Defects in Materials
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Lecture - 26
Extrinsic Faults and Thompson Tetrahedron in FCC

Welcome you all to this course on Defects in Material. In the last class, we looked at how to visualize intrinsic stacking fault. Today, we will try to look at how to visualize extrinsic stacking fault, and then we will also consider different types of a reactions by which a perfect dislocation in an fcc lattice can split into partials. And the interaction of this partials which are moving in the same slip plane as well as in other slip planes in different slip planes, their interaction we will look at it. And the last point, which I would like to concentrate today is on the need for Thompson tetrahedra and how it helps in understanding the different dislocation reactions this is all we would like to cover.

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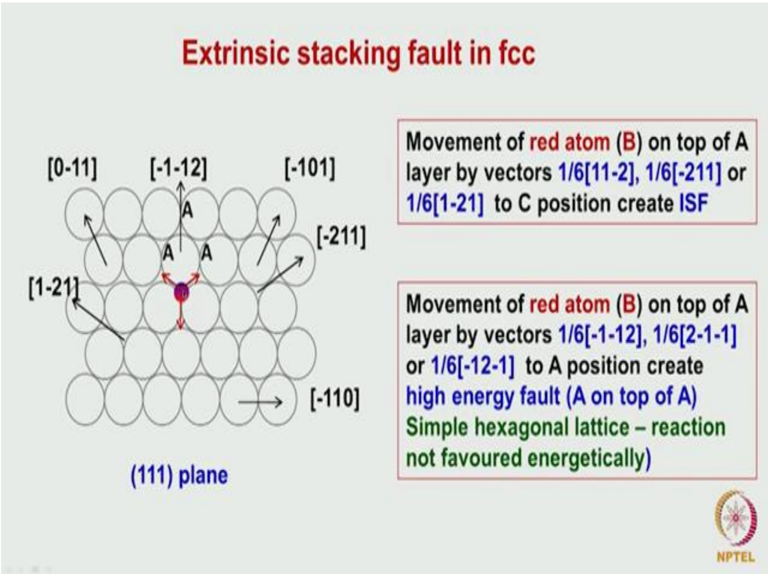

Because we mentioned in the last class, that if you look at this picture this is an A layer and that atom which is there on a B layer, this B layer atom if it moves from here to here, or from here to here, or here to here generates a stacking fault. So, this vector is specific.

If we consider moment of a this atom from here to this position, or in this position, or in this position which is essentially nothing but the reverse of these directions that will lead to essentially a high energy fault that is what is expected. Or what will happen is that this atom this B atom will be brought to this position which is on top of A, so it will generate a sort of a hexagonal lattice, this is essentially. Whereas, here it moves from here to here this position it comes to a position which has got the same energy as the position which is occupying, but only it changes the stacking sequence that is what an intrinsic stacking fault is. We will try to understand how a moment of atom from here to here and an extrinsic stacking fault they are equivalent.

So, here what I had just shown is that what all the different perfect lattice translation vector directions which are being shown, these translation vectors also can split into partials, and depending upon the direction which one will create extrinsic stacking fault which one will create intrinsic stacking fault we will look at it just after some time.

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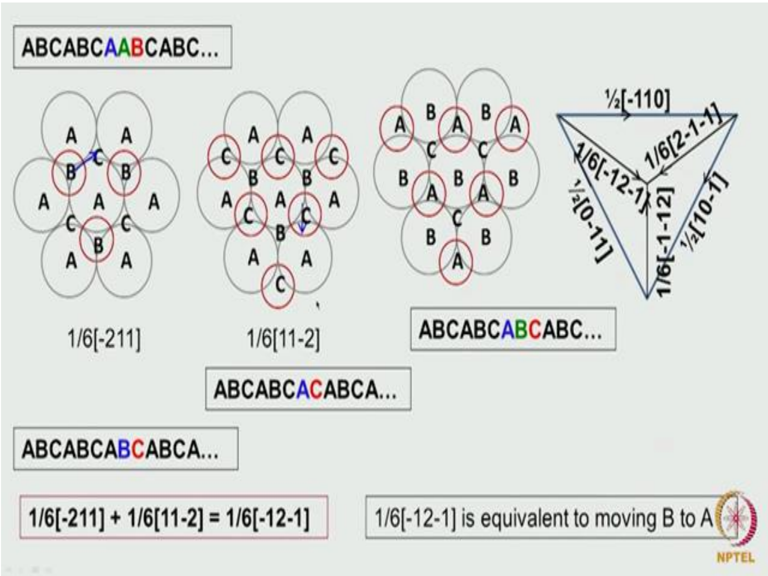

You look at this stacking of this layer, which is being shown. This is a atom which is shown large is in the A layer; atom on the B layer is shown here, and this is the position C layer where if an atom which is sitting on this A layer in B position. If it moves from B position to C position that will create an intrinsic stacking fault. Here I had shown just the one particular section of a Thompson tetrahedra are essentially, what I had shown on 1 1 1 plane what all the different directions corresponding to perfect translation vector as well as partial vectors. If you see from here to here, this corresponds to a vector moving from here to here. The vector from here to here perfect translation vectors is one moving from here to here; the one from here to here represents a vector which moves from here to here. And then a vector from here to this center or a vector from here to here, or a vector from here to here, they represent all the partial vectors that is what essentially is being indexed.

So, by a moment from B that is if you have to move an atom from B to C position essentially we have to move that translation will correspond to a vector which is 1 by 6. This direction is 1 by 6 to 1 bar 1 bar; opposite of it the reverse direction, so it will be 1 by 6 2 bar 1 1. So, if we give 1 by 6 2 bar 1 1 a translation, it will be moved from here to this particular position. Now, that is what is being shown in this slide. When the translation has been given that B atom has been positioned, so the B side is there those atoms which were there at B side now has come to the C side. Then when that comes to the C side, what is going to be the stacking sequence it is ABCABC. After A then the C comes then ABC like that the stacking sequence will go.

Now, next what is being done is that now if you look this is the C atom position, the A atom position is below it. So, in between these 3 C atoms, A atom is occupying a position that is the layer below the C layer. And this is the B atom positions that is B side positions, if the this atom which is sitting at A position, if I shift it from here to here that will involve a translation vector 1 by 6 1 1 2 bar, you can make out from here. That when I give that translation then what is essentially going to happen is that this A atom comes to this position B position that is what essentially is being shown here; not only that atom that shift is given to all the layers which are above that also A layer.

So, this A atom comes to this position, then the C atom which is there it will also shift to a new position that is essentially what is being the stacking sequence which is being shown here. That ABC ABC that A positions the BCA, now you can change no I think this is the position ABC BC AC AB CA correct this is what this position corresponds to. So, now it has reach the position, which is essentially here fault which is their existing on two layers. And this reaction if we now try to look at it here what we have given 1 by 6 2 bar 1 1, this is on the above the A layer, this is the translation which is given. Now, below the layer and above we had given a translation 1 by 6 1 1 2 bar, these two together will give rise to a translation 1 by 6 1 bar 2 1 bar, 1 bar 2 1 bar, 1 by 6 1 bar 2 1 bar is from here to here. That is essentially nothing but from here to this position that is from here to high energy position the B atom the atom occupying B side is moved from this position to this position is by this vector 1 by 6 1 bar 2 1 bar.

So, essentially what we have done is that by introducing intrinsic stacking faults on two layers, so the atom is being moved from one position to an identical position only though only an extra surface is being created. By doing this process, we are able to generate that is we are able to give it to the lattice an effective moment of atom from one position to another, which is equivalent to from here to here, this is how an extrinsic stacking fault is generated.

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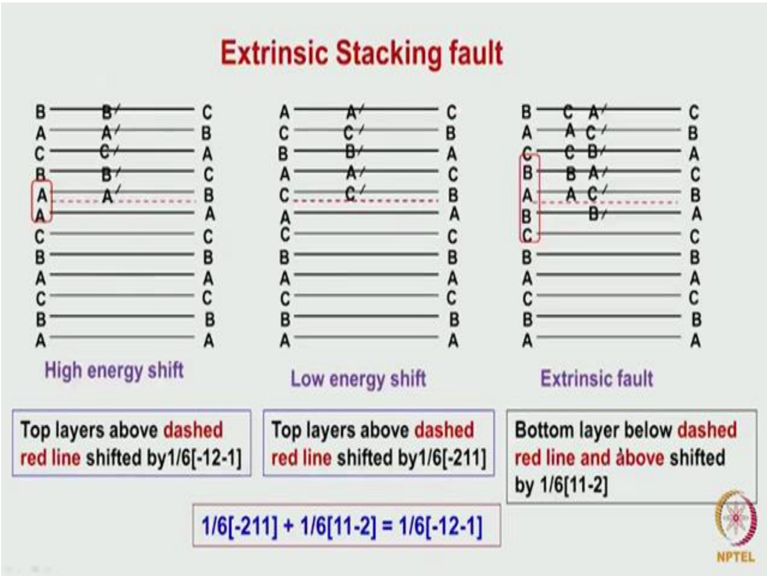

In fact, that same thing I had now just shown what I had shown with respect to a figure because there 1 1 1 layer, we were looking directly at the different layers along 1 1 1 direction. Now, we are looking at these layers, what we have done is essentially the layers are this line represents a cut section of the layer the layers are perpendicular to the screen all the layers are going like this. So, this is the ABC stacking sequence, movement of a partial by this above this it changes from B position, it moves to here that is by this vector 1 bar 2 1 bar if it moves it will bring a atom to an a atom position. So, this moment of a partial here will move all the atoms above also by the same sequence of shift and that gives raise to this sort of a stacking sequence. So, this is essentially a high energy position which is not allow.

