Defects in Crystalline Solids (Part-I)
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Lecture - 39
Thompson's Tetrahedron + Examples

So, in the previous class we started with the discussion of Thompsons Tetrahedron.

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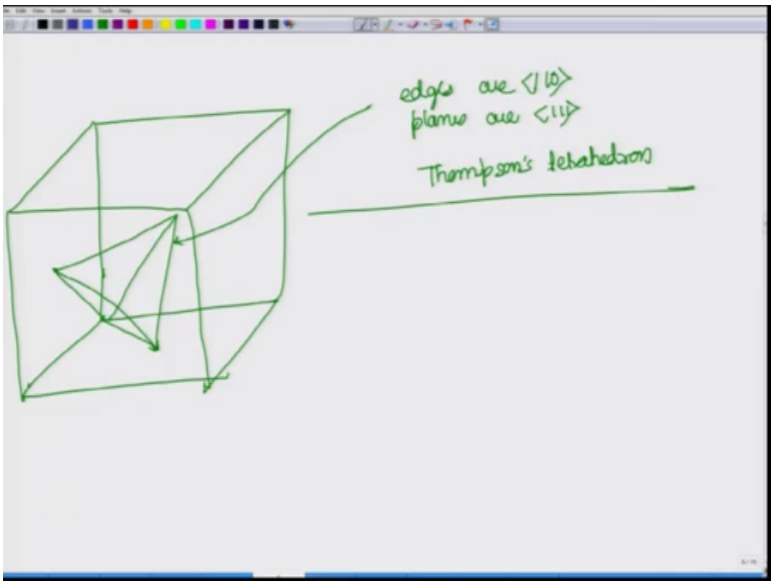

And if you realize this is the cube and inside the cube, if you connect all the face centered, the three of the face centered and one corner atom then, you get this tetrahedron. And this is the tetrahedron that I showed you in the previous class. So, this is a three dimensional tetrahedron.

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But as you can see when you print it and you can get if you search on the Google, you can find several links to find a printable form of it.

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You have to just fold it and then connect it together. Now, when you open this of course, if it is printed then it is it can also be represented in one page and it will look like the one that I have shown over here.

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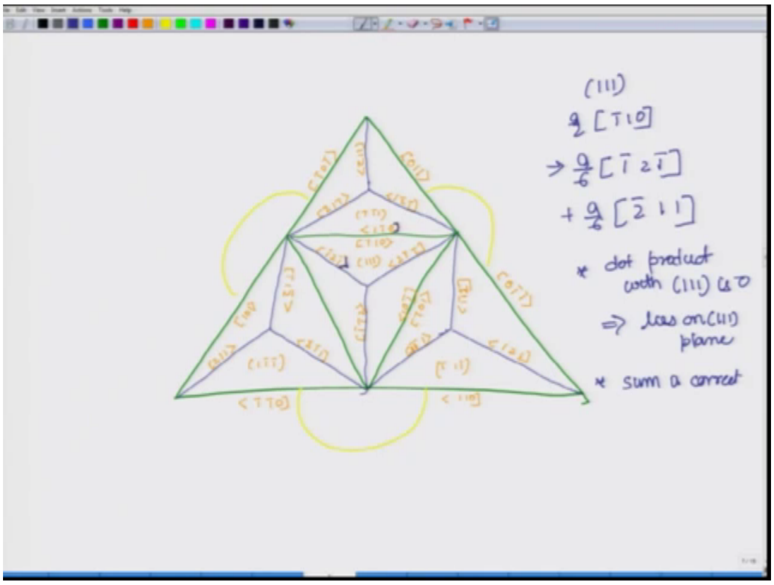

And once you have something like this then this is also as good as a tetrahedron, but only in two dimension and here you have to just remember, which side is connected to which one; for example, you must remember that this 2 edges are connected, these 2 edges are connected, these 2 edges are connected and that is when they form the tetrahedron.

So, this is the planar form of the tetrahedron. Now coming back to our tetrahedron, let us look at what all information is tetrahedron supposed to give us.

