Defects in Crystalline Solids (Part-I)

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Lecture – 40
Dislocations in BCC+Asymmetry of Slip

So, welcome friends to the last lecture for first part of this course on Defects in Crystalline Materials, towards the end I will also list out some of the topics that will be covered in the second part of the course, which would be most likely floated next year. So, in the previous class we completed 2 or 3 lectures, we looked at dislocations in a FCC system. So, we had a brief glimpse at how the dislocations structure is how what is there how they are different with respect to what we had understood about a simple dislocation system.

And there were several aspects, where we found that they are very different and although the concepts that, we were used where all the fundamental ones that we had already introduced for the basic dislocations. And, once you understand the basic dislocations and you know the actual structure in a particular system, then you can get more in a in depth information as you realized in the previous lecture.

We also use the concept of intersection addition of Burger vectors to see that the many times they will result in sessile dislocation, which is what leads to the work hardening of the material and you also get something like lock, lock is different from a sessile dislocation in the sense that lock ensures that, no other dislocation passed through that particular plane and once the that kind of dislocation has formed. So, that is difference between a lock and a sessile dislocate, sessile dislocation is all together in a different plane.

So, it just pins the boundary, it pins one of the dislocations at one of the ends, but otherwise it is not blocking the flow or glide of other dislocations. So, now that was dislocations in FCC system. Now in this last lecture, we will have again brief glimpse at another simple system, which is BCC, there are of course, several more complicated system which we will touch upon in the next part of the course.

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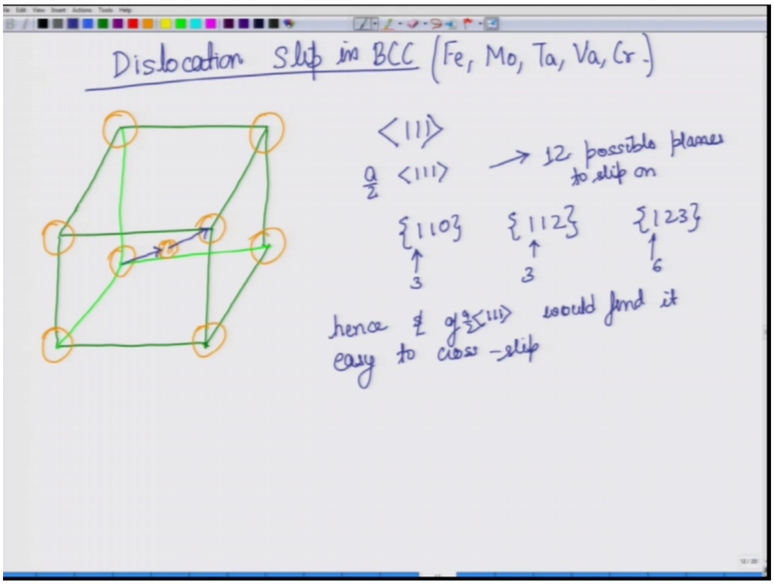

So, the topic here is and BCC and FCC are one of the most commonly found metals and alloys BCC, what are the materials that you find in BCC? Iron, ferric iron, molybdenum, tantalum, vanadium, chromium and of course, there will be several more, but these are some of the most well known systems in BCC. So, now, it is time to take a look at so, these dislocation slip in BCC and how they are different from what we understand ok.

So, let us look at. So, I will start with our usual BCC structure. So, I try to draw it as closely as possible, but there may at times it may be a little out of the shape, but hopefully with the concepts, you would be able to relate to it. So, these are the position of the atoms and this is BCC. So, there is a body centered atom over here. So in BCC, which is the direction, where you have the atom stretching? And we already know that it is along 1 1 1, but what is the shortest lattice vector? And you would see that if this would be the 1 1 1 from this point to this point, but the shortest lattice vector, because this is a body centered atom over here, the shortest lattice vector would be from here to here and similarly from here to here both of them are same. So, these are the shortest lattice vector and what is there magnitude? It is magnitude is a by 2 1 1 1.

