Defects in Crystalline Solids (Part-I)
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Lecture - 17
Volterra Model+Structure of Dislocations+Burger vectors

So, we started with Volterra Model which not only describes dislocation and disclination, but this model will also be able to distinguish between dislocation and disclination.

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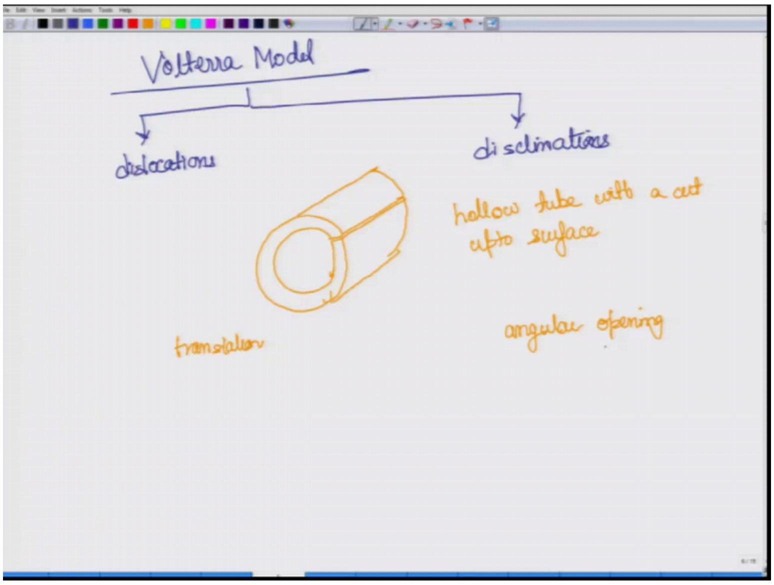

And the first distinction that we said, we have not yet showed it is that, for dislocation in this volterra model where you take a hollow tube you and you a take a cut then the two faces, there is only a translation. And if it has an angular opening, then it is disclination and the translation is dislocation.

So, with that, let us now start to look at what are the different translations and the what kind of dislocation you would expect or what how would they look like.

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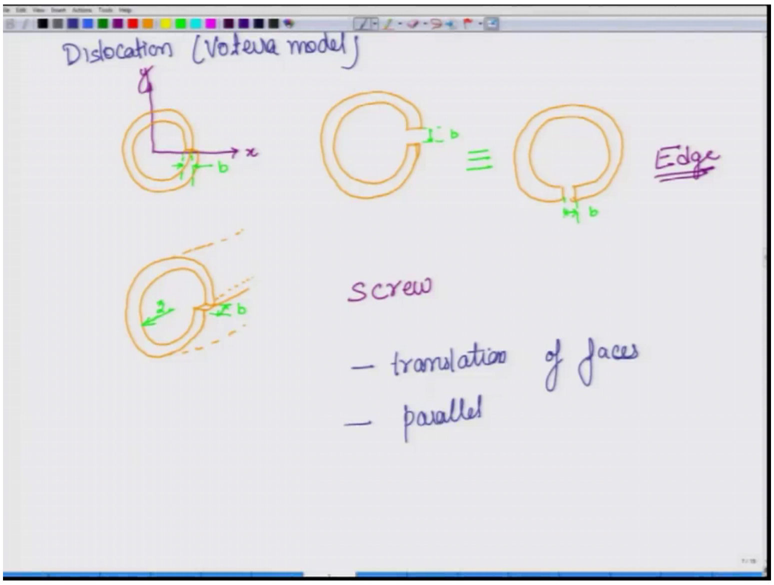

So, let us start with translation. So, let us say this is x and y. So, you see that this is a tube, we are looking through the center axis and we are only looking at the cross section. So, you can see that, the cut where there was a cut in this volterra hollow tube that along that cut there is a displacement along x direction. And this displacement, from what we know about dislocation can be termed as the burger vector b, so this is one kind of translation. What are the other translations possible? So this is in x the other is possible in y. And the two conflicts, there can be two different configurations for y translation.

So, here you see there is a gap, this so the faces have been pulled apart. The two faces are now pulled apart and therefore, this gap is again we know in terms of dislocation burger vector b. And very similar to this, the other configuration would look like, so this is the again, the two faces and the translation has taken place along these two for the two faces, the two faces have been again pulled apart. So, this is again burger vector b. These two are equivalent, now there can still be a third one which we will show here. So, here will have to show it a little bit in three dimensions.