So, instead how what we can do, what we did in the last case also that is in the previous slide also as I explained. The B atom that is above this layer B atom is shifted to C position, so this is how the stacking sequence have become CA, CA, it creates only an intrinsic stacking fault. Now, the layer above A layer, I had moved it from here to a B position. By doing that and not only that all by when I move it to here, all the layers above also will be shifted by that same way. So, when that shift is implemented, the C will move to A, this A will move to B, B will because it is a moves by one dislocation which has moved it here and the next dislocation in the another plane when it moves it moves it from here to here. So, now the stacking sequence has become CB AC like that.

This sort of fault, which are created are called as extrinsic stacking faults. The same reaction is given here. But what is important about this stacking fault is that the energy of this fault since it involves movement of atom in two layers more energy has to be spent, thus stacking fault energy is roughly one and a half times to two times that of the intrinsic stacking fault energy that is what the observation is.

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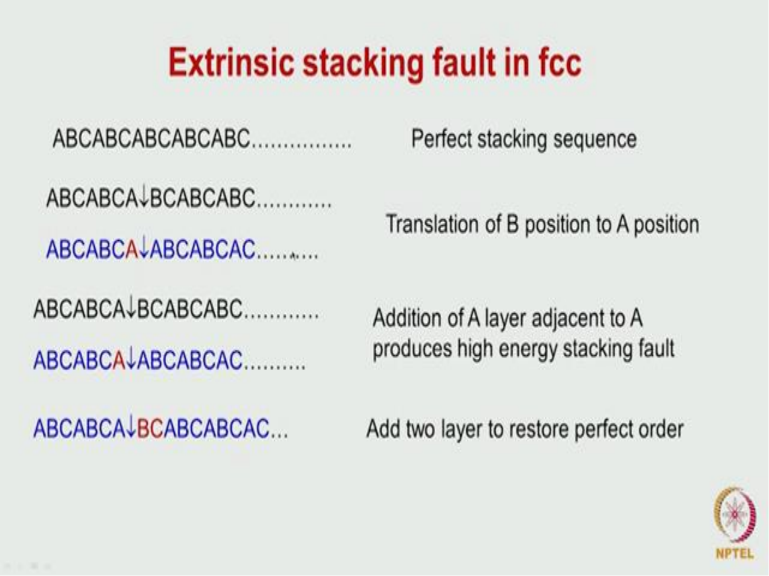

So far we considered the change of stacking sequence, there is another way the change of stacking sequence could be considered. I am showing it to various ways of perceiving the same perceiving the generation of the same extrinsic stacking fault. Here what I have done it is I have just written the stacking sequence this is a stacking sequence in along 1 1 1 direction in a perfect lattice. Now, at this particular point here, the B positions are all there, this B is shifted to an A position. If I do it the translation of B position to because above A there are two options are there B can be shifted to C position, or B can be shifted to an a position. If we shift it to A position it gives rise to a high energy fault correct.

What is the another way in which it could be done. You look at this stacking sequence, in this stacking sequence, if I introduce between a I and B another A layer that will also give rise to the same type of a structure that is either by shift of an atom or by introducing a layer also, we can generate the same type of a fault. But this again will also be a high energy stacking fault correct, because here we can understand something is much better than the way it has been shown. The earlier micrograph when you show with respect to the atomic positions layers the different layers then the advantage is that we can see the vectors and understand how the vectors change. Here we are just looking what the stacking sequence which has changed only looking at the stacking sequence.

In this or in this structure, whatever be the way we have generated this is what essentially is the stacking sequence which has form. To restore order we have to introduce two atomic layers correct then the order could be restored. Whereas, if you remember in the case of intrinsic stacking fault, if we introduce one extra layer that is good enough to restore the order, here we require two layers to restore the order. And the fault vector also if we try to find out essentially corresponds to nothing but how many layers have to be adder or subtracted. So, in the case of an intrinsic stacking fault, when since one layer has to be added, the stacking fault sequence if you look at it or if you remove one layer that is the vector of the defect which has been generated.

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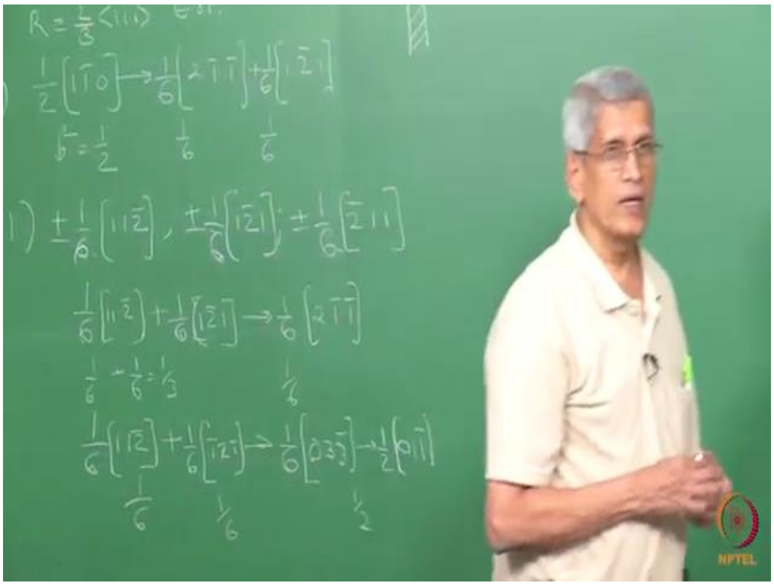

So, the fault vector for intrinsic stacking fault you can write it as 1 by 3 1 1 1 type; here the fault vector will turn out to be this is for intrinsic stacking fault, this is for extrinsic stacking fault. This is essentially we considered as a high energy fault, which normally does not occur that sort of a moment. What is the way in which it can be done? Instead of adding, we considered one way in which shifting of atoms on two layers we can create the extrinsic stacking fault which is equivalent to moving an atom from one position to a high energy position that we have considered.

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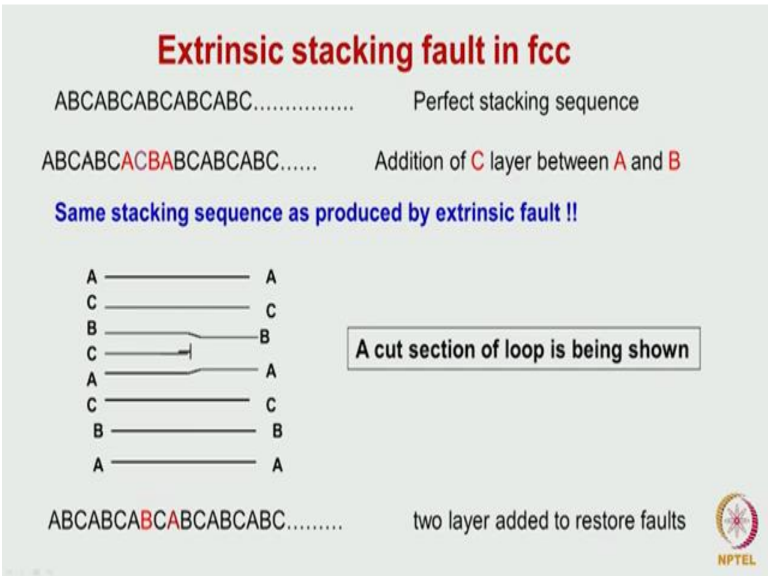

Now, we are looking at another way. The other way is that if you add one more layer to a perfect stacking sequence, but now it is not between A and B, between B and C or between A and B instead of adding A layer if I add A C layer then what will happen the stacking sequence will become ABC ABC CA CBA. This now becomes the same as by creating intrinsic stacking fault in two layers, how we achieved the extrinsic stacking fault, the same stacking sequence comes. Because you see here, here B added between A and B another one layer, but in position which is an A position. Now, what we have done is between them we have added an another layer on top of an A layer which is essentially in a C position. Because all other layer atom positions remains that same, this produces the same stacking sequence is produced by extrinsic. You can see it here this is ABC, ABC it is there. I am showing just one half of it the loop you look here; here I had added one layer partially when this layer has been added the rest of the layers remain that same.