Now, if you remember from our discussion on slip direction and slip plane, we said that each of this 1 1 1 direction is contained on several of the slip planes. So, what are those several of the slip planes? So, ideally 1 1 0 would should be the slip plane, but we saw that there are other or it has been observed that, there are other slip planes that occur in

BCC; so, 1 1 0 1 1 2 and 1 2 3 type. So, this is a family of planes as you can realize and what is very interesting about BCC is that, if you take 1 Burger vector like this can, this particular Burger vector can lie on 3 different 1 1 0 planes it can lie on 3 different, 1 1 2 planes and 6 different 1 2 3 planes. So, in all 1 1 1 were Burger vector has 12 possible planes to slip on. So, that is a really large number of slip lines that it is available and it implies that a screw dislocation of 1 1 1 type would find it very easy to cross slip ok.

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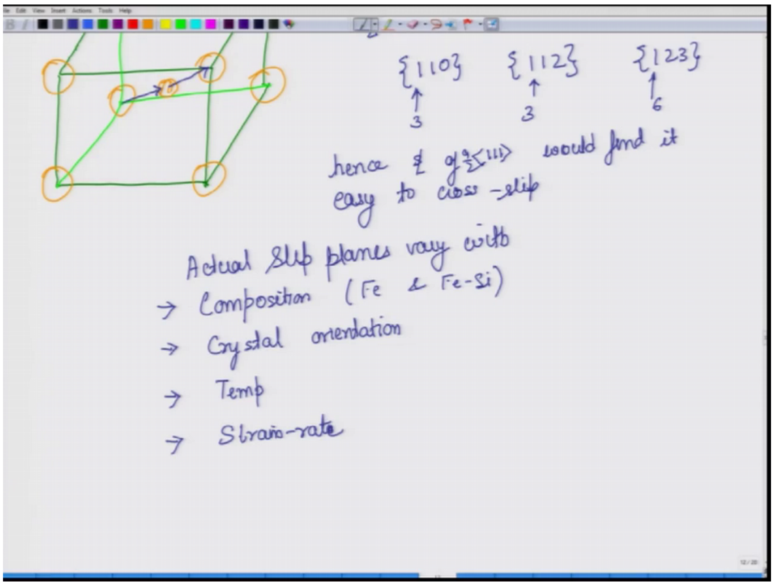

So, that is even the ideal condition that all the 3 planes are equally probable or equally preferred. However, in real system it has been found that which particular slip plane will activate it depends on lot of factors. So, what are these factors? So, actual slip lines vary with several factors, what are these factors? The first and foremost is composition and people have seen that for example, iron and iron and silicon both of them are BCC, but they show different preference for slip planes.

So, composition does matter crystal orientation. So, if you are applying the load along 1 to along a 1 1 3 5 or 2 3 4 or 5 6 7 based on that different particular planes would be preferred. So, crystal orientation is one factor then, temperature some of these planes that, we have listed over there are more preferred at higher temperature others are preferred at lower temperature. So, temperature is another aspect strain rate now, against temperature and strain rate, if you realize they have interdependence. So, along with temperature strain rate also makes a difference, when you apply largest strain rate other some planes are preferred and it will depend again on which particular material system we are talking about. So, for one highest rated one some particular mid slip planes may be preferred and for some others some other matter slips planes may be preferred.

So, that is the fundamental about the BCC slip system and as now we can clearly see from the diagram, the Burger vector would be b by 2, sorry a by 2 1 1 1. So, that remains constant only there are 3 possibilities of different planes. Now, let us get to the unique features of BCC, which will help you understand why we why I kept saying that in real system dislocations are little more complex than what we have the looked at the simple systems ok.

