**Defects in Crystalline Solids (Part-I)**
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Lecture - 38
Partial dislocations contd…+ Stacking Fault

So coming back to our vectorial representation of the Burger vectors, so let us say that this is our original Burger vector and it splits into partials.

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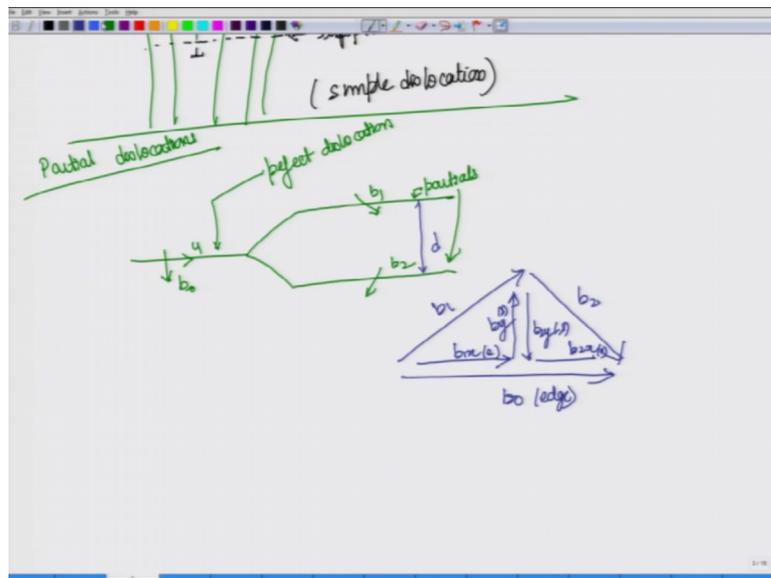
So, this one is edge remember that part and now when we have this partials b 1 and b 2 so the component and here the line vector is like this. So, remember the line vector is like this for the original vector, so the line vector like this and we assuming that this is also the line vector for the b1 b 2 and in this particular part there will be transition phase, but over here looking at it u remains same.

So, when we come to the resolving partial Burger vectors along the x and y axis, what it means is that b1 x is actually nothing but a edge dislocation. So, this is e b 2 x is similarly dislocation and b1 y and b 2 y are actually screw dislocations ok. Now what do we see here that there is a pair of oppositely signed screw dislocations and if we assume something like this where the distance between them is d, then we can find out or we can write a equation for what should be the forces between these screw dislocations.

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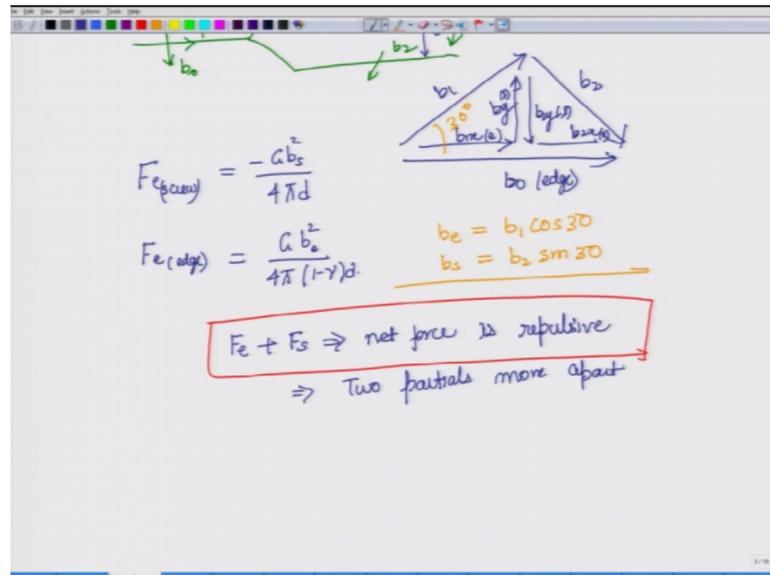
For oppositely signed dislocations whether it is edge or screw we know it is attractive. So, we can give a negative sign to it, so it will become minus Gbs I will write s for screw will find out or will write it in what exactly this will boil down to in a moment Gbs square by 4 pi d and there is also force between the edge dislocation of these are in the same direction. So, there is edge dislocation here there is edge dislocation here distance between them is d and this will be repulsive in nature. So, the sign will remain positive and there will be 1 by nu in the denominator, so if the Burger vector I have written as e so this is but now what is this b s and b e. So, whatever we had here as b1 or b 2 which is of the form b1 is of the same type as b 2 is of the same form as a by 6 1 1 2 and the angle here we know is 30 degree that you can find out directly from geometric.