So, now you can see or I hope you can see, that this in this cross section that I have drawn. This has been the translation has taken place along the z direction. So, this was the z direction or actually going into yeah so, coming out of it is the z direction. So, the faces have been translated along the z direction and again this gap that has been created will be the burger vector, from what we have already, from what we already know about the dislocations. So, this is what we know or what we have about dislocation. So, yeah so let me dislocation using volterra model.

Now, as you can already realize that over here, the three of these, in these you know the first three that you have drawn here. There is somewhere some amount of similarity. There is no you can say it is shrewdness; there is no screw component into it. And therefore, you would realize, from what we have understood about the dislocations that, this is edge dislocation. We will talk more about these two different kinds of dislocations, but for now just let us say that this is edge dislocation, it does not have any screw component and this one as you can realize has a helical structure. So, this is called a screw dislocation or dis model or dis configuration, describes a screw dislocation.

Here just to repeat, there is translation of faces taking place. And another characteristic of translation is that, the two faces the along which it has there has been a cut, they are always parallel. So, even in this screw if you look the two faces are still facing parallel to each other. So, either they are shifted like this, they shifted like, this, or they are shifted this, which are the three x y z direction So, as long as it is shifted like this or like this then, there is no screw component and it is edge dislocation. And if it is like this, but it has been pulled in this direction and this being the z direction. So if it is pulled in this direction, then as edge screw component has been added and this is what leads to screw dislocation.

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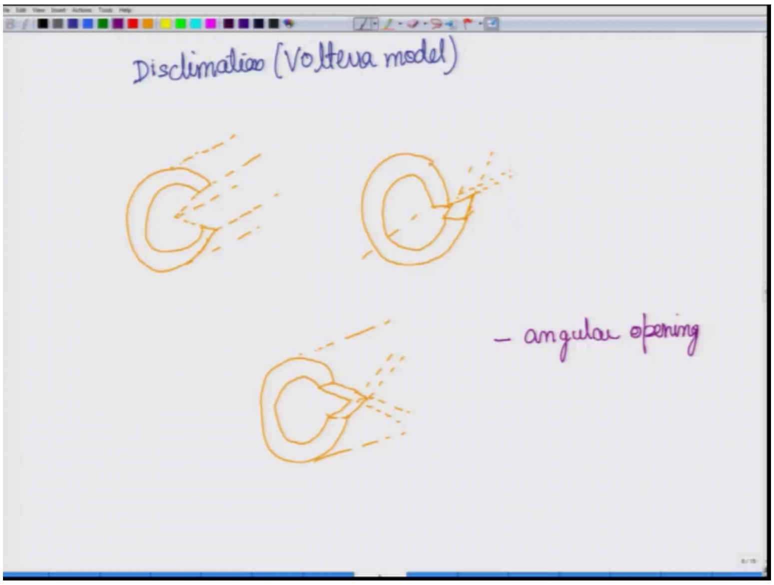

Now let us look at disclination using volterra model. Now as we said that, in this particular case what we get is angular opening. So, you will see what we mean by this angular opening. So, let us see. So, these are the two faces that we had and you can see that they are no more parallel to each other; they are. So, this is the axis, I am just trying to draw in dotted lines, the edges of this hollow tube and the main thing that we want to show you here is that, the two faces are not parallel and they are at an angle. So, this is one way of getting the angle, other way could be that these two are open like with a screw component. Although we do not have something like edge and a screw over here, but still you would see that, over here you can have something like this.

So, you can see that, the two faces in this particular case. They are, in this particular case, they are being rotated along each other. So, there is a rotation in this two, in these two and then again there is a angle from the original configuration. So, this is another configuration and the third configuration is that is along the rotation along the y axis. So, it will look something like this. So this is the tube and the two faces are now like this. So, the two faces are again at an angle and they are opening or like this. So, in all these three cases you can see that, there is we can describe this transformation as angular opening.

And now, with in retrospect we know that, these are a different kind of defects which are called as, disclination and the first three that we described is a different kind of defect which is dislocation So, let us summarize what are the differences. So one of the things that we have already seen is the how the faces open one in one of them it is just translation, in the other one it is angular opening.