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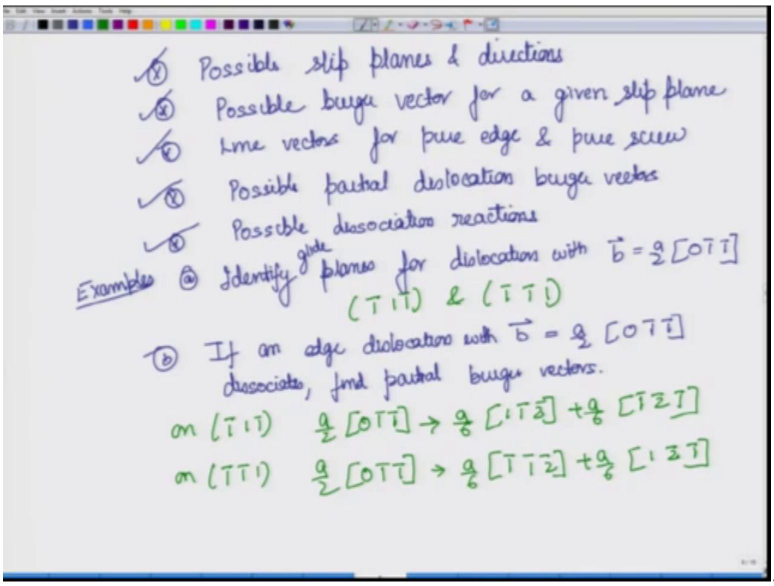

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So, tetrahedron is can give us possible and remember FCC, that goes without saying because we are talking about the FCC slip systems. So, the tetrahedron can give us possible slip planes, and directions. It can give us possible burger vectors and it also gives us what is possible burger vectors for a given slip plane. And you remember that, I said that if you consider edge dislocation you have to take perpendicular and from there you can also find out what will be the perpendicular direction and therefore, you can also find line vectors.

So, you can also get line vectors, for pure edge. And pure screw is obviously very simple because, it is along the burger vector so, pure edge and pure screw. I also show in the previous class, I also showed you that, this Thompson tetrahedron can give you possible partial dislocations, dislocation burger vectors. And I will come to all of these in a moment again just to reiterate it and it also gives you possible dissociation reactions.

So, just looking back at our tetrahedron, this is how that tetrahedron was and I will go back to our planar model. So, here is the planar model and you can see I have written here, all the possible slip planes that are all the information that is given on the tetrahedron.

So, these are your slip planes bar 1, bar 1 1, this is 1 1 1, this is 1 bar 1 1 sorry 1 bar 1 bar 1 and this is bar 1 1 bar 1. And these are the burger vectors for the full dislocation, so for this particular plane 1 bar 1 bar 1 1, these are the 0 1 1 bar 1 0 bar 1 bar 1 0 1 0. These are the directions and if you add if you multiply it by a by 2, that becomes the burger vectors. So, this gives you that, it is yes indeed, it is able to give you possible slip planes and directions. Now coming to possible burger vectors for given slip plane.

So, yes if this is the slip plane we are talking about bar 1 bar 1 1, you can just look at this triangle and all the information given here is then about this particular slip plane. So, these 3 are the possible burger vectors for this particular slip plane. And these blue lines, we have not yet talked about which is in the next point, which is possible partial dislocation burger vector, but before that it can also give you information about line vectors for pure edge and pure screw.

So, like we said if, this is your burger vector for a pure edge dislocation then, it has to be perpendicular to this. And fortunately, for us that in this direction is also given here, which is actually for the partial burger vector, but it will also become the line vector for this edge dislocation. Screw dislocation as I said earlier and you would remember it is simple whichever direction the burger vector is that is the direction of line vector for a screw dislocation. So, screw dislocation is always known, but here you are also able to get to know the line vector for edge dislocation. Even here if this is your burger vector, you know this is the perpendicular direction. So, for about a pure edge dislocation with 0 11 on bar 1 bar 1 1 plane the line vector would be bar 2 1 bar 1.

So, we have seen yes this is true, this is true, this is true. Possible partial dislocation burger vectors and this is where you comes the blue lines come into the picture. So, all the blue lines that you see are displaying the direction or the vector direction for the partial burger vectors. So, yes all the partial and these are only possible burger vectors, it is not that it is only showing you a part of it, all the partial dislocation burger vectors are listed here. So, yes and it will also it says that it will also give you possible dissociation reactions.

Now this is another very important and useful quantity that you can get from here. So, it is right time for you to download one of these Thompsons tetrahedron, you search on Google and printout on one A4 sheet paper and then cut it down and you will join it to make the tetrahedron or even if if you like you can use it on a plain sheet of paper.