So, now if you look at the stacking sequence, it has changed, it becomes the same as that of an extrinsic stacking fault. This type of fault is nothing but an interstitial fault that is by adding one extra layer in between we can generate interstitial loops. Interstitial loops are nothing but extrinsic stacking fault. So, essentially if I take a mirror reflection of it the other part would have come that is what it would have been a section of the fault.

In this fault also, I have to add two layers that is corresponding to between A and C one layer has to be added a B layer, between C and B, one A layer has to be added. So, if I add two layers, I can restore the order a perfect lattice could be generated. So, this extrinsic fault which is generated also is equivalent to now you can see that in both the cases by addition of only two layers whether the atom is shifted from one low energy position to a high energy position or by creating fault on two layers to restore the fault essentially two atomic layers have to be added to restore the fault. So, the fault vector will turn out to be as I have mentioned the same value. Is it clear?

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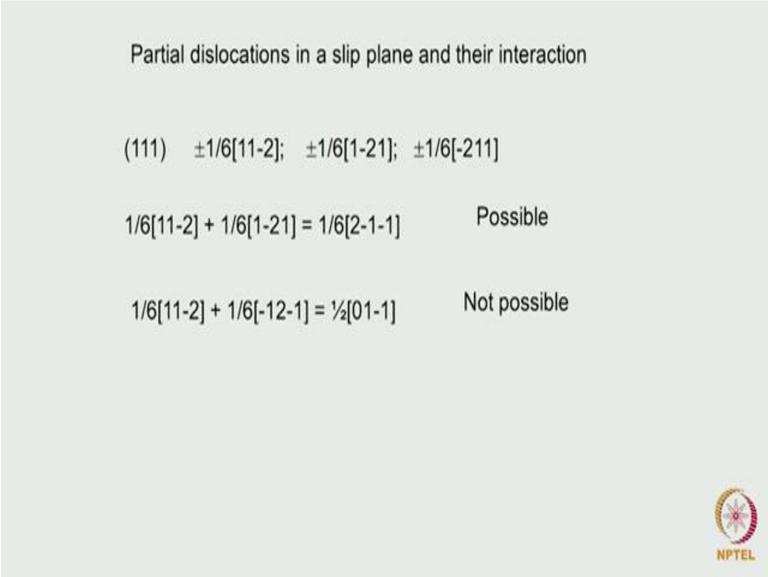

Let us consider some possible dissociation of dislocations into partial. Because what we have considered it how a movement of the partial dislocation generates fault. We know that in a material, whose stacking fault energy is very low, the dislocations would like to split it into partials that is the first tendency which dislocation will have because when its splits into partial, over all there is a reduction in energy of the system instead of remaining into as bar 1 that is this dislocation.

Student: (Refer Time: 19:44).

No this is 1 2 bar 1, if you add both of them together this will become. 3, this will become 3 bar, and this will become 0, this is correct. And what is going to be the B squared value here is essentially half here it is 1 by 6 here it is 1 by 6. So, because of this, this reaction is permitted because the stacking fault energy gets lower.

When the stacking fault energy gets lower that is one part of it. The other part is that these two dislocations essentially are in an orientation, where a repulsive force acts between them. If you try to calculate the force between these two dislocations, it will be repulsive that means, that this dislocation will try to move apart. But when they start moving apart the dislocation is present here, and it splits into a partial - two partials with a region between them. And assume that this width of this region is extremely small even smaller than initially when they have started splitting, smaller than that of the burgers vector. Then when it tries to split some surface has to be created, because a fault is created in between stacking fault is created between these two partials that means, some fault is created mean some extra energy is required to create that surface energy will be required. That surface energy is balanced by the gain in energy, which is going to happen between this dislocation splitting into partial.

Now, what is going to happen is that if the stacking fault energy is very high even at a distance which is very small the gain in energy is being balanced. If the stacking fault energy is small the separation between the partials can be large, so that the width of the dislocation is quite large that is what it will happen in the case of low stacking fault energy material. So, you essentially these are all the reaction by which the dislocation can split into a partial perfect dislocation, and this reaction which we have considered is on 1 1 1 plane.

Let us see what all the types of partials which we can create in 1 1 1 plane. These are all the type of partials which we can create in 1 1 1 plane. This will all be 1 by 6 because these are all perfect translations. So, this is going to be the burgers vector of the partials. These partials we can try to look at suppose we have one partial which is there 1 by 6 1 1 2 bar it interacts with an another partial 1 by 6 1 2 bar 1. What will be the net resultant one 1 by 6 2 1 bar.

Student: 1 bar.

1 bar correct. So, here if we consider it is 1 by 6, this is also 1 by 6. So, total becomes 1 by 3, here it is 1 by 6. So, this reaction is possible correct.

Let us look at that same dislocation reaction. This reaction, but the burgers vector of one of the partial is reverse 2 1 bar. Now, what is going to happen is that this will turn out to be half 0 1 1 bar. Now, the B squared is 1 by 6, here it is 1 by 6, here it is going to be half, so that means, that this reaction is not possible, that is a dislocation perfect dislocation can split into partial. But a partial dislocation, if they have to join together and form a perfect dislocation, it will not happen under equilibrium condition. We have to apply a lot of stress to make these two dislocations joint together. This is the take home point from this reaction, so that means, that energetically this reaction is not possible.

Then let us consider interaction between partials. Now, we have considered interaction between partials which are lying in the same slip plane; only this type of reaction will happen whichever be the combination which you consider. Suppose, consider a partial which is lying on an another plane 1 1 bar 1 also, a similar reaction we can write it. Then we can find out different combinations which will give raise to energetically favorable reaction, which we can find out, that part of it because there are many reactions will be there many types of possible burgers vectors of dislocations will come partial dislocations. That part of it I would a give it as an assignment which you can work it out and find out what all the possible reactions which gives raise to which are possible, and energetically possible which are not energetically possible. But I will consider a case where a reaction which is possible. In that case, when the dislocations interact, what is the sort of a burgers vector of the dislocation, which is being produced, as a result of this interaction.

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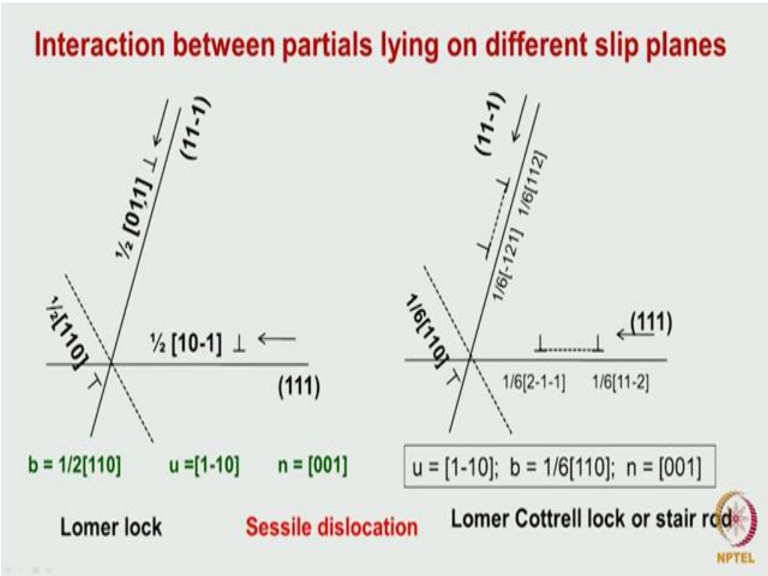

This what I have done it is taken the case which we have considered earlier in the case of a perfect dislocation where perfect dislocations moving in two slip planes which have interacted together and formed a Lomer lock. Now, we assume that since the stacking fault energy of the material is low, this dislocation has split into partials on each of this plane. The reaction by which this dislocation can split in 2 is given here; and the reaction by which this dislocation can split energetically favorable reaction by which it can split that is given here. So, these are all the two partials.

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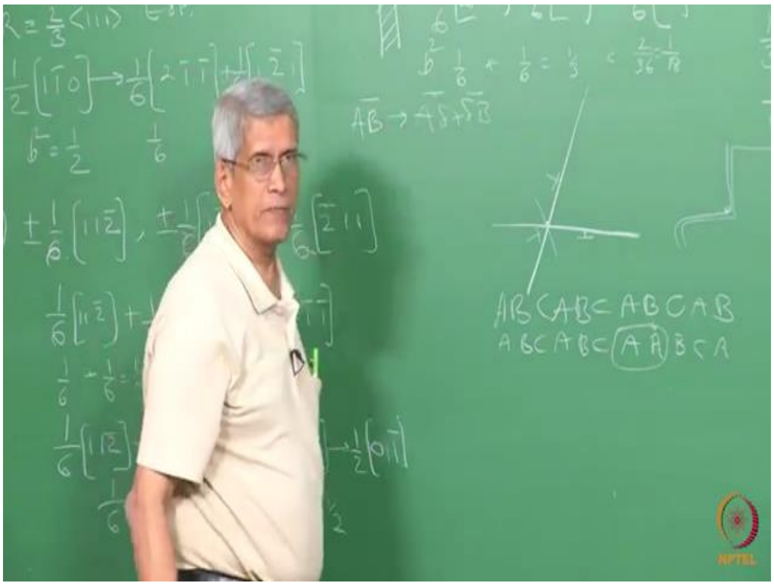

Let us look at these two partials. This dislocation is moving in this direction this moves in this direction. When they come and interact the net sum of these two interactions what it will turn out to be, this is 1 by 6 1 bar 1 bar.