So, now the Burger vector for the edge dislocation would be cos 30 of this, so let us say let us call this as b 1, so this will becomes b1 cos 30. So, the b edge is equal to b1 cos 30, similarly the Burger vector for the screw dislocation would become b 2 sine 30. Now when we put this over here you can I will leave this exercise to you, that what will be the net force, will it be attractive or repulsive and as you would see that it would actually come out to be net force is repulsive, meaning that this partial will repel this partial. So, they will want to move away from each other, so that 2 partials are like this and because of the repulsion they will want to move away from each other.

But what happens when they move away from each other, so this is important information that we have here that F e plus F s this net force is repulsive. Which implies that two partials move a part, now it is the two partials which are moving apart and if you look at it in terms of the extra half plane what it would look like is something like this which is not a very very good scenario in terms of a energy and a little difficult to draw at the same time so let me ok.

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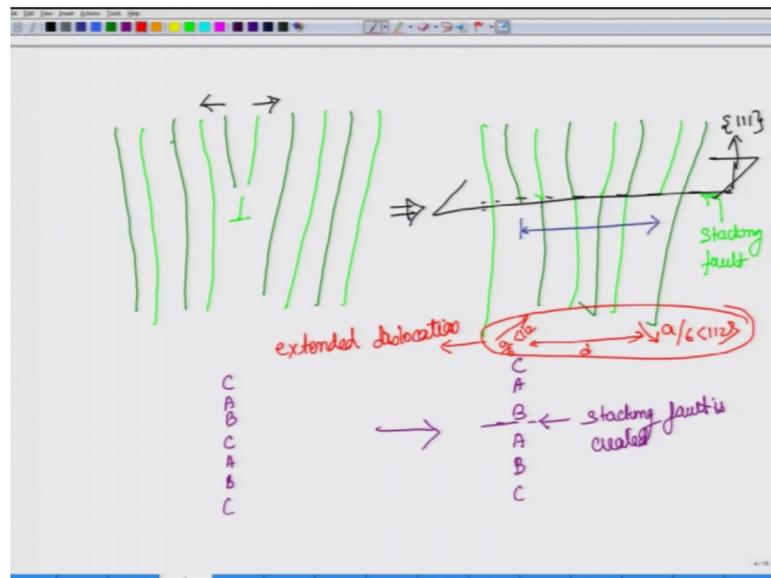
So, I will have to first draw what we already had earlier, so if the dislocation was perfect this is how it would be and in the alternate planes we had like this and now. But these are the 2 extra half planes that that perform part of the partials and they will want to repel each other, so they are repelling each other and what you will get is something like this. As I said it is not very easy to draw I am just trying out here to draw this and let then I will be able to explain to you. So, now what do we have here so I have already made a mistake here ok. So, here this was your extra half plane which is dark green color this is extra plane light green color, so this is the perfect crystal.

But now these to want to move apart so extra green plane comes over here the lighter green plane comes over here, but the bottom side of it were still in the same place because only the top particles are moving and because of that what you will get called as a stalking fault. You remember now let me remind you again that this is what is this plane, this plane is of the type 1 1 1 and 1 1 1 have A B C A B C kind of packing.

So, in this particular case when your partials are just move apart then it displaces and it forms a the atoms nearest neighbor atoms and what you will get. So, in this particular case if they let us say it was something like C A B C A B. So, this is A B C A B C sequence that should have been there, but now after this what will happen for the region in between these. So, we are only talking about region in between these because, beyond this is still perfect crystal, but in between this region what will happen is C A B.