So, yes coming back to possible dissociation reactions, so you can see, let us say we are talking about let us talk about a central triangle which is for the 1 1 1 plane. And let us say, this is the burger vector of the dislocation of the full dislocation. And when it dissociates you the when it dissociates, these are the 2 possible not possible it will break into these 2 partial dislocations with these partial with these burger vectors.

So, bar 1 1 0 will break into bar 1 2 bar 1 and 2 bar 1 bar 1 and you have it remember you have to multiply with a by 6. And another thing that you must realize is that, there is an arrow given here. So, for example, here I forgot this arrow is in this direction. So, if this is in this direction. So, you have to get the partial burger vectors also in this direction. So, this is ok, this is in this going in this direction, but this is in the other direction. So, you will have to take negative of this.

So, for example, if I want on a 1 1 1 plane and if it is my a by 2 bar 1 1 0, that is dissociating then just looking at this I should be able to say a by 6. So, you have to remember a by 6 is a factor over here and the burger vector will be bar 1 2 bar 1. And this is in this direction, but if you add vectorially it should be in the opposite direction, so we will take negative of this plus a by 6 and it will negative will be bar 2 1 1.

And now, let us see if it satisfies all the conditions. So, is bar 1 2 bar 1 present on 1 1 1 plane, so let us take a dot product and you will see that it is just 1 1 1, so just add these and it is indeed coming out to be 0. Similarly if you add all these basically, take a dot product with 1 1 1, so, dot product is coming 0. So, yes dot product is 0 implies lies on 1 1 1 plane. Second you add these, so this is minus 1 and this is minus 2; so, this becomes minus 3 this is 2 plus 1 minus 3 and minus 1 plus 1 0. So, this inside the bracket it becomes minus 3 plus 3 0 and there is a 6 a by 1 by 6 factor. So, it becomes 1 by 2 and this becomes minus 1 1 0 and this is what we have on the left hand side.

So, this reaction is also the sum is also true. And therefore, the two things to check have verified. So, the sum is correct. So, this is rightly giving you, if you on the other hand, if you had taken 2 bar 1 1 instead of bar 2 1 1, then you would have committed a mistake. So the when using the Thompson tetrahedron, so you have to be careful and see which is the direction for the vector given. So, there is a it is a vector, so it has a direction, it is not just a line, it is a vector. And for all of these a particular, so, let me correct at one of the few places. So, you have to anyways download it on your own and cross check because, many of the sites I have seen that, there is one common Thompson tetrahedron and there is there are a couple of errors in that. So, you have to cross check it and this is the way to cross check.

If, you are talking about any one particular plane you just take a dot product to find it for the burger vectors lies in that and then, you take the sum to see if, the partial burger vectors do indeed give the sum as given. And also use the one where a vectors direction is given because, without that it will not be helpful for you ok. So, now, let us say, I give you a task of listing.

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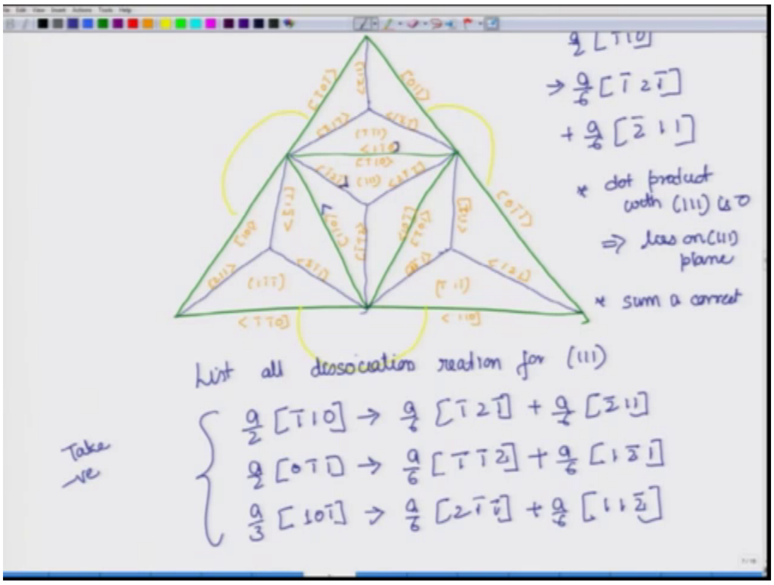

So if I tell you the task that lists all dissociation, reactions for 1 1 1 and I am not worried about the sign right now, you can take it positive or negative. And in here there is one particular orientation that is missing so, let me write that down this would be 1 bar 1 0. So, this is the plane I am talking about. And there are only 3 full burger vectors, so take one of these; let us say, I take bar 1 1 0 which, I have already done, but anyways for the sake of completion I will do it here again. So, a by 2 bar 1 1 0, this dissociates into a by 6 bar 1 2 bar 1 plus a by 6 bar 2 1 1.