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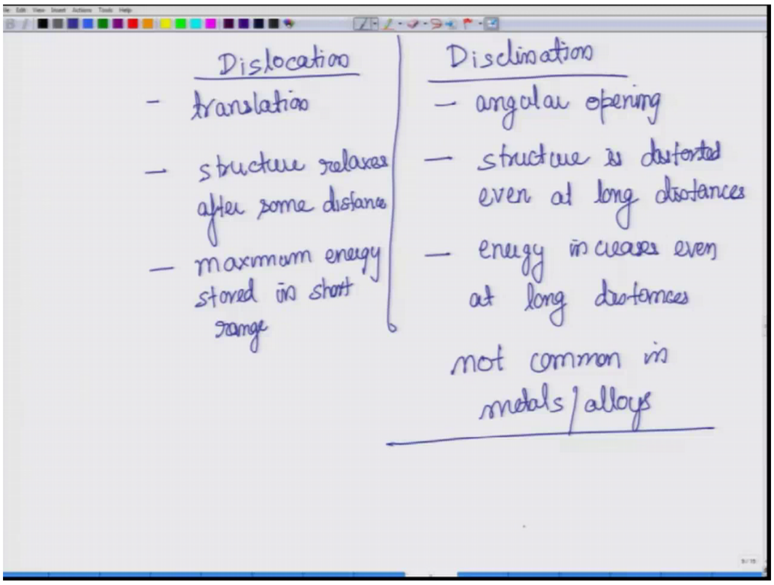

So, can we summarize that dis the distinction between dislocation and disclination. So, first and foremost let us try to what we already know is that, there is translation in dislocation and what we know about disclination there is angular opening. So, this configuration leads to angular opening and which is what describes it as a disclination. But that is actually not the basic definition. If you look at it, even the structure wise you would see that, at long distances in dislocation the structure relaxes which will not be possible if it is disclination. The way it has been described here that, angular that angular opening leads to similar structure throughout a long range and therefore, the structure does not relax.

Over here, in the disclination structure is distorted even at long distances. Now what will be the implication for this distortion in structure? No there being relaxation in dislocation in the structure and with there being no relaxation or being there being a consistent distortion, the direct effect would be an energy. So, the what will be the what you would see is that, maximum energy in a dislocation is stored in a smaller distance because, that is where maximum distortion is taking place, outside it is relaxed it is like a perfect crystal. So, no more energy stored over there.

While in disclination that is the structure is such that, this trans this distortion continues all the way to the long range and therefore, energy keeps on increasing. You know the further you go the energy is even further even higher, but in dislocation beyond a certain point you would see that energy saturates, it does adds very little to it. So, maximum energy stored in short range. Theoretically you can say that, it there will be some infinitesimally small energy even at long distance for dislocation, but that will be negligible. While in the case of disclination at long distances, you will still be able to add sufficient amount of energy. So, energy increases even at long distances.

Now, that is the way to describe or differentiate dislocation and disclination. But now which one are we interested in dislocation or disclination? Now as far as metals and alloys are concerned, this disclination is not common in metals and alloys and like I said that, our focus is to some extent on metals and alloys. So, we will not continue our discussion with disclination anymore and we will now focus on dislocation. So, now, let us go to dislocation and we will start with basic structure.

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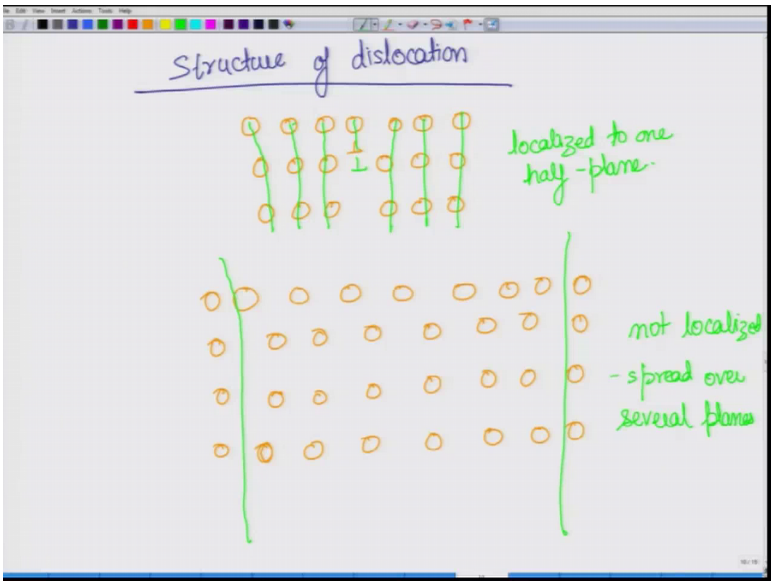