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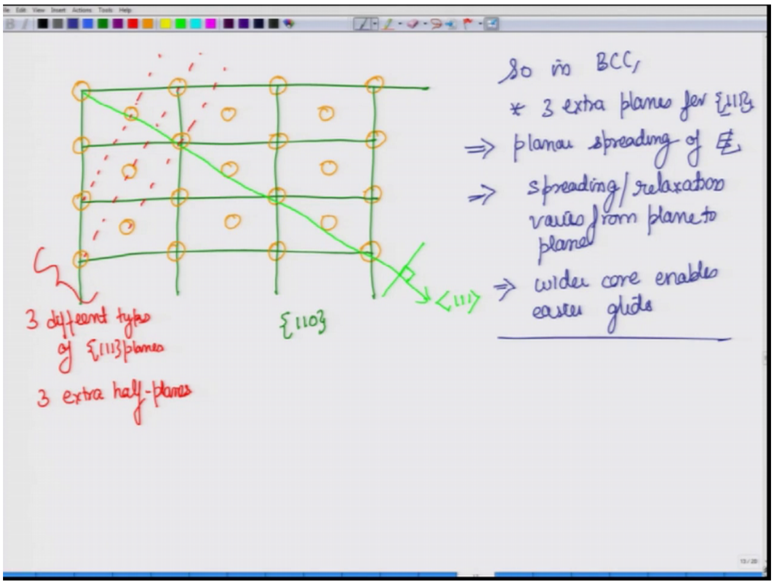

So, for that let me draw, so, I will draw only these 3 cells in the direction of 1 1 0 plane. So, what we are looking at here is 1 1 0 plane of a BCC. So, if it is a 1 1 0 plane, where should the atoms lie and if you go back here, this is the 1 1 0 plane and as you can see this side is smaller, this is a while, this is a root 2 and in the one of the atom lies at the center others lie at. So, keeping that in mind, we will draw the atoms over here and the reason I am trying to I am drawing this is that the 1 1 1 planes, which will form the extra half plane. So, if you are talking about a 1 1 1 direction of dislocation movement. So, this is moving along this direction and this is the one this is the Burger vector 1 1 1 therefore, these are all these planes all would be 1 1 1.

So, I want to show you, what are the 1 1 1 planes actually, how the 1 1 1 planes actually look like. So, if you look over here and again going back here for a second, I want to show that this is your 1 1 1 direction as you have would have realized and over ok. So, I have just draw one more atoms at the center, now which are the 1 1 1 direction over here. So, let us there will be two 1 1 1 directions here. One will be along this like all these are 1 1 1 directions, but I will draw just one of these which is this one, this is a 1 1 1 direction. So, how should the 1 1 1 plane be located? It should be at the right angle to this right, the right, the plane or the plane, the planes would be oriented not that planes normal, but the planes would be oriented like this because 1 1 1 direction is pointing to the normal of this.

So, the planes should be like this and now I will try to draw the planes. So, which are the planes here at 90 degree to this? And again these are all 1 1 1 planes. So, if when you come to this particular position, you would see that it has it is now back to the same location at this one was therefore, in this particular direction this one is same as this one, but overall there are 3 different types of slip planes over here 3 different. So, if you had formed extra half plane. So, there will be 3 extra half planes.

So, this is again different from what we have learnt about simple system or even a FCC. So, here you have 3 different planes for the 1 1 1 planes and because there are 3 different planes, there will be some difference in the behavior, what are the difference in behavior? So, in BCC what you would see is that? So, first we have realized that there are 3 and this would imply that, there will be planar spreading of edge dislocation. So, there will be planar as spreading of edge dislocation, but this is spreading or relaxation.

So, in the core basically you can say that there are 3 extra half planes and that would mean that the overall core would be spread out to a much larger distance, that will be the planar spreading in edge dislocation and that planar spreading will depend will be different from particular plane to plane. So, planar spreading varies from plane to plane. Now I said that it has wider core, but you remember from our earlier discussion that, whenever you have a wider core then, it means that the dislocations are better able to glide means glide becomes easier. So, that is another aspect added to this BCC. So, wider core enables easier glide. So, these are some factors or some aspects that come out with respect to the fact that, there are more than 1 extra half plane for BCC also.