So, this is the way it is to be done, this we have already done. Now let us go to the other one, which is a by 2 0 1 bar 1. So, now, I am taking this one and the direction for this is given in this direction ok. So, this vector is given in this direction, so I can simply take it like that, it will become bar 1 bar 1 2, plus this is in the other direction, it is pointing this way, I want it in the other way. So, I will take the negative. So, this will become a by 6 1 bar 2 1. So, this is the second one, now for the third one which is this one. So, I will take it like this, which is 1 0 bar 1. So, it is coming in this direction and this is good, so I will take it as it is a by 6 2 bar 1 bar 1.

For the next one, again it is pointing in the opposite direction, so I will take the negative. So, it becomes 1 1 2 bar. And you can see that without doing any calculation, I am able to get all the possible reactions, there are no more reactions because, there were only three full burger vectors, so there can be only three partial dissociation reactions. Yes, obviously, you can take a negative that is also possibility, but it is one and the same. So, take negative; so, you will get if you want to include that as a separate then it will become 3 into 2; otherwise, you have three different reactions that are taking place and this tells you how to solve this problem ok.

Now, let us so, this one we have already done, so possible dissociation reaction yes. Now let us try to solve some examples. If I ask you to identify planes for that is what are the glide planes, identify glide planes for dislocation with burger vector equal to a by 2 0 bar 1 bar 1 ok. So, at first if you are not familiar with Thompson tetrahedron, this may look very daunting, but then you just come over here and you start looking what where this particular direction lies. So, we are talking about 0 bar 1 bar 1 and where do we see? So, this is one place that you see, I do not want to mess it up. So, I will just point out from outside. So, one of the plane is bar 1 1 bar 1 and by default you should know that this is the edge ok.

So, this edge will lie on two planes. So, once you have found this, you automatically know that this is connected to the other which I have shown by yellow line. So, this will also lie on the bar 1 bar 1 1 plane. And this is shown as negative here ok. So, that should not confuse you, if I am asking for 0 bar 1 bar 1 then, you can also look for 0 1 1 and the two of and like I said, it has to lie on two of the planes and these are the two planes. So, the two planes onto which these lies are bar 1. Let me write it in different. So, that is one example.

Now, let us solve look at a little bit more difficult problem. If an edge dislocation with burger vector equal to a by 2 0 bar 1 bar 1 dissociates. So, you are given that a particular dislocation dissociates, find partial burger vectors. Now, so far you would have realized that using Thompson tetrahedron is very useful and yes, we can use it over here also, but then you also have to use it smartly. For example, when it is given that the burger vector is this and no plane is given. So, by default you should remember that, this particular burger vector will lie on two planes and on both these planes or partial or dissociation reaction can take place.

So, first let us find out what are the two different planes where this particular reaction can take place and that we already have solved in the previous one. So, these are the two different planes; bar 1 1 bar 1 and bar 1 bar 1 1. So, we look at these two planes here and now we will look at. So, this is the full dislocation burger vector we are talking about and this is the partial dislocations burger vector. So, we can this is one possible set and this is another possible set. So, you will have to be smart and write that both of them are as possible.

So, you will write on bar 1 1 bar 1 the possible reaction is a by 2 0 bar 1 bar 1 will give a by 6 1 bar 1 bar 2 plus a by 6 bar 1 1 bar 2 bar 1 actually, it is also minus and on bar 1 bar 1 1 plane, this will this is again the same burger vector and it will dissociate into a different. So, there are two information that you are getting one that it will dissociate onto two planes and second that the burger vector on both the planes are different.

So, this is the total or the full answer. If you had just written just one part then it would be incomplete. And even though, you have the concentrated and you would have looked on this particular plane and you form this reaction and you would have thought your answer is complete, but that is where you also need to apply your brain that, this each burger vector will you can lie on two different planes. Now let us ask some more difficult question.