Student: (Refer Time: 27:42).

Since this is 1, this is.

Student: 1.

1.

Student: 1.

And this is turn out to be 0. Look at the self energy, here it is 1 by 6 here it is 1 by 6 is B squared and this will turn out to be 2 by.

Student: 30.

36 correct, so it is 1 by 18. So, here it will be this plus it will turn out to be 1 by 3. So, this is small, so this reaction is possible correct. But if since by interaction of these two dislocations a new dislocation is formed that dislocations line direction has to lie in the intersection between these two slip planes, the intersection between these two slip planes, the line direction will be 1 1 bar 0.

So, but the line direction and the burgers vector are perpendicular to each other that means, that this dislocation is a edge dislocation. If it is an edge dislocation then u cross b will give the slip plane the slip plane will turn out to be 0 0 1; that means, that this dislocation is going to lie on a plane which is the density of packing is very small. In such a case, the friction stress is very high, so this dislocation is a sessile dislocation this sort of lock is called as the Lomer Cottrell lock.

There is an another name also is being used which is called as a stair rod of dislocation. Why it is called as a stair rod, is that is a dislocation which has formed here one dislocation has come here there is an another dislocation is there these two are also two partials which are there the other two partials have joined together and formed a dislocation here with a burgers vector like this. Now, this looks like a staircase [FL] that is you have a staircase in which you remember that in a staircase when we put

Carpet, what do we do to hold the carpet in place we put a rod, so that the carpet can be kept in a staircase like this by putting a rod here and anchoring it that is called as a stair rod. For the stairs, we put it that is the name, which is being given to this sort of dislocation. Is it clear?

So, we have considered the energetically possible reaction which we have considered. There are many other reactions which one can consider like this, there are many types of each of the reaction give rise to different type of partial dislocation; some of them will be a stair rod dislocation. And most of them are going to act as obstacle to moment of perfect dislocations that is what is responds that is what it adds to the dislocate forest of dislocations. Any dislocation which has got a low even a perfect dislocation, if it is lying inclined with respect to the slip plane and the result shear stress in that plane is small that will also act like a perfect dislocation. So, there are many dislocations with different type of burgers vectors can be there in the forest dislocation these dislocations also add to it.

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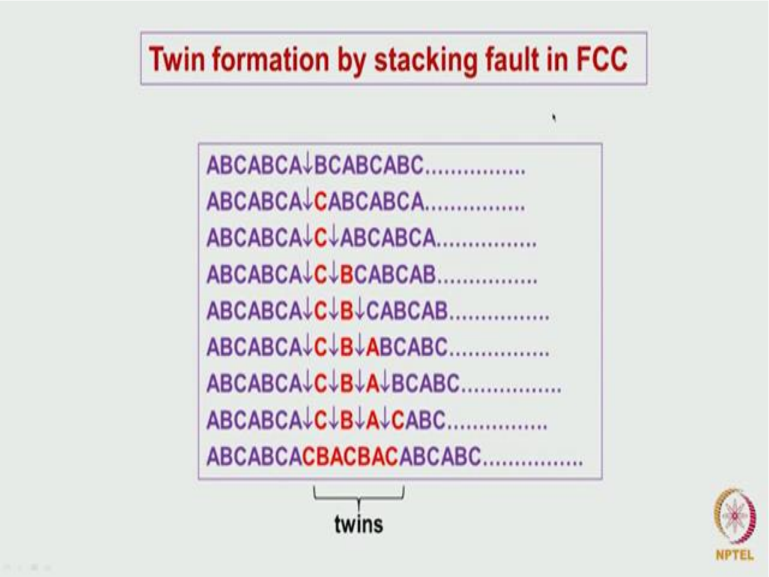

Another example which I wanted to take as a arc the other one is that we consider the stacking sequence. Just looking at the stacking sequence we found that how intrinsic stacking fault can be formed, how an extrinsic stacking fault can be formed. Suppose, I form an intrinsic stacking fault on every layer, so what has been done is that this B atom has been moved to C position, your stacking fault is created now CACA, it has come. Now, the atom just next to it that is this a atom is moved to B position, so I create another intrinsic stacking fault. So, this has become C B then the atom next to B this C it is moved to A position, so it creates another intrinsic stacking fault.

Now, if you look at it, the stacking sequence has become CBA, and then if I can move B to another one, this B is being moved, so it become C. Now, if you look at the stacking sequence CBA CBA like that it becomes. So, across this plane the stacking sequence on this side is ABC, ABC, this side is CBA CBA, one is a mirror image of the other. That is by moving a partial dislocations we generate intrinsic stacking fault on every layer, we can create twins. These sort of twins are formed in materials which have got low stacking fault energy during deformation. And generally the name which we used to describe them are we call them as micro twins. This terminology which you might have seen in many papers they say the micro twins (Refer Time: 33:55) form.

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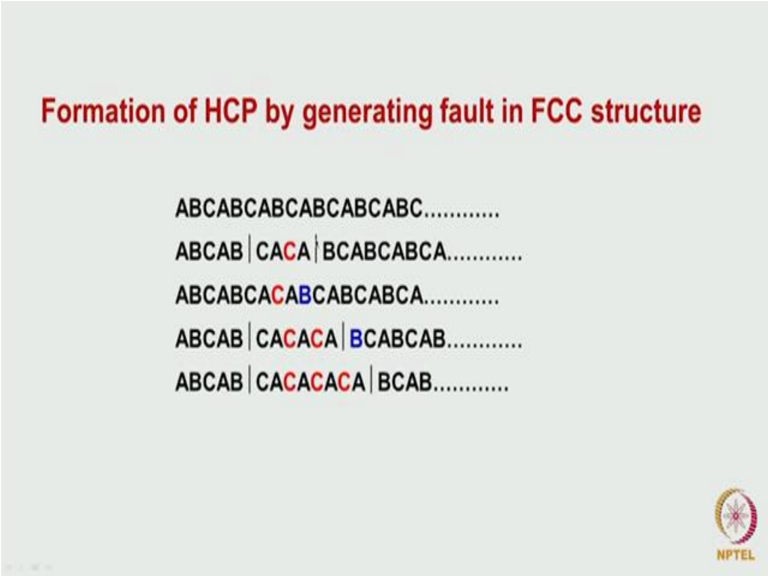

Just let us consider the case in which not in every layer, but every alternate layer an intrinsic stacking fault is created. So, here what we are considered an ABC ABC stacking sequence. Then this C layer is there; after the C layer, ABC ABC this is ABC. This B layer is moved to C layer then this layer will move. So, this is how the stacking sequence is, now what I do it is that this layer B layer, this is A layer, this is the next layer this is being moved to an another layer that is not this layer I said a alternate one. Alternate one means that you leave this and come to the next one. So, this B layer is again shifted then will go to a C position this is how the stacking sequence .Then the next alternate one if I move it then this B layer will come to a C layer.

Now, if you look at the stacking sequence this is ABC, ABC, now we are able to form CA CA CA CA that means, an AB AB type of a stacking sequence. This way by creating overlapping stacking fault, but creating stacking fault not on every layer, but on every alternate layer, we can generate hexagonal close packed lattice. Or hexagonal close packed lattice itself can be considered that is formation of hexagonal lattice can better they are related by a defect structure, that is by generating stacking fault in fcc, we can generate a hcp structure. There are many structures are rare in ordered alloys where or in disordered alloys by generating either stacking fault or in the other case and deface boundaries that is the fault vector, which is not a vector in the real lattice, we can generate another structure.

Like here itself we can take an another example we considered the stacking sequence like ABC, ABC. If I move this B layer to an A position, this will become B, this will become C like this it goes. So, this if you see it AA means that that is hexagonal the arrangement of atom in each of this plane is hexagonal, one on top of the other creates a symbol hexagonal.

That is. So, this is also an another type of a transformation. So, any partial vector in a lattice will generate another lattice. So, these lattices you can consider at that is defect related lattices, which we can generate this way.