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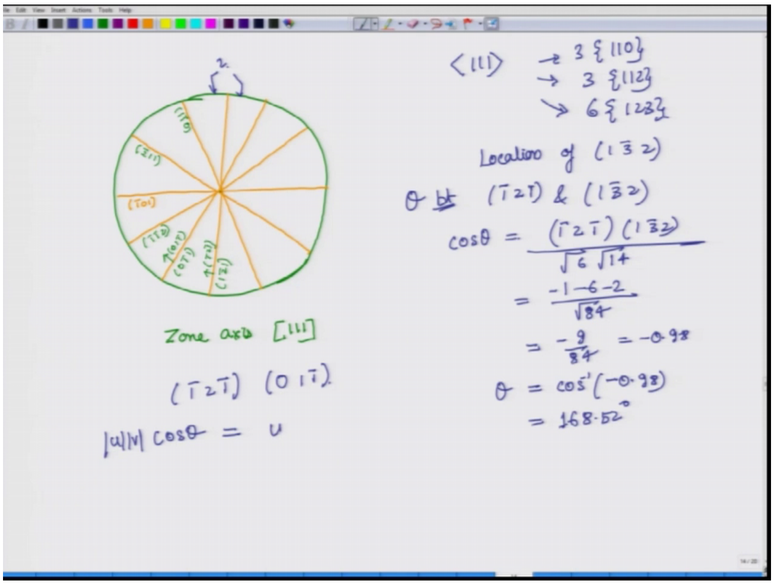

Now, coming back to the original point that there are lots of different slip planes; so, in BCC we said that each 1 1 1 is contained in 3 1 1 0, it is contained in 3 1 1 2 and it is contained in 6 1 2 3. Now if you remember in FCC, we had that simple model of to the Thompson Tetrahedron, which described all the possible slip planes and deductions, but here you can realize that even one of the slip plane slips solid slip directions, let us say we are talking about bar 1 1 1 that itself will have 12 different planes. So, it looks unlikely that we can have a simple model like that. However, there is in a x if you have been exposed to x ray diffraction, you would know that there is something called a zone axis.

Say if we take zone axis along 1 1 1, we will be able to plot the prilative orientation of different planes. So, that has been that is something that has been done and let us look at, one such zone axis. So, here we are using the zone axis of 1 1 1. Now, in this zone axis of 1 1 1, first I will draw just from what is well known 1 1 0 1 1 2 planes and they come out like this and for our benefit it turns out that, they are all oriented at 30 degrees to each other. So, it makes our job a lot more easier, now let me mark out these planes. So, these are the 6 different planes that, we talked about 1 1 0 and 3 1 1 2, which are listed over here and what you would notice is that I have pointed out in one direction the other side would be the negative side of this.

Now, the question is these 3, these 6 would most likely be always easy for you to locate on a zone axis, what about the 1 2 3? How do we find out what is the position of let us say 1 bar 3 2? So, if I am interested in finding location of 1 bar 3 2. So, how do I find this? So, here all the other 6 planes are given very nicely, but now I am interested in finding the, 1 bar 3 2 location and this is where our understanding simple trigonometry will we very useful, we know if we let us say, we take 1 particular plane. So, let us say we take one or the particular plane, we will take is the bar negative of this one. So, we will take 1 2 bar 1 ok.