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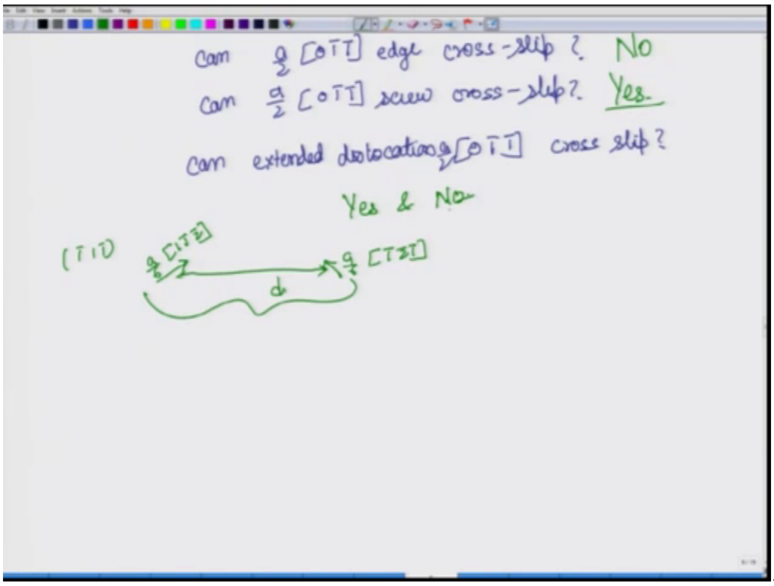

Can a by 2 0 bar 1 bar 1, the one that we have just discussed, so, I will just keep continuing with this cross slip and this we already know that the answer for this is No, it cannot. What about can a by 2 0 bar 1 bar 1 burger vector same, but now I am talking about screw dislocation. Can this cross slip and yes the answer is Yes, this is or something we already know that, pure screw dislocation. And in this particular case, we have already seen that this burger vector lies on two different planes.

So, yes it can cross slip, it can cross slip from bar 1 1 bar 1 to bar 1 bar 1 1 or and back onto it. So, that is also possible. However, now my question becomes more difficult and it is can extended dislocation meaning it has broken or dissociated. So, the burger vector the sum of it is still 0 bar 1 bar 1 cross slip and the answer is yes and no.

So, first let us draw what we are trying to say. So, this is let us say it is on one of the planes, which is bar 1 1 bar 1 and you have extended dislocation meaning 2 partial vectors something like a by 6 1 bar 1 bar 2 and over here a by 6 bar 1 bar 2 bar 1. And there is they are separated by some distance d, this is the whole extended dislocation.

So, the question was whether it can cross slip and the answer is no. If the simple answer is no, but yes it is still possible, let us see how.

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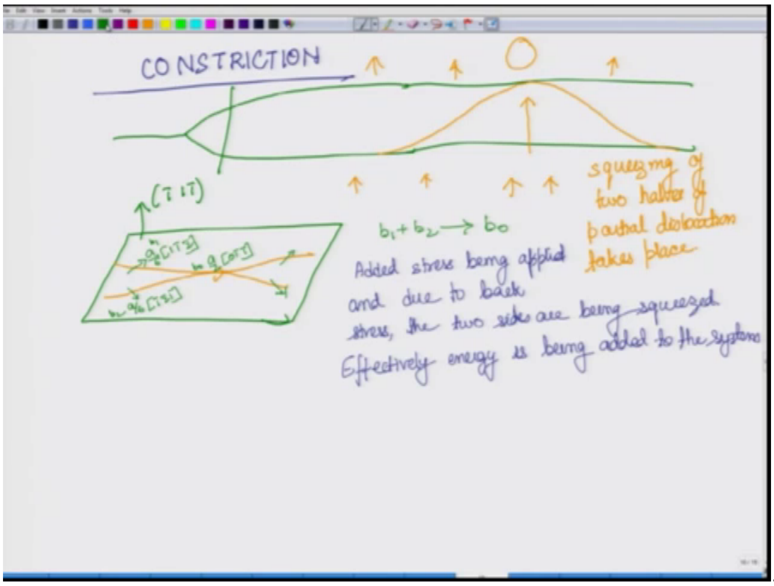

The answer lies in phenomena called Constriction. We saw that a dislocation line like this, it gets dissociated and it is something like this. So, in effect you will have, so you would in general you would what you would see is 2 parallel lines and let us forget about this part. So, we have we look at 2 parallel lines where, one of them is the leading partial the other is the trailing partial. But now let us say that, you apply some form of energy or some back stress acts onto this leading partial and you keep still keep applying. So, this is moving originally it was moving, let us say but and you keep applying and there is some obstacle comes in and you keep applying stress and in effect energy.