Now, here C should have come, but now it will be the A type of plane, so now there is a repulsion there is there would be energy extra energy because now these 2 atoms are setting one very close to each other which is not there low energy configuration and because of that the energy in this particular region increases. So, now it will be beyond this only at this particular layer there is a stacking fault. So, this is the stacking fault which I have represented over here, so this is plane is same as this plane so this is the stacking fault and in another words what you have is a partial dislocation like this which is of the type n by 6 1 1 2 and there is this width d and then again another partial dislocation a by 6 1 1 2.

So, this whole system this is called extended dislocation, this whole thing is called the extended dislocation and it will act for most of the cases it will act like 1 unit, so if you apply stress it will move simultaneously and so on. But more important aspect is that now we have a stacking fault energy over here, which means that there will be some energy associated to the region wherever this stacking fault has been created. So, if the thickness is d and the energy would be so, energy would be proportional to d.

While, F net would be inversely proportional to d, meaning it would become smaller and smaller as d becomes larger and therefore there will be equilibrium spacing of partials. What do what I am trying to say is that the width of the extended dislocation would be dependent on material properties and it is not very difficult to show that this width would actually be proportional to G b square by 4 pi gamma. And, what is gamma here this is the stacking fault energy and to be precise let me again draw where is this d. So, this is one partial this is another partial there is stacking fault and this whole thing is wide d, the width of this is d which is what we are calling as the extended dislocation.

So, this d will be proportional to G b square by 4 pi nu, now so we have we see that based on the Burger vector, the stacking fault energy there is a fixed d. Now what you can observe experimentally is d so it and you already would know G and b it would also mean that you can find out what will be the gamma that is the stacking fault energy of the material and people have indeed calculated or not calculated based on this equation. Actually they have back calculated the energy and they have found that for aluminum the spacing is.

So, let me put it in a clean table so this is the spacing, this is the gamma and this is the material, so for aluminum people have observed that width is a smaller width would mean that gamma is very large and it does indeed come out to be 140 mille joule per

meter square, which is high as you would see compared to other materials copper width is 5 a much thicker and therefore the energy is smaller.

So, smaller energy means the dislocation partials are able to move apart much further away and silver is even smaller small again since the energy which would mean larger width. So, we get 7 a and this is the stacking fault energy that people talk about when this with respect to FCC, which is also related to the twin energy twin boundary formation and this has also to do with the partial dislocations. Now that we have discussed the partial dislocations I will pose one question to you, this one this particular extended dislocation was formed using a edge dislocation, so we assume that this is the Burger vector sorry.

So, we assume that this is the Burger vector this is the line vector and similarly here not similarly here this is mixed character, now that is another important aspect that you should realize that the partials are always mixed character because, or by default they are mixed character because as you can see the line is lying at 30 degree. So, if it parallel to the original u it will have a mixed character it will have both edge and screw character that is what we saw we when resolved b cos 30 and b sine 30.

So, this is what we saw assuming that this is a edge dislocation, now tell you have to go back and see if I were using a originally screw dislocation; so Burger vector is like this line vector is like this and therefore this would be a little bit different. So, b1 and b 2 these were these will still remain if as long as it is parallel to you, they will still remain mixed character. Of course, the real partial dislocations now that I am talking about let me draw it.

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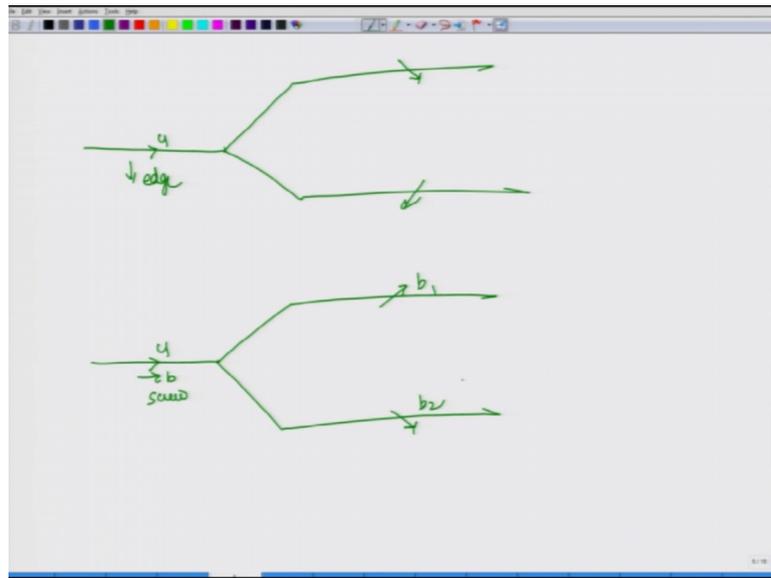
So, this is the one that we solved, the question is whether you will get net repulsive force when you are talking about as dislocation width parallel that is screw character this is screw and over here you can assume these are your and in most general case like I said partials will be mixed character ok.