So, now we are interested. So, this is the direction would for bar 1 2 bar 1, this is the orientation for 1 bar 2 1. So, now, we are interested in finding the angle between bar 1 2 1 and what is the theta between this and 1 bar 3 2 and we know that there is a very simple relation for this we can say cos theta is equal to bar 1 2 bar 1, I am sorry, I should use the plain notation and I will take the square root of the sum of the squares of these. So, this will becomes 2 square, plus 1 square plus 1 square, which is 6, this will be 3 square plus 2 square plus 1 square. So, this will be equal to 14 and this will come out to now, you take the dot product between sorry you, yeah you take the dot product between these two. So, it comes out minus 1 into 1 minus 1. So, minus 1 this is minus 6 and this is minus 2 divided by root 84.

So, this is equal to minus 9 by 84 that is ok that, but now we can from this we can say theta is equal to this comes out as minus 0.98. So, theta is equal to cos inverse and this will be 168.52 degrees ok. So, looks like we have let me, we have found very simple way to find out the planes. So, here from here we will be able to draw a 168 degrees, somewhere over here which is 10 degrees, before this plane we would be able to see this plane. But then someone may ask, why how do we know that, this is 168 degree in this direction and not this direction and one may argue that theta is positive, we should take theta in the positive direction, but then this is angle between bar 1 to bar 1 and 1 bar 3 2. It does not say that, it is with respect to bar 1 to bar 1, it could as well be with respect to 1 bar 3 2 meaning this particular plane has to be at 168.

So, if I drew it like this and 168.52 from here. So, now, we have the dilemma of whether the one this particular plane is over here or over here both of them are approximately once not approximately, they will be 168 in this direction and 168 in this direction. So, how do we solve that dilemma? And a simple way out for this is to look for one of the planes, which is already oriented with respect to this 1 bar to 1 and whatever value of theta we get if it is the positive theta then equal to this much 30 degree then, we would know that this theta has to be taken in this direction. If it comes out to be negative theta then, we will know that this is the negative direction and we have to take positive in this direction ok.

So, now using this, what we will do is we will find the angle between bar 1 2 bar 1 and 0 1 bar 1. So, you know 1 0 1 bar 1 is the opposite or the negative of this. So, this direction is the one we are talking about. So, we have taken and we are taking. So, next we will go back and we will find in the we said that if this is u v.

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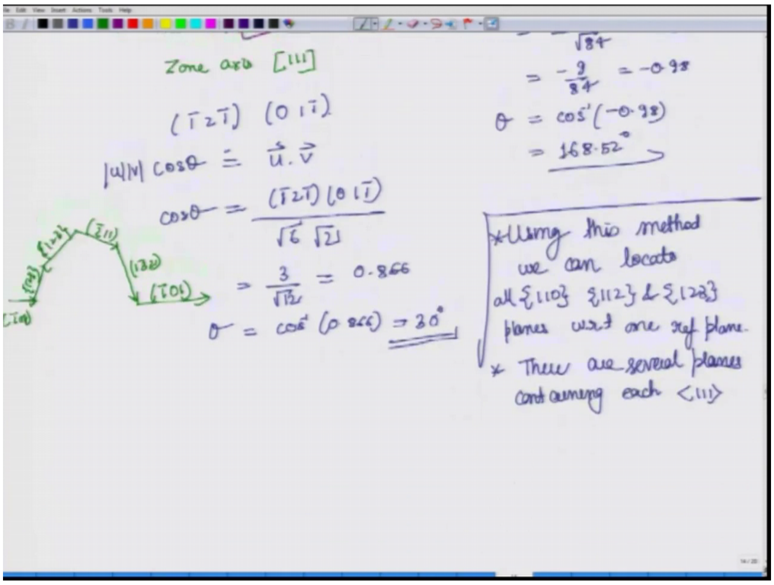

So, u v cos theta is equal to u dot v and using this we have earlier showed that, cos theta is equal to bar 1 2 bar 1 0 1 bar 1 and we will take the sum of the square. So, 1 square plus 2 square plus 1 square is equal to 6 and 1 square plus 1 square is equal to 2 and this dot product will be minus 1 into 0 0 2 plus 2 into 1 2 and this is plus 1 again. So, 3 by root 12 and this comes out to be 0.866 therefore, theta is equal to cos inverse 0.866 and this is equal to 30 degree.