So, what will happen? This part is not able to move, but this part keeps moving and therefore, you would end up with something like a so, this part has moved and got constricted. You know understand the meaning of the word constricted meaning constrained or trying to or basically, it has been pulled together or pinned together, constricted that is what is happening over here. The two parts of the partial of this dissociated partial dislocation they get constricted, they get forced or squeezed together, so, this is what is taking place, so the squeezing of two halves of partial dislocation takes place.

So, let me now try to put it in more perspective by putting a actual value of some plane. So, let us say we are talking about bar 1 1 bar 1 and I will keep using these planes because, we have already looked at the possible dissociation reactions one over here. So, let us say this is so, this is the region which where it is constricted and over here the burger vector and what will be the burger vector over here? We know it is we know from the earlier problem that we solved it will be 1 bar 1 bar 2. Similarly here, it will be a by 6 bar 1 bar 2 bar 1 and it is same over here also some because, it is still on the same plane, where these b 1 if you can call it b 1 b 2 this is b 1 b naught.

So, this is b not, this is b 1, this is b 2 and we have something like so, at this particular place what is happening is b 1 plus b 2 is getting converted to b naught. And how is that possible? That is possible only when you when there is some added stress being applied and due to back stress, the two sides are getting squeezed. Effectively you are adding because, you can see this is a reaction which is energetically not favorable. So, effectively you are adding energy into the system. Effectively energy is being added to the system. So, how will it cross slip, let us see.

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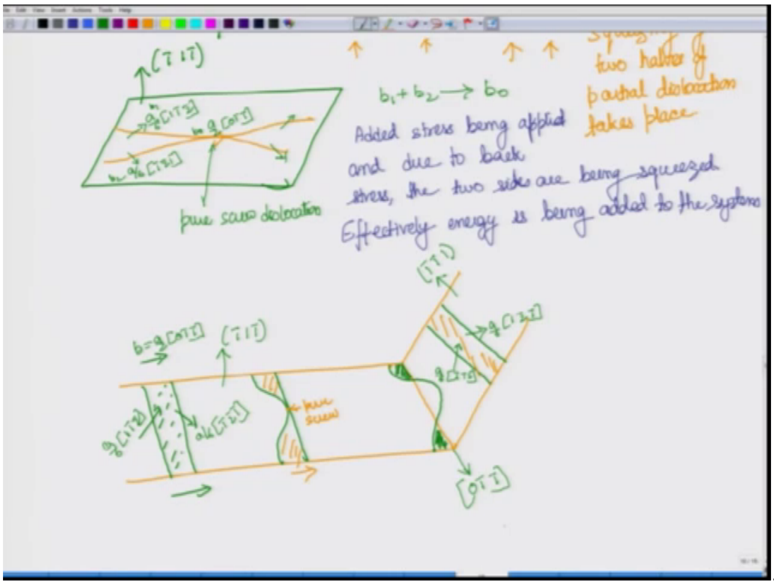

This is now once it has constricted; so, at this particular point what is it? At this particular point it is pure screw dislocation and we know that pure screw dislocation can cross slip.

So, let us see what happens at this point. Let us say this is the, let us say this is the this is our dislocation which has been dissociated. So, this is I am shading it to just to show that this is stacking fault region. So, there is some stacking fault and we already know that there are some burger vectors associated with it and I will again note down those. And let us say while and it is that it is moving in this direction. So, at some region because of some added energy or because there is back stress some region gets constricted. So you have something like this.

And I will have to draw it, so that it is parallel ok. So, this is now the constricted region that we have been talking about. So, this is pure screw as I said mentioned earlier also and rest of it is the stacking fault and it will keep moving in this direction along with this and there is this one let us say there is a particular because of again some obstacle it wants to cross slip.

So, now this is something like this will happen. So, this particular region which was the pure screw dislocation first intersected this line and then, I we know that the pure screw can cross slip. So, the pure screw cross slips and the rest of it is for the mixed dislocation and it remains like this and up to this part you can you still have the stacking fault. So, this is the constricted region and this is the extended dislocation region and once again once it moves on to this place. So, let us say it has completely moved on to this place, so now, it can again expand. And remember at this particular point we should also keep in mind what are the burger vectors.