So, we are not looking in a nindex structure yet, you look at to that later on. But let me just describe you some lacunae, about dislocation structure that is usually given in textbooks. It is not to mislead, but for in the to make it simpler, the way it is drawn is it is too simplified. So, the way it is drawn is usually like this. So, you have so the way it shows, in the textbooks it looks like, the dislocation is actually limited to just one half plane. So the presence of particularly this edge dislocation that, we are talking about.

So the edge dislocation that we are talking about is limited or localized to one half plane So, even before we start getting to understand more about dislocation, let us be very clear that these are not really localized. The way it would look like in a real structure should be something like this.

Now here if you look at it, where is the dislocation? Now that is a very big question, if you start looking it is not so easy to find out or locate where the dislocation is. In fact, if you were to really describe where the dislocation is then, you would say that the dislocation lies somewhere inside this. So, that what I am trying to emphasize here is that it is not localized; usually it is spread over several planes. And therefore, if you look at a tm image which will actually show you rows of atoms. Over there people have to apply a different technique which is called making a burger circuit, which will look in the next topic. So, that is where, the when you use that, then you are able to say inside this somewhere there is a dislocation because, as we said most of the time there may be cases where it is very localized. But most of the time the dislocation would not be localized.

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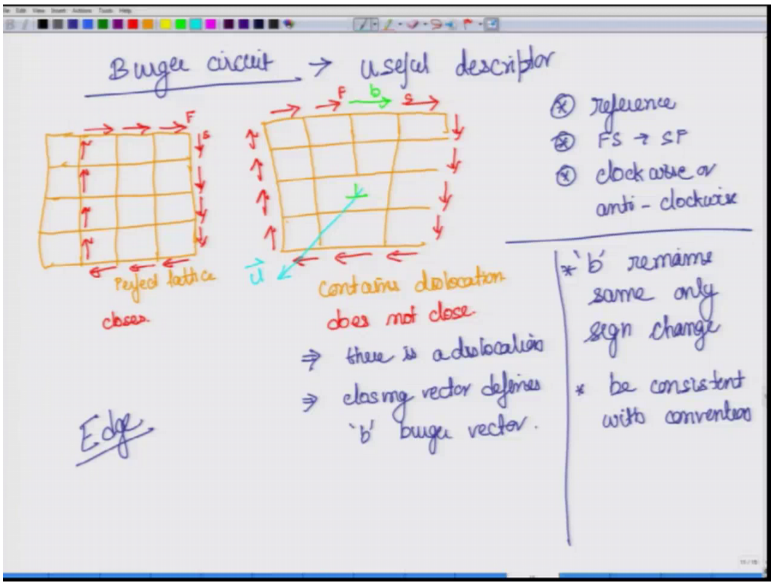

So, now let us look at, what is called as burger circuit. So, what is the idea? Usually it is difficult to identify dislocation using the textbook schematic. Hence are useful it is a use, it serves as a useful descriptor. In a real lattice order in a real tm image, when your where you are able to look at rows of atoms, there you can draw the circuit and locate that, there should be a dislocation. So, how does it work? Let us look at it So, let us say there is now again as without loss of generality, I will now go back to our a textbook schematic. So, from the textbook schematic, we know that a dislocation would look like, something like this and here I am drawing it as line instead of atoms. So, the corner of these you can assume are the atoms. So, this is our dislocation, so over here it will be described as the dislocation. So, let me, this will be a region with a dislocation. Now how would a region with without a dislocation look like? Let us draw that too.