And this is oriented positive 30 degrees. So, we get positive 30 degrees and this is also 30 positive 30 degree. So, we know now that 168.52, has to be drawn with respect to this plane in the positive direction and therefore, so, this plane is 1 bar 3 2. So, first thing that you see is that, you are now able to locate. So, using this method, you can locate not only the 1 3 2 1 2 3 planes, but also if you have one of the reference directions and you know what are the other planes that would like, when you can locate all 1 1 0 1 1 2 and 1 2 3 planes with respect to one given plane

So, actually you will have to have two given plane, no let me correct that once you have one, you can always say whether you will take positive direction or the negative. So, if you can have the, inverse symmetry of this. So, you just need one reference plane; so, with respect to 1 1 0 1 1 2. Once you just need one reference plane and you will be able to locate all these planes. So, that is one thing, second thing is that you see that how there it is such a crowded field, we have only drawn 6. So, far and this one was the seventh and there are 5 more means that there are several planes as we mentioned earlier there are several planes containing each 1 1 1 direction ok.

So, that is another thing that we see and how do we make sure that, the planes that we are drawing are actually in that particular 1 1 1, it contains the 1 1 1 axis then again, we use the simple old rule of dot product, if the dot product is 0. So, we know that it will lie on that that particular plane said that particular plane will contain that particular 1 1 1 and we are also given the information that, we have to have 3 1 1 0 and 3 1 1 2 and 6 1 2 3. So, that will also make your task easier, you just need to find 3 different combinations of 1 1 0 if excluding the negatives and similarly 3combinations of 1 1 2, once you have 3 planes of 1 1 0 or 1 3 planes of 1 1 2 or 6 planes of 1 2 3, you know that you have all the planes possible that contain this particular 1 1 1.

So, this makes our BCC system very interesting and this also takes us to where we had earlier mentioned through the glide plane. Now you can look at this and I will try to draw it somewhere over here. So, if you look over here, you have some planes bar 1 0 1, it can glide to another plane, which may exist given that there are. So, many 1 2 3 planes, I am not sure right now, then you can have another one of these 1 2 3 planes and this one looks closer to bar 2 1 1, this one looks closer to 1 bar 3 2 and you can come back or you can still be in some of the other planes.

So, this is some of one of the 1 2 3 planes, you will once you have located all the 1 2 3 planes on to this zone axis, you would be able to plot what which particular you will be able to plot it at those angles and then you will be able to point out which particular orientation it is.

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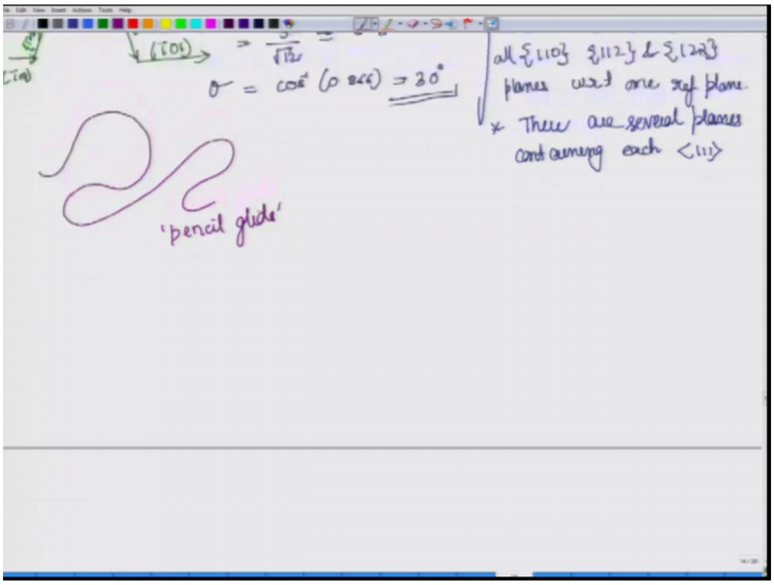

So, now we have, what is called as pencil glide, you remember this is what we called pencil glide. So, this is on the macro scale it would look like this is moving in a very pencil or arbitrary direction and we call this is pencil glide. So now, looking at the zone axis you would know, why it is called a pencil glide.