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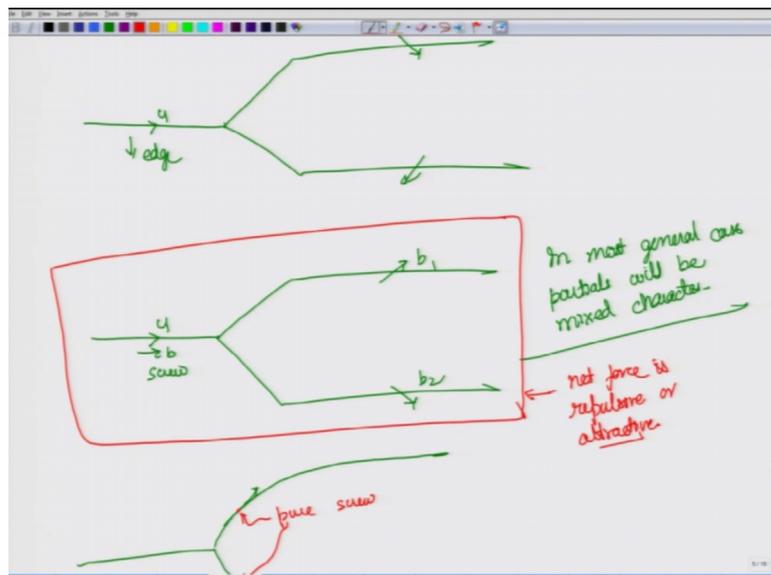
Now what I mean is that you can also have line going like this and since the Burger vector is like this somewhere over here it may still be parallel somewhere it may still be perpendicular, so there well just like in a regular dislocation there may be certain points

which are pure edge and pure screw. So, here it is pure screw and so on, so here also this will be pure screw, but in general it will be have a mixed character. However, what you have to go back and look is see whether the net force comes out repulsive or attractive ok.
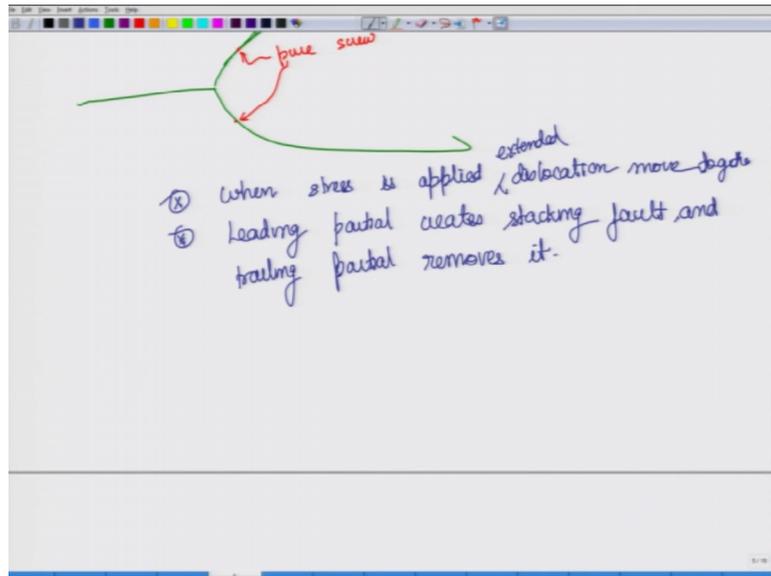
So, now few things before about this extended dislocation, before we move on to understand more about the partial dislocations sorry before we start to move about finding out ways to describe dislocation in a FCC system. So, when a stress is applied dislocations move together the extended dislocations move together, the leading partials now there are 2 dislocations over here. So, if we apply one of them is leading partial the other is the trailing partial, so the leading partial creates stacking fault and trailing partial removes it. So, these are some important aspects when we are talking about the partials.