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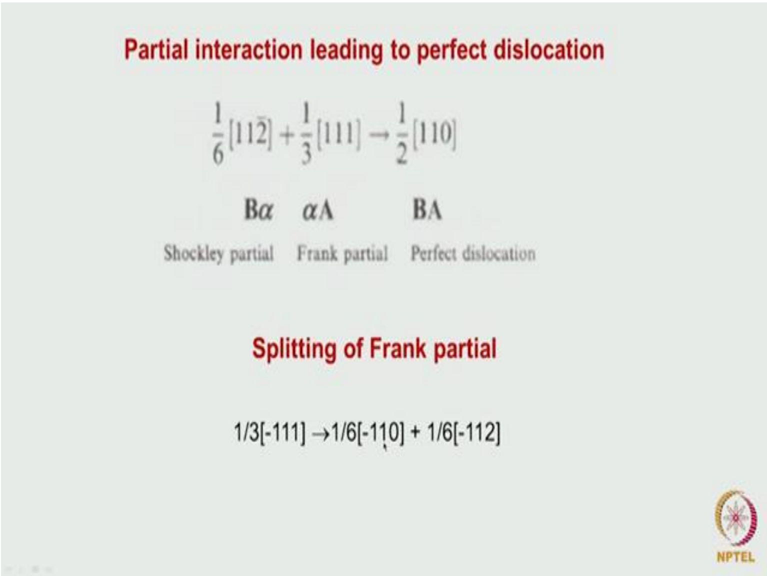

What all the other type of reactions, which we can consider. So, far we considered partials and these partials are called as Shockley partials that is all partials 1 by 6 1 1 bar 2 type are called as Shockley partials.

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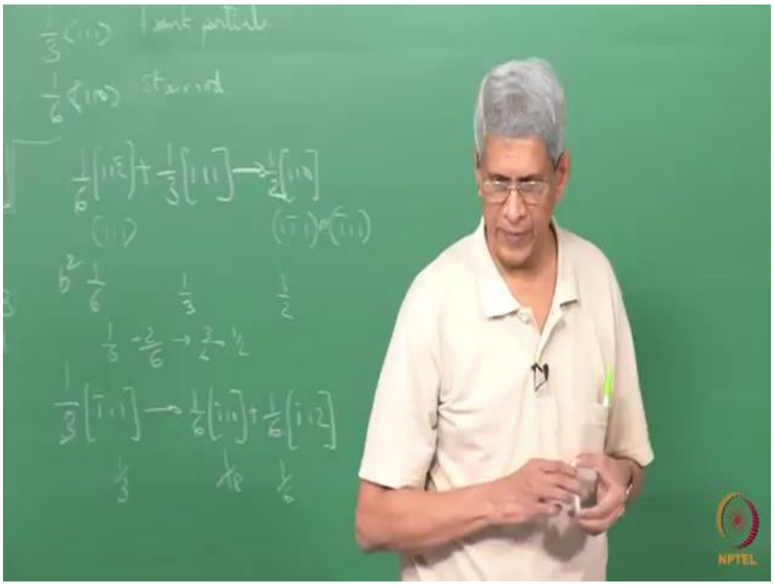

1 by 2 1 1 1 type, they are called as Frank partials; then 1 by 6 1 1 0 type, these are called as.

Student: 1 by (Refer Time: 37:57).

Stair rod, there are 1 by 3 also, there are many are there different names are being given. Suppose, here we are considering a case where there is a partial there is a frank loop is there it is in lying on 1 1 1 plane. This one is a partial, this is also lying on 1 1 1 plane. And these two partials interact, what happens they generate 1 by 2 1 1 0 that means, that the fault is removed, because this dislocation has become a perfect dislocation. But in which plane this dislocation will be lying, this gives raise to half 1 1 0, here both the dislocations are lying on 1 1 1 plane. This dislocation is going to lie on either on 1 1 bar 1 or 1 bar 1 1 plane, because the burgers vector should lie in the direction should lie in the slip plane and that means, that the resultant dislocation have a burgers vector which is inclined. And energetically this is 1 by 6 B squared if we consider here what at the value it will be going to be.

Student: 1 by 3.

1 by 3, and this is going to be half. If we add these two 1 by 6 plus it is 2 by 6 correct. This will be essentially going half. So, this reaction is there, there is no net gain or loss and energy, but still this reaction can occur when we applied load, there because load can

till the balance of the reaction, it can supply the energy which is required for this sort of reactions to happen. That means, that during deformation if this sort of faults which have formed like in aluminum alloy when it is being quenched, this sort of vacancy loops are formed. Other dislocations or in many other alloys, some copper also when take that if this loops are formed in many of the in many nickel base alloys it has been seen. Then movement of these sort of a partial, but there is a very complex reaction I am do not want to go into a details of it, but in principle you can make out just by looking at the consideration of the burgers vectors that this reaction will un fault the loop itself.

Then another one which we considered is that your frank dislocation itself if you consider this can split into one with 1 by 6 1 bar 1 0 plus 1 by 6 1 bar 1 2. This is an interesting one; energetically this reaction is this will be 1 by

Student: 18.

18, this is going to be 1 by 6, and this is going to be 1 by 3. So, essentially this only a very small fraction which it adds; this reaction is energetically favorable correct. In fact, this is the reaction which is responsible for creation of stacking fault tetrahedra, I am not going to all the details of it, but you take it from me that this sort of reaction is responsible for a stacking fault tetrahedra is to be generated during deformation. Because in many radiated materials as well as in many silicon system, people have seen stacking fault tetrahedra forming in deformed samples.

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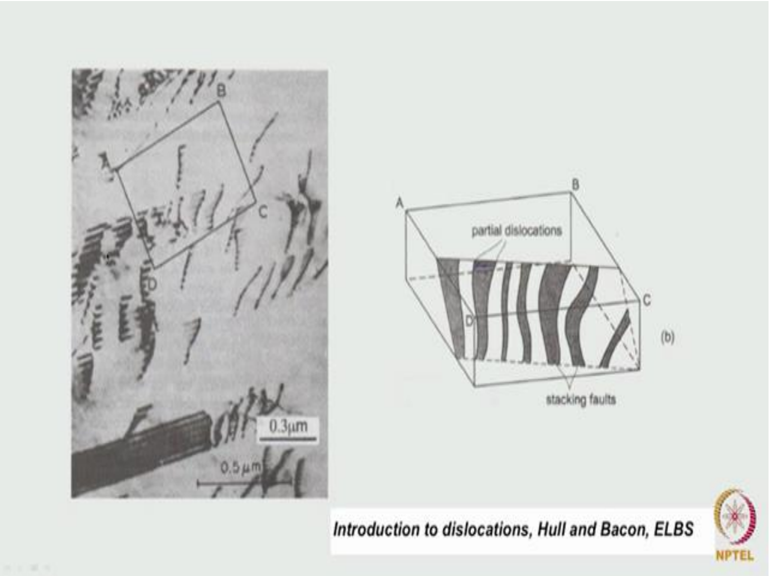

So, this is just to give a flavor of how in an electron microscope the faulted microstructure will look like. Is there here if you look at it this is all the dislocations are split into particles, so we can see their fringes corresponding to stacking faults. But at the end of it here we can see a partial, which is also visible in these cases in this particular one the partial is visible only on this side of it that all depends upon what is the sort of burgers vector which have used to image them that imaging condition decides whether the fault is visible or the partials are visible or both are visible, they all depend upon the different type of G vector which we used to image them. Here what we are trying to show is how in three dimensions part of the sample which was (Refer Time: 43:45), how the faults will be lying on those planes generating stacking fault between them.

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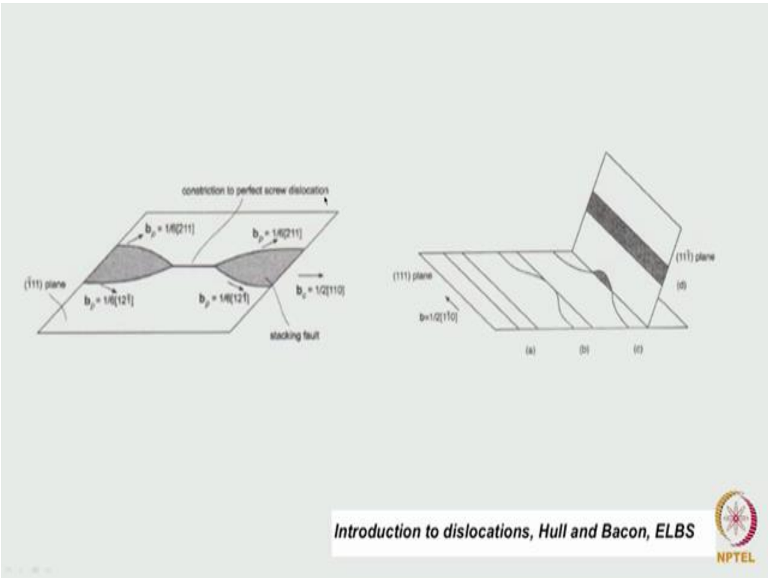

This is an another example, where we consider where the stacking fault itself has formed a constriction to a perfect screw. This construction only can cross slip because the when it has become a perfect screw dislocation if some obstruction is there to passage of the dislocation then it can cross slip that is what essentially is being shown here the constricted part has cross slip and it has again splits into a partial.