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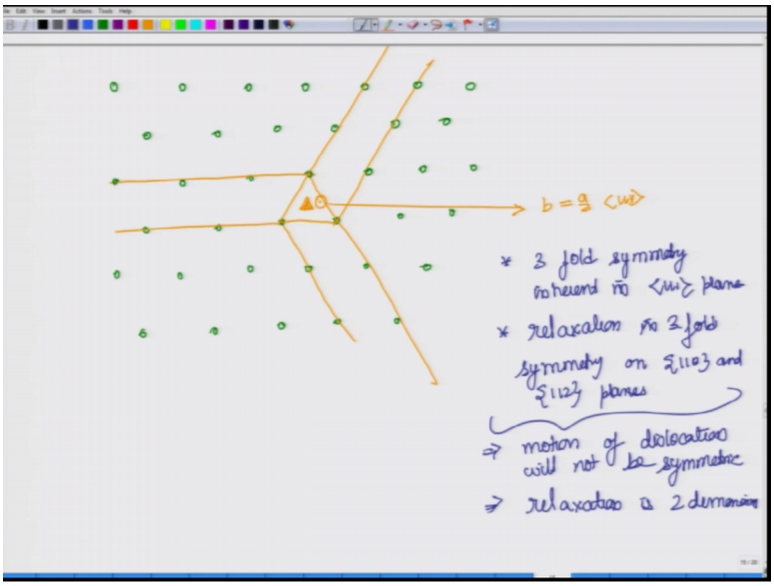

So, this is so far about the edge dislocation. Now, the screw dislocation is also not so simple or so straightforward in a BCC. If you were to look at the screw dislocation this will look like. So, first let me again draw. So, what I am drawing is again the 1 1 1 plane and these are the lattice sites containing atom and again if you realize that I am drawing a point model meaning the atoms are not touching while in reality they will; obviously, be touching.

Now if you look at this geometry, you would realize that it has 3 fold symmetry this geometry has 3 fold symmetry and if you were to let us say, take a dislocation screw dislocation, somewhere which will have the Burger vector along, this which is this is the 1 1 1 plane. So, this is also the 1 1 1direction and. So, the screw dislocation lies perpendicular to this plane. So let us say, this is the core of the screw dislocation and the Burger vector is coming out, which is equal to a by 2 1 1 1.

Now, with this symmetry you would realize that, this will have or this will have a threefold symmetry something like this. So, if the screw dislocation can be seen to have a core over here, while it will have threefold symmetry like this. So, there will be if you take 3 arms. So, this will show like this, which are all at 120 degrees. So, what is what do we know so, far? That it, has a threefold symmetry, which is not because of screw dislocation it is inherent in the 1 1 1 plane. Now because of this symmetry, what will happen is that, whenever it relaxes it will relax in one of it relax in a 3 dimensional or threefold symmetry. So, relaxation will also take place on 1 1 0 or actually and 1 1 2 different planes. So, the relaxation of this structure will also be will also have threefold symmetry and once you have a structure like this, you can realize that motion is no more one that motion will not be symmetric.

So, one thing that we can, based on this we will say that the motion of dislocation will not be symmetric. Second what we can say is that since, this is the core structure and the core is non planar ok. So, far if you looked, if you remember in only in the edge dislocation, we talked about relaxation the, which took place in that plane the plane which contains the plane normal to which is the extra half plane. So, in the all of those edge dislocations the relaxation takes place in that plane that plane, where there is largest shear stress. However, in BCC you can say realize that, this is the relaxation will be two dimensional because of this threefold symmetry.