Now, there are several possible type of dislocation and all of do all of them in the FCC dissociate into partials, what are the Burger vector for this how do we know about this and for that again we will have to go back to our FCC unit cell.

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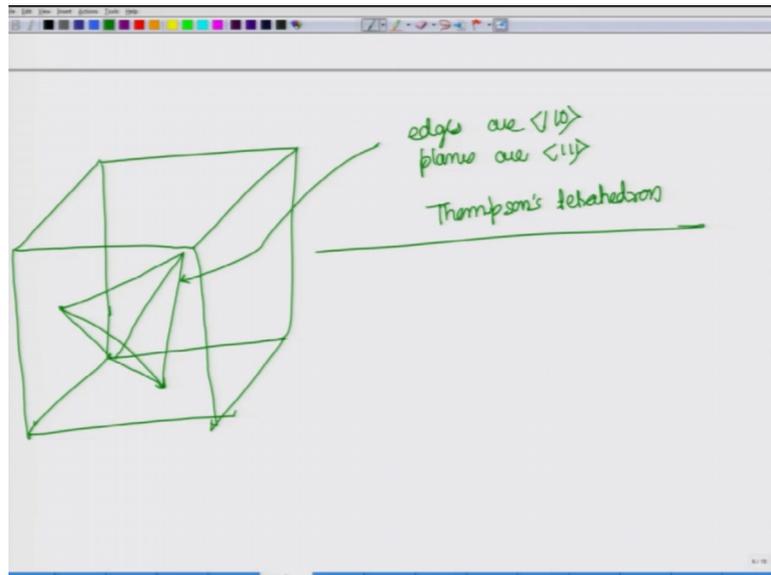
So, here if you connect these atoms which are the face center over here with the one over here like this, what you get is a tetrahedron and you would be able to see that the edges here are 1 1 0 and the planes here are 1 1 1 and this is called Thompson's tetrahedron. So, there is a model which has been made out using this function Thompson tetrahedron which very nicely explains all this edges and directions. So, now I will show you the model.

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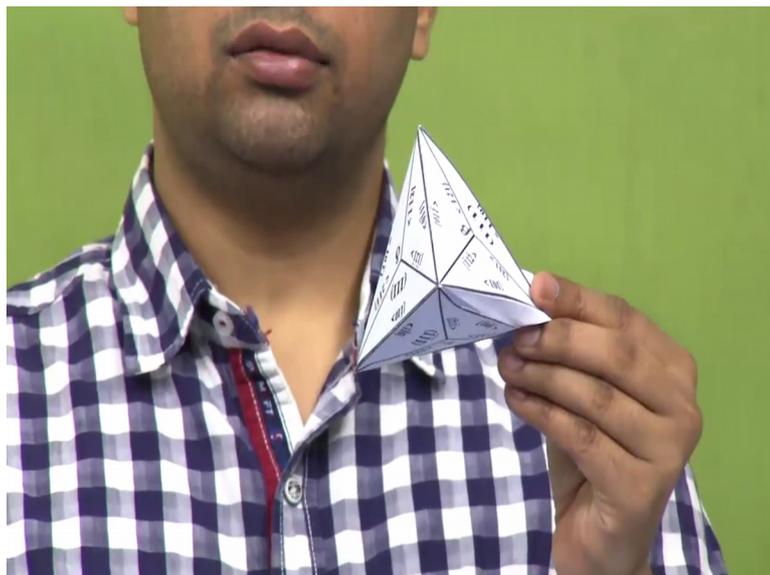
So, this is the model that I was talking about in the diagram that I showed you that it is the tetrahedral and you can see this is the tetrahedral it has 4 faces and each of the edges of this tetrahedral. Now if you go back in the diagram and then compare it with this you would realize that it represents one of the 1 1 0 direction. In fact, it covers all the possible 1 1 0 direction and all the possible 1 1 1 planes, so these are all the different 1 1 1 planes that are possible in the FCC system, these are all the different 1 1 0 deduction that are possible in the 1 1 in the FCC system.