So, this will be a perfect lattice. On the left hand side, we have a perfect lattice over here contains dislocation. What the burger circuit tells you is that, you draw starting from somewhere, you start drawing arrows ok. So and compare that row, that set of arrows with that is with the similar thing in the perfect lattice and the gap that you see in the region were containing the dislocation will describe the burger vector and if there is a gap first thing is that it will implies that there is actually a dislocation So, let us see what we are I am trying to say here. So, let us say that this is we are going one in the right direction, four in the bottom then, again three to the left and again four to the top and since I had gone three to the left, I will come back over here and we already have three over here.

Now, compare this with over here we come down four, we come down three left, we again go four up, this is a circuit, so and we then we go three left. So, he is start this is finished and discloses, but this one does not close. If it does not close, what does it mean? It implies that there is a dislocation. So, here this was the start and this was the finish, so the we will talk about convention, but this according to this convention, this will be our finish to start, this will be our burger vector. So, this is a dislocation and this dislocation is given by this burger vector b. Closing vector defines b which is the burger vector.

So, now this methodology tells us two things, one that there is a dislocation and it also tells you what is the vector or associated with this. This vector is what describes the slip in the system. Now what you will realize is that, a lot of thing here over here depends on, what kind of assumptions we are making or what is the protocol that, we have adopted here. So, we will need to establish some convention. For example; first let us say we have used this as a reference. So, your reference can be different, maybe you could have said that, this is my reference and over here, I will see where the difference is coming and that difference will be taken. Second will be whether, you are talking about FS or you are talking about SF, meaning finish to start or start to finish. So, for example, you could have drawn from here to here or here to here.

Similarly, whether you want clockwise or anti clockwise; so, now, you can see that, whether depending on how, you select these three parameters or these three conventions, your burger vector direction would be different. Now I will tell you something in advance that, the burger vector will remain the same no matter, what convention you take, but only the sign would be different. Whether you are going this way or that way and it will depend on, it can change depending on your reference whether, you are taking FS to SF or SF F to S or S to F. Whether, you are taking clockwise direction for the circuit or you are taking anti clockwise direction to the circuit. And therefore, what we will do is establish a convention.

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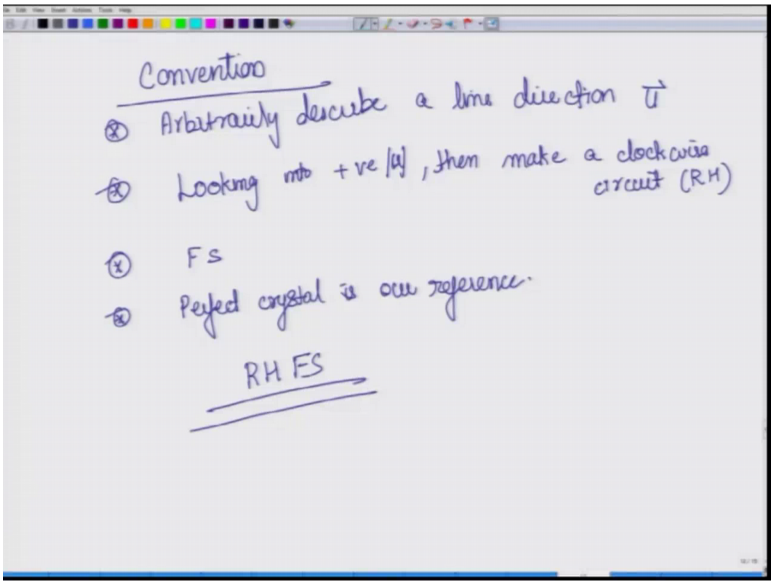

So what is that convention that we will establish? And you have one more thing before I go ahead. So since, I have already given you that burger vector remains same, only signs it changes.

And what is the importance of sign that, sign is what will describe it various mathematical equations. And therefore, to be consistent, you should also be consistent with the convention, so be consistent with convention. So, once we have decided, this is the way I am taking the reference and this and all these three, then you stick with that. That is what this particular analysis is telling us. Now next another thing is that, this is one kind of dislocation which is the edge dislocation. The other one is the screw dislocation. So, over there also you have to describe a convention and it need not be same as this one. You can have a different convention for edge and a different convention for screw dislocation. But as long as you are consistent, it will your mathematical values would not change because, you can realize that if the sign changes. And therefore, instead of adding you may be subtracting and similarly instead of getting positive energies, you may get negative energy that would make a lot of difference.