So, this particular what was this plane, this plane was bar 1 1 bar 1 and what is this plane, this plane is bar 1 bar 1 1. There are not more possibilities than this, so there is there is no doubt of confusion here. Now over here the overall burger vector we know, burger vector is equal to a by 2 0 bar 1 bar 1 and over here, the partial burger vectors we know is a by 6 1 bar 1 bar 2, over here it is a by 6 bar 1 bar 2 bar 1. And when it comes over here, it is now on a different plane. So, when it expands this time the burger vectors are different.

So, that is why more important thing most important thing that I wanted to stress here. So, now, this particular dislocation, this partial trailing burger vector is a by 6 and you can go back to the previous example and see that, this one is bar 1 bar 1 bar 2. This one is a by 6, 1 bar 2 bar 1 and as you can clearly see these two partial burger vectors are different from these two partial burger vectors. And what will be this line vector, now this is a pure screw dislocation at this point and the overall burger vector is a by 2 0 bar 1 bar 1.

So, this must be 0 bar 1 bar 1. And that you can also again cross verify from the Thompson tetrahedron that, these two planes intersect at this particular direction. So, this is the direction and when only when the constricted region coincides or intersects with this direction that, it can cross slip; once it cross slips, it can again expand and when it expands, it can it will expand in with burger vectors of different characters or of different value.

So, there are a few more things that we should understand about this constriction.

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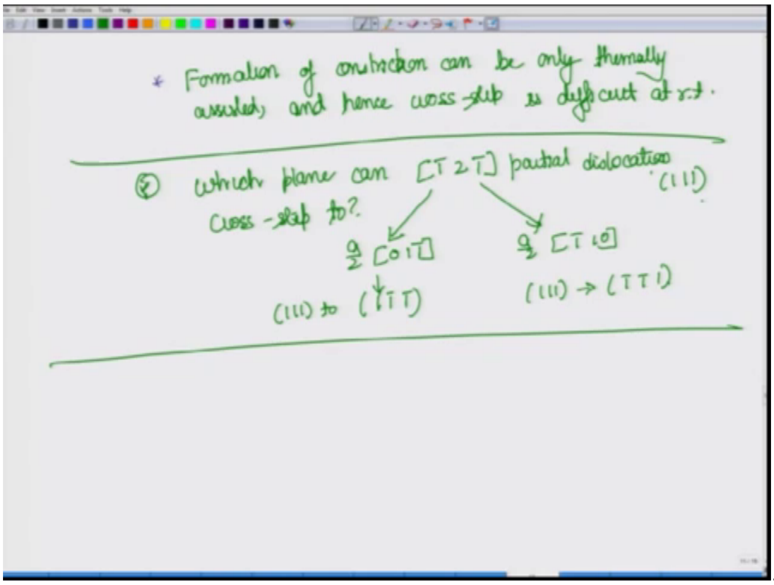

So, let us see before we end this part. The formation of constriction can be only thermally assisted. And hence, and this is the reason that, you do not see it at room temperature ok. So, this is one important aspect about it. Now before I end this lecture, there are few more things that I want to leave you with about the FCC. There are so many other things that we have we there can be about to learn about FCC dislocations, which we will see in the next part of the course. So, for example, can you based on what we have taught you say, which plane can bar 1 2 bar 1 partial dislocation cross slip to?

So, the answer is not very difficult. So, first if you can if you have followed the lecture carefully, you would know that this is a partial burger vector and it lies only on one plane. So it cannot cross slip. However, it can become a part of one of the full burger dislocations and in that case, it can cross that full burger dislocation can cross slip. And what are those full dislocations? There are actually two different full dislocations, one of them is a by 2 0 1 bar 1, the other one is a by 2 bar 1 1 0 and again each of them are common on 2 different planes, this is already on our bar 1 1 bar 1 plane.

So, this will cross slip onto 1 bar 1. Actually, this is not on this 1 1 1 plane and my mistake. So, this particular one lies on 1 1 1, so it will slip from 1 1 1 to 1 bar 1 bar 1 and this one will slip from 1 1 1 2 bar 1 bar 1 1 ok. So, this is something that i hope you have been able to solve on your own. There are there is one more thing that I want you to worry consider.