So, what do we see we have 1 2 3 and 4 different 1 1 1 planes and of course, the negative of it. So, if you ignore the negative there are only 4 distinct 1 1 1 planes and how many 1 1 0 directions we have we have 1 2 3 4 5 and 6 different directions 1 1 0 directions for a FCC system. This is not all we get a lot more information from this Thompson tetrahedron now I will focus on one particular plane. So, now you look over here this is one particular 1 1 1 plane and I will rotate it, so that the 1 1 1 that you see is in the right orientation.

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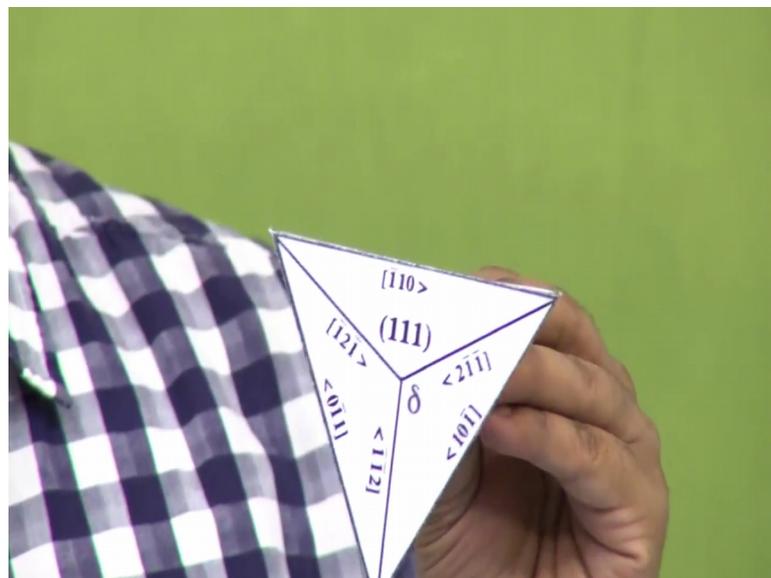
So, now this is re1 plane where in this particular case it is actually the 1 1 1 you get 3 different 1 1 0 direction and this 1 1 0 directions again we are just taking in not taking the negative, if you take the negative then there will be the other side. So, but in direction these are the 3 possible 1 1 0 directions.

So, it means that this particular plane can have Burger vector like this Burger vector like this Burger vector like this and if we are talking about pure edge dislocation. So, Burger vector with this will have line vector like this, Burger vector with this this Burger sorry dislocation with this Burger vector edge dislocation would have line vector like this dislocation with Burger vector like this will have a line vector like this. So, it is also giving us the possible direction for the edge pure edge dislocations.

Similarly, the screw dislocation which have to be parallel to the Burger vectors, so the screw dislocations will be oriented either like this like this or like this. Now what else do we see from this even before I go to the partials which is also information that you can obtain from this Thompson tetrahedron, another thing that I want you to observe is that. Now let us look at this is one type of 1 1 1 plane and now let look at another type of 1 1 1 plane.

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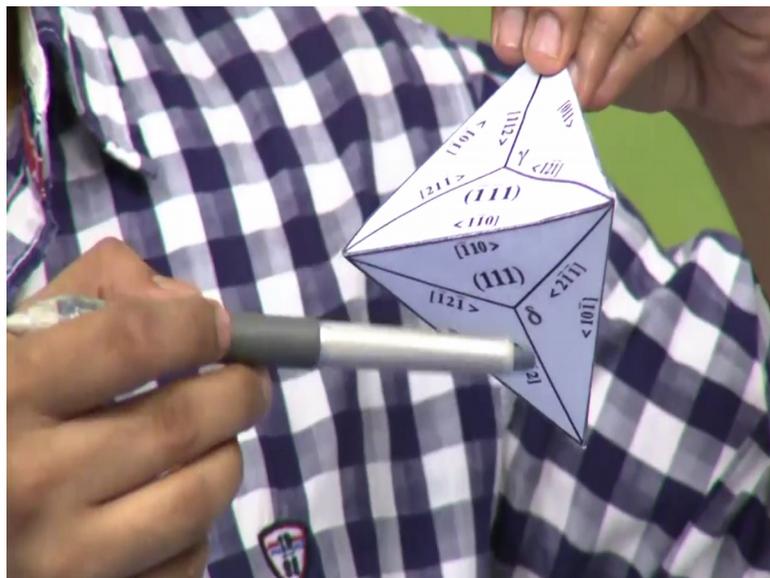
Another not type but another member of the family 1 1 1 plane. So, this is bar 1 bar 1 and 1. So, what the what do we see that these 2 planes have one common edge and this common edge represents the common Burger vector in the 2 planes. So, this is another important information that we get that, whenever that 2 planes there will be one common Burger vector other Burger vectors are not common. So, this particular plane can have dislocations with bar 1 0 bar 1 and 0 1 1 1 which is not common to this one. So, in other words it can it would mean that if you have a dislocation with Burger vector in this