So, to be consistent all you have to do is remain consistent with the convention. So, what is this convention? So, for example; in this particular convention we will arbitrarily describe first and foremost describe a line direction. So there is to be a line direction u. Then how do we draw this clockwise and anti clockwise? Again we will say in this particular case we are this particular course the convention we are adopting is that, looking into positive u, means u vector is coming on to u; you are looking into this, then you have to take make a was it clockwise circuit.

So, this is also described as right hand convention. Now on a last one is we will take FS, meaning finish to start. So, this is the last convention meaning wherever, you are you have finished, you will take for the vector from there to start. And another thing which was with respect to reference, so the perfect crystal is our reference. So, overall this will be described as RHFS convention. Now we can go back and see that, this is what we have done. But we have not yet described, what is the line direction here. So, since this is going clockwise, it means the line vector must have been coming out and therefore, we will draw the line vector like this. So, the line vector would be like this. So this is the line vector coming out of the plane and therefore, we have been able to draw clockwise.

If we had taken the line vector going in, which is something that we have to describe or we have to assign to it, then the circuit would have been from the other direction. It should have been clockwise which means, from this direction it would have been anti clockwise and that would have meant the burger vector sign would have changed. As you can realize that you change one of these and you quickly change the sign, but the burger vector remains same, meaning this b in magnitude and overall the direction remains same, only the sign sense changes, whether it is positive or negative. So, that is for the edge dislocation, now let us move on and look for a screw dislocation.

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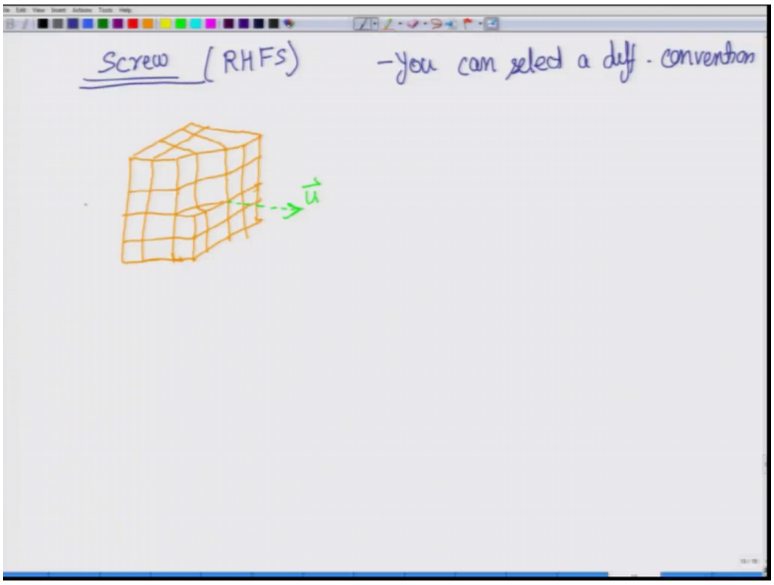

So, now we have already described the convention and here like I said, we will stick with RHFS. But remember that, in this you can select a different convention. However, like I said we will stick to the same convention that we applied for edge. So, edge and screw need not be done in the same way, but we will assign it separately. But when you will see that, when we talk about mixed dislocation then, in that case you will have to describe it in the u direction cannot keep changing, it will have to be consistent.

Now, here let me draw it is a little difficult. So, draw and see observe carefully how it is to be done. So, what we are trying to draw here is a screw dislocation. Hopefully you are able to observe, what is going on over here. Is we have something like a cube to begin with? But now it has been deformed such that, there is a screw component over here. So, as you can see that, if you look along this, so now, we will also describe it as some positive u direction. So, this is the line direction and for the screwed screw dislocation and over here, you can see that if you go like this, there is a step over here. So, this is or a kind of a helical structure. This is what is described as a screw dislocation which I am sure you are already aware, but now you are looking from looking at it in a different perspective. We are trying to describe how it will, how we can use this to come up with the burger vector for this.

So, this is like this and now what we need, we have said it is RHFS and we have already described a u. So, which way should the burger circuit go? Now this is the positive direction and you have to draw a clockwise over here. And accordingly you will also have to draw a reference frame. So now, in this particular lecture, I will leave you with this and you try it on your own before, you start to see the next lecture, where we will actually draw the circuit and get to know what it is the what is the burger vector for this.

Thank you.