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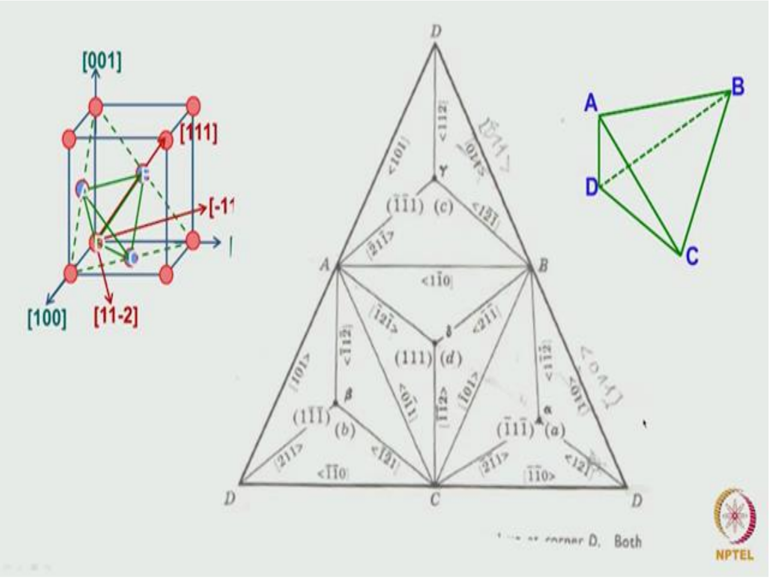

Now, let us look at Thompson tetrahedra. Why is a Thompson tetrahedral is important is that here when we load many of these reactions that is a perfect dislocation splits into a partial. Suppose, we apply a load to the sample in which direction which one has to be the perfect dislocation, because we have seen that one direction of a partial creates a intrinsic stacking fault; another direction creates moment creates a high energy fault. So, we have to be very careful about which is going to be the leading partial, which partial the moment of it generates a stacking fault which is the one which follows it, where the trailing partial which closes the fault and they move together. This has to be fixed correctly whenever we assign burgers vectors to the partials which are generating stacking faults.

For these this sort of an arrangement is good; not only that when we consider many deformation processes this Thompson tetrahedral extremely useful to visualize it. These are all the two aspects which I wanted to emphasize in this lecture. This is an fcc lattice; in this fcc lattice, this is the origin I had just shown the other atom positions which are close packed directions which are adjacent to this. If we join all these vectors together that forms a tetrahedral. You look at this tetrahedron joined by in this tetrahedron the points which are ABC which are joined together; this surface is nothing but a slip plane.

And ADC is another slip plane. So, this tetrahedron when we look at it, it represents nothing but all the slip planes. The surface represents the slip plane, a magnified view of the same is being shown here. Now, this vectors that all the edges represent perfect translation vectors because from here to here, or here to here, or from here to here, they are represents half 1 1 0 burgers vectors. So, they represent perfect translation vectors. So, edges represent perfect translation vectors. And the center of each of the surface if we consider and join them to these A, B and C here, and name it as delta because opposite to D, we are naming it as a Greek letter delta, then these form the partials of that type 1 by 1 1 2 bar type. These are all, so all these represents partial dislocations then from this d to this delta if I look at it that vector will represent 1 by 3 1 1 1 type.

So, essentially in this Thompson this tetrahedra the surfaces represent slip plane, edges represent perfect translation vectors, from the face center to all the edges, they represent the partial vectors, a vector of partial dislocations and then the corner to the opposite face center that vector represents the frank partials, almost all the dislocations which are there can be represented in this one structure itself.

Then the other convention which is followed is that if I look at this structure from outside that is from outside, I am looking into this structure. And if by a movement of a the translation vector here, we generate there is move atoms from one position to another position, which are atom sitting on the next layer. Those movements will be represented by some vectors, how exactly is done now we will describe, but before we go into it lets consider that this tetrahedra is easy to visualize it is good. But if you wanted to work with and find out the reactions looking at the tetrahedra is going to be very understanding it is very difficult. What we do it is that at the corner this d, we open out and then when we open it out, this will become like a plane surface correct, so that is what essentially is being drawn here. That is from that d we cut it like this all the surfaces and open it into a flat surface, then this is how the Thompson tetrahedra will appear.

And here all the line directions vectors everything is being marked. And this will be this is A to delta, this is the reaction. And what happens is suppose we look at a B this vector. AB can be written as A delta plus delta B this is how vectorially we will be representing it. This delta B is essentially if you look at it, if the movement when we look from outside onto this layer because the atom is there are another atoms which are going to sit on this surface and this surface as well as on this surface. The projection of an atom on this surface will be here that will be moved from here to a direction from delta B if it is moved that will create an intrinsic stacking fault. That is the convention essentially is that if we are looking into the Thompson tetrahedra from outside and displacements are being done on the atoms outside of this surface then delta B, delta C and delta A will generate intrinsic stacking fault.

Suppose, I look at the structure from outside, but suppose the moment of the atom is taking place inside of this tetrahedron that is equivalent to looking at an atom planes which is below the surface. They are below the surface if we look at it, then exactly the opposite will take place A delta, B delta and C delta will generate a intrinsic stacking fault in those cases. Both the cases intrinsic stacking faults are created, but in one case if it is above, it is going to be delta B, delta A, delta C. And if the vector the moment of the partial moves atoms below this plane ABC, then it will generate that is to create intrinsic stacking fault the burgers vector of the partial will be A delta, B delta and C delta. Actually, this will become very clear if you look at it.

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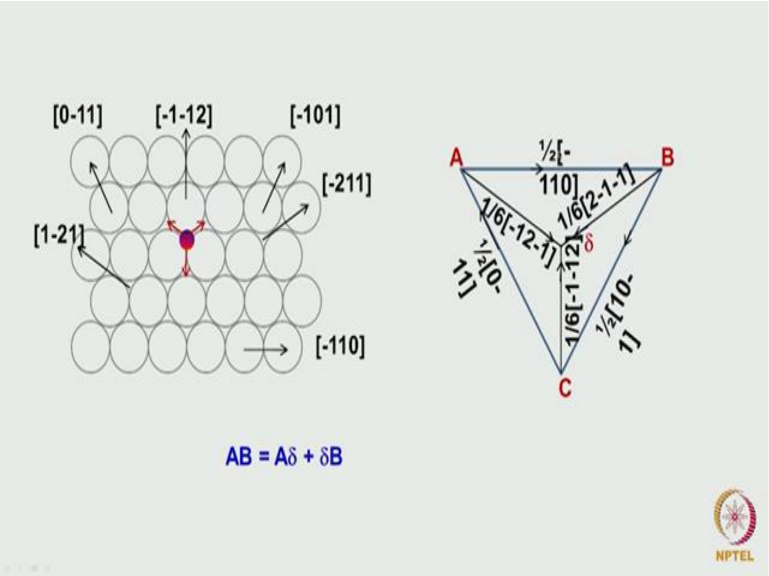

What I have done here is I have just shown only that one part at that ABC face of the tetrahedron which is being shown. You look at this atom, this is a atom, this is the atom which is on this layer the above it. If it is moved from here to here, this will generate an intrinsic stacking fault, or from here to here, or from here to here that corresponds to from this center delta to A, delta to B, delta to C, now it is be very clear.

Now, we look at an atom this is if it is A and this is B and the C atom has to come here, but below A atom, C atom will be there at this position correct that atom how it will be shifting. So, this C atom, if it is shifting in that position it can shift from here to here, or from here to here, or from here to here which is opposite to from here to here correct on the top layer that will create an intrinsic stacking fault. So that means, A delta, B delta and C delta will create intrinsic stacking fault. So, the convention which we do follow is that if we consider moment of atoms on the top layer then in this reaction which we have written delta B is the one which is going to create the intrinsic stacking fault.

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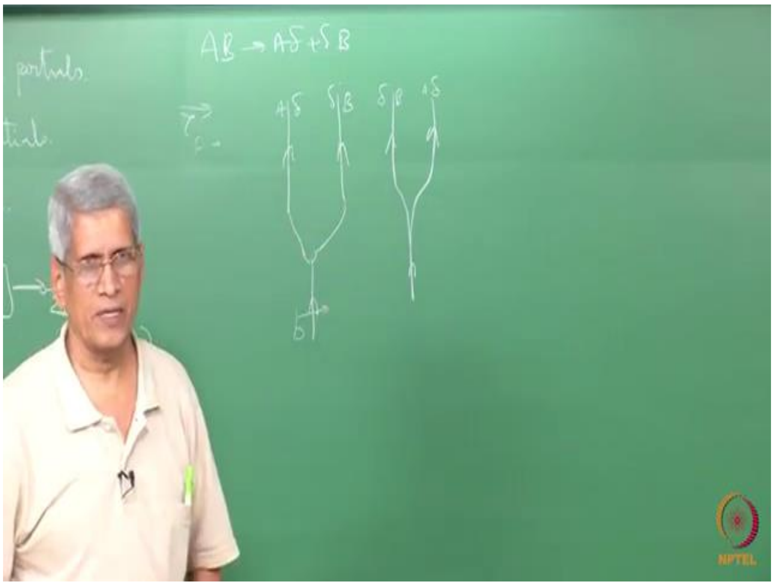

So, if we have a dislocation, I can write in that is a dislocation which has I will just join to routes. So, this is a perfect dislocation. This has split into a partial. And where to fix these two vectors is what it is, I apply a stress in this direction this burgers vector B is in this direction you assume this of the perfect dislocation. Then you know where the force on this dislocation is always if it is an edge type of a dislocation, the force is going to act in this direction. So, the dislocation will move in this direction that means, that as the dislocation moves which has split into partial, the first dislocation should create intrinsic stacking fault. That means, that the delta B should come here and A delta will come here, this is how it is being placed clear?