particular case with the common 1 is 1 bar 1 0, then a dislocation with Burger vector 1 bar 1 0 can (Refer Time: 23:53) in bar 1 bar 1 1 plane or in 1 1 1 plane.

So, there can be a cross slip of dislocation and when we talk about cross limit as to be screw just keep that in mind. So, screw dislocation with this particular Burger vector can cross slip only on to this and you remember we solved one example where we showed that the p 1 that there was a dislocation moving from p 1 to p 2 to 3 and we when we said that p 1 1 p 1 and p 3 have to be same there cannot be any other possibility. So, there is these are the only 2 planes and therefore if it moves from here over here then it can only move back to this one because, the Burger vector does not change. So, this particular dislocation with the constant Burger vector can only move in either of these 2 planes.

So, that is another important aspect that we see from the Thompson tetrahedron. Next what else do we see? We see that there are 4 different planes and all the 4 planes are connected to the other plane at least by one common direction. So, it would mean that it will mean 2 things one that every dislocation will have will be able to every dislocation in FCC if it is a screw dislocation will be able to cross slip. Another that it will be able to cross slip only on to 2 different planes, it cannot have any third option and next that all the 2 all the planes would be connected with each other, they can be connected in the sense that here we have one common Burger vector for each. So, if you see 1 1 1 and 1 bar 1 this is the common one if you look at 1 1 1 and 1 bar 1 1 then you see that this is the common one, if you look at this one and this one then this is the common one. Similarly, for other planes we will have some common directions.

So, these are the information that we are able to obtain for full dislocation, now let us look at what is information do we get about the partial dislocations. So, yes Thompson tetrahedron is powerful that it gives you also information about partial dislocations. So, let us say this is now full dislocation Burger vector, now that these 2 directions that you see over here these 2 directions which are almost at 30 degrees not almost it is exactly at 30 degree, they are the Burger vectors of the partial dislocation for the dislocation that is sliding on this plane. So, remember all though this particular direction is common in 2 planes, but if it is sliding in this particular plane then it can get only these 2 Burger vectors as partials. So, for this one bar 1 1 0 Burger vector of full dislocation it can dissociate into bar 1 2 bar 1 and we will this is in this directions. So, will have to take the other direction which will become bar 2 1 1.

So, that will be that 2 partial Burger vectors and you see that your calculations or your mathematics of FCC becomes so easy using this Thompson tetrahedron, you do not have to apply your brain. Whether it is you should apply your brain, but you do not have to do the calculation every now and then to find the dot product and find whether it is coming out to be 0 or not, so all those information are inherent over here. Now still one more aspect that we see over here is that these Burger vectors they are not on the edges ok, the partial Burger vectors they are not on the edges they are inside the plane. What does that mean? It means that these that these partial dislocations cannot cross slip, even if they are screw dislocation they will be confined to only this particular plane; it cannot move on to from this one to this one.

So, if you are let say if you this happens to be the line vector of the partial dislocation, so it will come as dislocation. But unfortunately for it this is the only part only plane on to which it can glide, it cannot glide on to the other plane. So, these are some very important aspects that you are able to get from it, you are able to get the full partial full Burger vectors. You are able to get the partial Burger vectors, you are able to get the planes on which the dislocations can move and you are also able to find where they will cross slip. There are more utility to this and we will come back to this when we talk about it in the next lecture.