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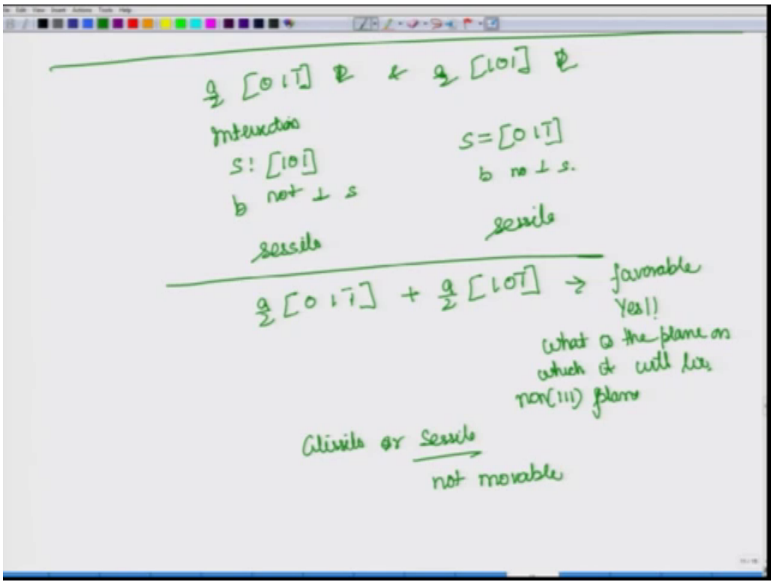

So, let us say you are given a by 2 0 1 1 bar dislocation and a by 2 1 0 1 dislocation and we have also talked about the phenomena of intersection. So, tell me what will be the step direction over here and you would see the step direction is 1 0 1 over here, because this will be the burger vector step direction here would be 0 1 bar 1.

Now, what do we see, this is the burger vector, this is the line vector; are these two perpendicular, no they are not perpendicular. So, the burger vector is not perpendicular to s, here also burger vector is not perpendicular to s. So, this step that has formed, this cannot lie on any of the possible 1 1 1 slip planes and therefore, this will be sessile, this step that we have formed will be sessile. Now the last, if the last equation that I want to leave you with is look at this equation, these are two dislocations and let us say that, these two dislocations combine So, first you have to find whether, this reaction would be favorable and I will give you the answer, you have to just look at it what will be this answer would be yes it is favorable.

Second is what is the particular what is the plane on which it will lie is it. So, what you will find is that it lies on a non 1 1 1 plane. So, that answer also I am giving, but you have to find the specific which particular plane. So, what that mean is it glissile or sessile, answer is it will be sessile that is not movable and this is something called as lock dislocation lock.

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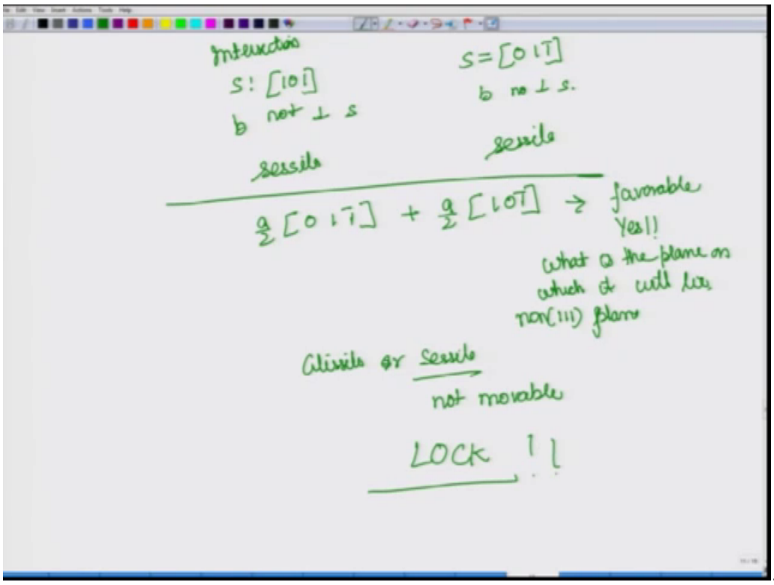

So, I will leave you with this curious thought, what is what a dislocation locks, there are several kinds of dislocation locks particularly in FCC. So, you look through it and next time when we meet will be discussing about the bcc dislocations so.

Thanks.