If the same reaction we consider that it is taking place not on the top layer at the bottom layer then what will happen is that in such a case so this A delta will be placed here, delta B will be placed here, because at the bottom layer is where the deformation is occurring. And the direction in which it is being moving is in that same direction, understand that. This can be fixed looking at Thompson tetrahedra following this logic very easily. Is it clear?

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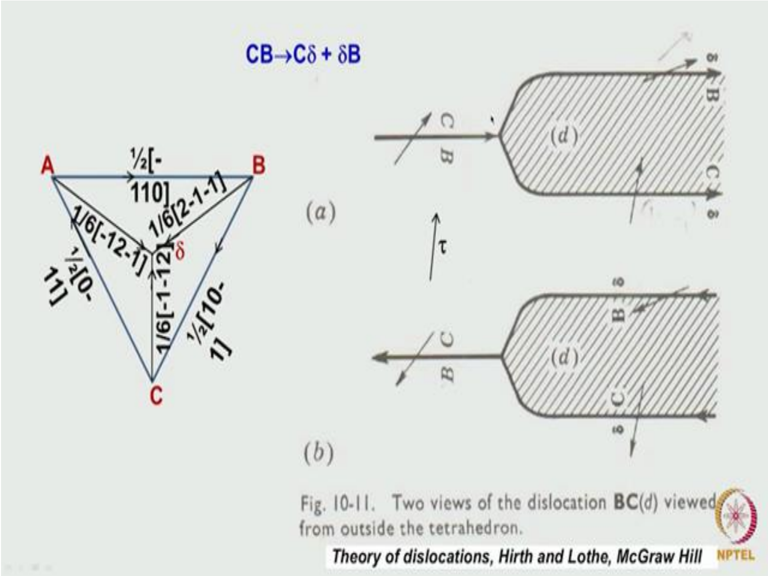

That is exactly what is being shown here we are considered a vector C B that changes into C delta plus delta B, we can see that here. In this case, this is the direction of the stress and the dislocation movement is in this direction, then the delta B will become the vector generating an intrinsic stacking fault. In the other case, where this is the direction of the burgers vector; now, we can see that a B delta becomes the leading one and delta C becomes the trailing one, is it clear?

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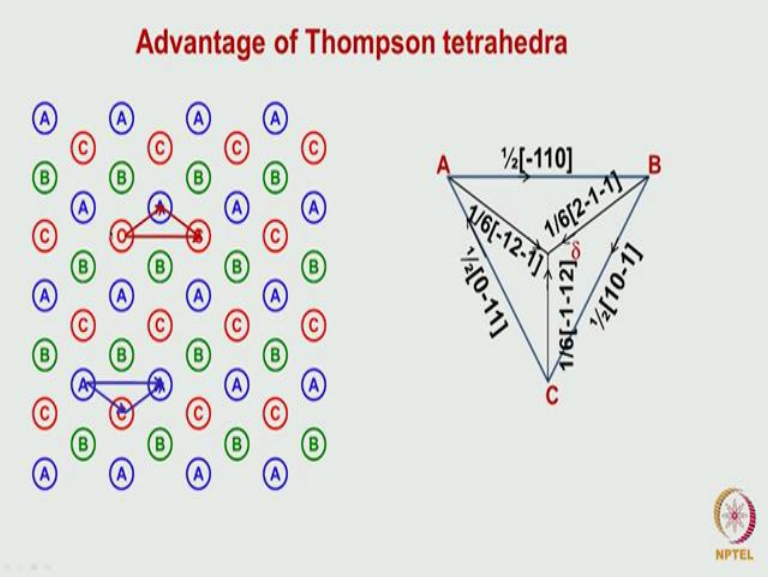

Essentially, the same thing is being shown here schematically. Now, you can consider that seep, but I will not spend time on it. I had shown it in this slide also in a different way how we can consider this various reactions that is the if you view from outside the tetrahedron, delta B will be the leading partial, this will be the trialing partial.

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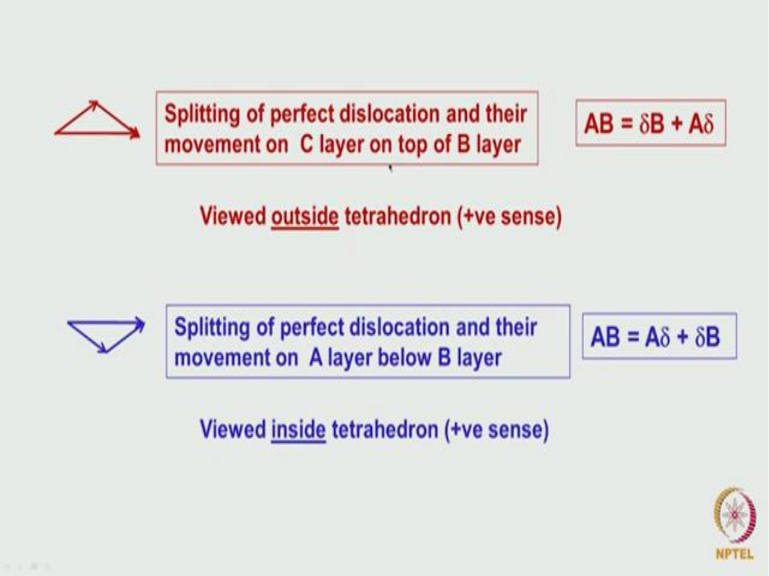

The other way round as I mentioned a delta will be the leading partial that is when we view from inside of the tetrahedron or from there, we look at a movement which is taking place below the surface of the tetrahedron. Then A delta will create an intrinsic stacking fault and that will be the leading partial.

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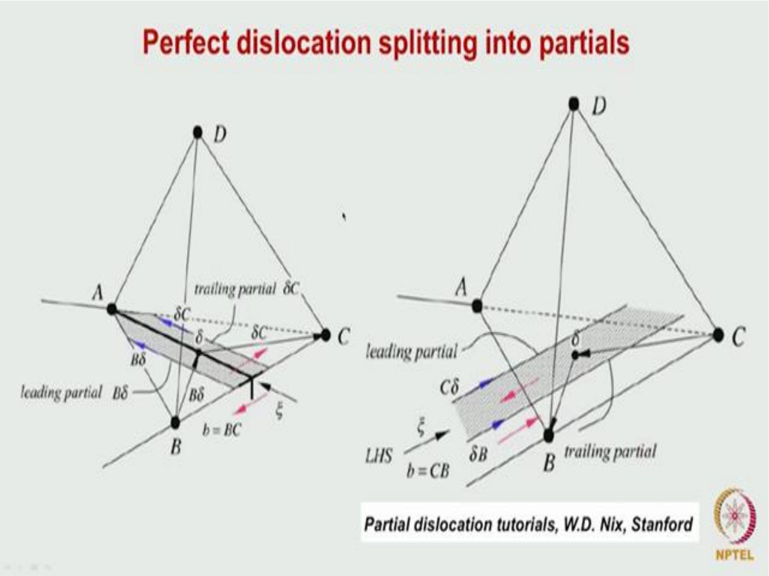

Just I am showing one or two examples to illustrate why it is very important in visualization because on this, this is a tetrahedron, which is being shown where an edge dislocation is split into a partial. So, where the B C is the burgers vector of the dislocation, so if B C is the burgers vector, it is splits into B delta plus delta C. This reaction if you look at it is all taking place within the tetrahedron; that means, that B delta will create intrinsic stacking fault. So, B delta is being shown here and delta C is the one which is trailing that is what is being marked also B delta is a leading partial and delta C is the trailing partial. Similar thing happens for a screw dislocation also we can show how the leading and the trailing partials are being placed. This is if you look carefully you will understand it.

