you have a step in the screw dislocation like this. In case for here the two screw dislocations are intersecting and both of them have burger vector perpendicular to each other and the line vector, the step vector that you get they will have the step direction or the step line vector would be. So, this line vector would be parallel to this burger vector this step will be parallel to this burger vector.

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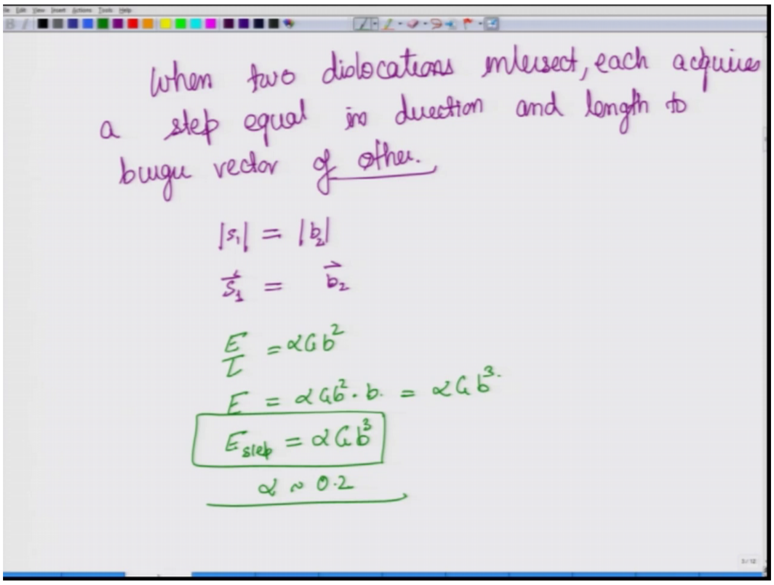

So in simple words we can say that, when two dislocations intersect each; it will happen to both because it there is nothing specific special about one. Each acquires a step equal in direction and length ok. So, this is another aspect length of the step is also equal to burger vector of other.

So first thing each acquires, so do not get confused that why this one was not getting a step this is also getting a step, but only that you will not be able to see it is in the direction of the line vector of this particular dislocation. Second is that the step let us say, this is we signified with s then the length of s is equal to length of the burger vector. So, this is step in 1 is equal to burger vector length of the burger vector of 2. And the direction of s is also equal to the burger vector b 2 s 1. So, length of s 1 is equal to b 2 length of and direction of s one is equal to b 2.

So coming back here, if you look at this particular length or this step, this step is equal to so I do not want to draw too many lines here because we have other things to show over here. So, this is step that we are looking at. For this, so let us say this is step s the magnitude of this s is equal to the magnitude of b 1, because this is s 2, this is happening in dislocation 2. So, I will call it s 2 magnitude of s 2 is equal to magnitude of the burger vector b 1. And this direction is equal to burger vector 1.

So, it is pointing in that same direction or s 1, I should say is parallel to b 1. So with this, I will just describe it at one place I used to become clear that; what are the important aspects of dislocation intersection. So, these are the different cases and we will get to see few more things about this dislocation intersection and the most important part we have already understood is that when two dislocations intersect each acquire step and not only that, but the step has certain characteristics, it is not just in arbitrary direction in each of these. For example, even here if you look both of them; so if you talk about. So, let us for the sake of completion because here we had only 1 clear step visible. So, for the sake of completion let me do it here for this one s 2 is equal to b 1 and s 2 is parallel to b 1. And for this one which is step 1, magnitude of this is equal to b 2 and s 1 is parallel to b 2.

Now based on this we will come back and look at whether it is kink or edge, and whether it is kink or a jog, and whether it is in the same plane or it is on the other plane, it is whether it has a screw character or a edge character. So, to just one more step, one more point here that since we have described that this is has 1 unit length. So, we can say that energy per, we know that energy per unit length of a dislocation is equal to alpha G b square. So, for if you look at the step we can say energy is equal to alpha G b square into, length is what: is equal to b so it will become alpha G b cube.

So, E step and here we are not talking about the per unit length because we already know the length which is very small and it does not have very long order, long range of effect, so alpha G b sorry cube, where alpha is of the order of 0.2. So, this is additional information that we can get here about the step.

So, we will come back to this point and we will discuss more on the whether the kink and jog character and edge and screw character. So, see you in the next class.