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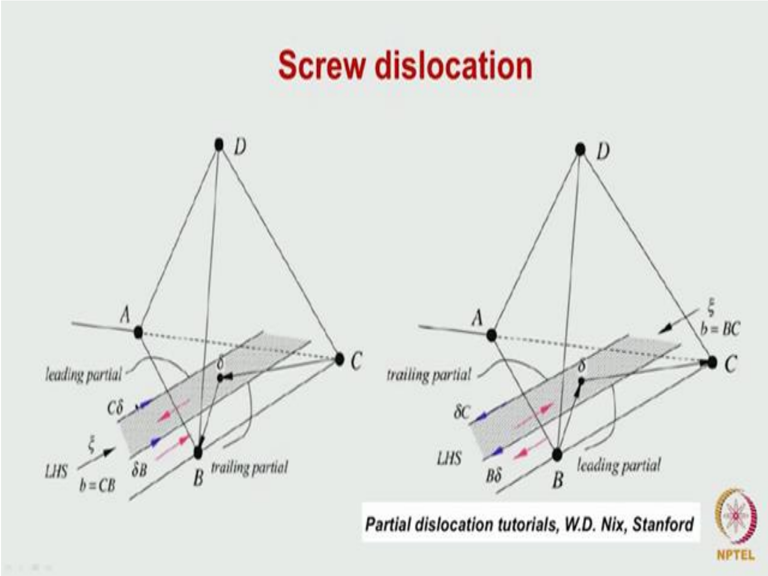

Here I had considered where the sense of direction has been changed then the leading partials also change. Here the C delta is the leading partial, here B delta is the leading partial, but both the dislocations the splitting of the dislocations into partial and the movement of the partials are taking place with the tetrahedron. So, either C delta or B delta one can create has to be the leading partial. You understand that?

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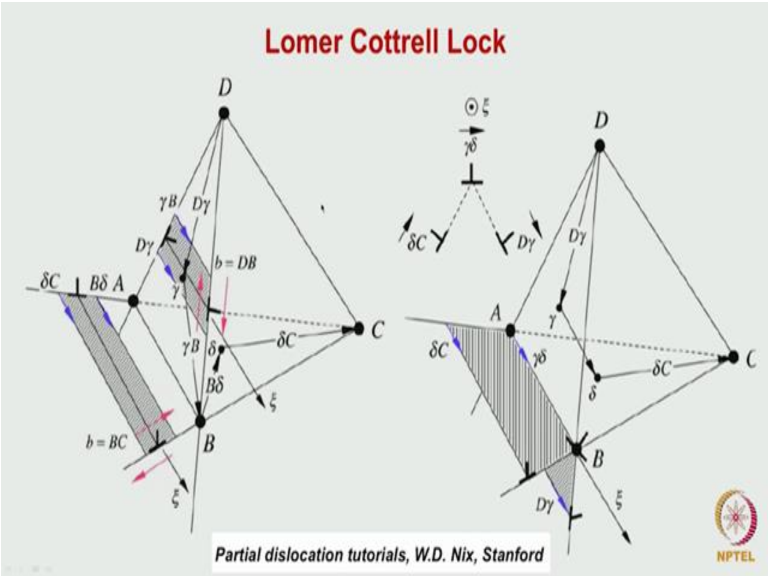

Especially, the Lomer Cottrell Lock which we considered that we can understand if you look at it very easily. You see that this is one plane in which that ABC plane, where the dislocation, which has split into partial they are moving. This is another plane in which the dislocations which has split into partials they are moving. And if you consider here this B delta, and gamma B when they join together, this will generate gamma B plus B delta will generate nothing but gamma delta by vectorial addition it will turn out to be. And this is what essentially is nothing but where we have written this reaction this that is this a Lomer Cottrell lock 1 by 6 that is gamma delta its magnitude is 1 by 6 1 1 0 that is a burgers vector. And this also becomes very clear because otherwise.

Student: (Refer Time: 61:00).

A visualization is very difficult like previously the way I explained. We are not able to visualize it. Now, we can visualize all the slip planes, all the splitting of the dislocations to partial in a different planes, how they are moving. Now, they have moved and joined this is delta C which is remained here and this is the stair rod, this is the other part of the dislocation. Now, you can visualize very clearly see that this is a stair rod, which is forming correct.

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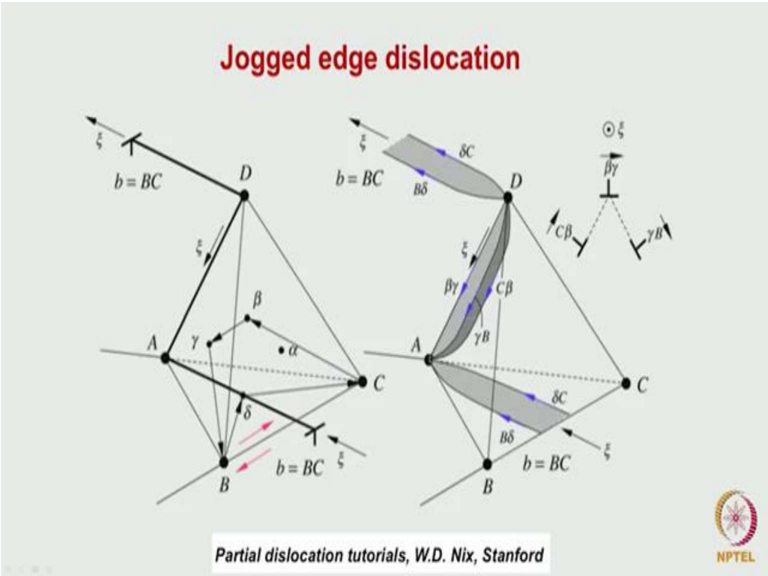

Another case, which we can consider it is the what we considered so far was essentially dislocations in two planes perfect dislocations which has split into partial. When the stacking fault energy is low, the dislocation itself will be curved. One will be one part will be lying on one plane, another might have cross slip and then it might have moved into a parallel slip plane. Such cases and if the dislocation split into partial that is what is being considered. You consider this case the burgers vector is the same B C for these two segment. This dislocation essentially will have a burgers vector AD, this is how the dislocation looks like perfect dislocation, because in this a Thompson tetrahedra it is easy to visualize. Now, this is split into partial forming a constriction then when this has separated it has just formed a stair rod of dislocation, and the other part of the stair rod of dislocations are there. Then this part of it also parallel slip plane it is split into partials.

Now, when you look at it, you can visualize that in three dimension, how these dislocations are lying, that visual feeling we get it when we use Thompson tetrahedra to write or draw all the dislocation reactions that is one advantage of using Thompson tetrahedra.

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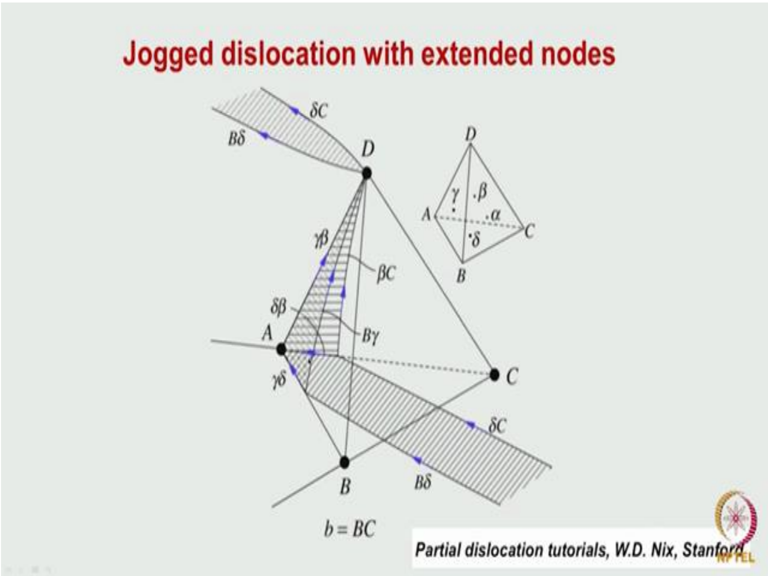

There is an another picture which you can see that where from this node as some it has just formed an extended node and form two more of these stair rod of dislocations. So, all these things now you look at it physically how these splitting looks like you are able to visualize it. All these things we are able to do it, because we are using in Thompson tetrahedra and on which all the dislocation reactions we are marking it. This is one great advantage in using Thompson tetrahedra. All reactions look very complicated, but you can visualize very easily. In fact, if in this one, I look in this direction, assume that in a t e m, I am looking at this sort of a reaction, which is occurred this is the beam direction. So, the projection of this is what you are going to see on the image.

What you see in an image is a projection, but the Thompson tetrahedra gives you a three-dimensional visualization; as it appears. So, that is why it is a very powerful one and. In fact, you might have noticed that in most of the books instead of writing the burgers vectors of the dislocations, you will always find that they write like A delta, B delta this is the nomenclature with which it is being written. The Thompson tetrahedra is being this nomenclature is routinely is being used to represent different, it is a perfect or partial dislocations.

So, I have tried to give a brief idea of the splitting of dislocations into partials, what all the type of partials which they can form, and what is the need for Thompson tetrahedra. Because you can understand that using Thompson tetrahedron, we are able to fix where in which direction the leading dislocation it has be, out of the two dislocation which will be the leading which is the partial all these things we can understand and place them when we do it on a Thompson tetrahedra using the Thompson tetrahedra.

I will stop here now. In the next class, we will look into dislocations in other structures like bcc and hcp also we will try to look at it.