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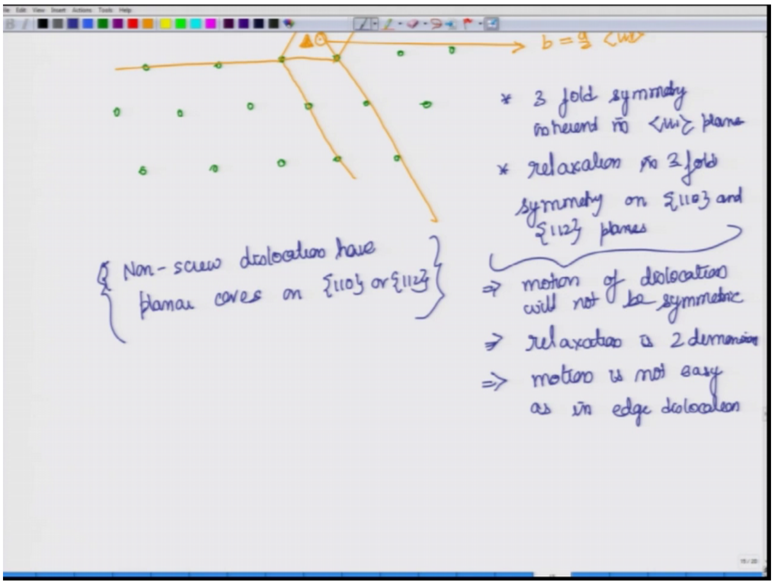

And when it is two dimensional relaxation it would imply motion would not be easy as at this point, it will I would also like to mention that non screw dislocations, I am calling non screw meaning edge and edge dislocations. So, non screw dislocation have planar course. In fact, they will also have course or basically relaxation on 1 1 0 or 1 1 2, but it will be planar in nature compared to the non planar nature of thus, screw dislocations.

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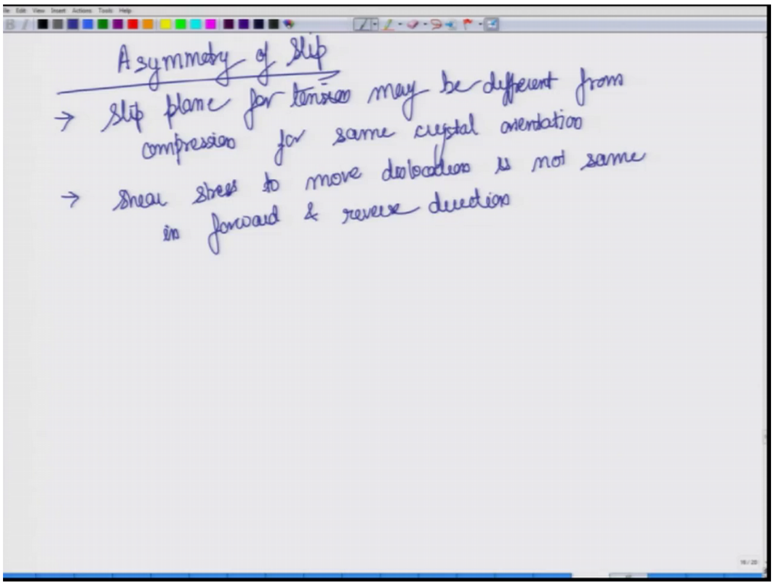

So, this is another great you can say distinctive feature of the dislocations in BCC, now this is still not all and let us look at one more interesting aspect about the BCC. So, because of the asymmetry or you can say three dimensional nature of threefold symmetry of the relaxation core of the screw dislocation, you I will already mentioned that the motion would not be symmetric or not isotropic in all the directions. The motion will not be similar. So, that is also something you would have realized. So, that an interesting aspect of this is asymmetry of slip in BCC, what you observe is asymmetry of slip.

What do we mean by asymmetry of slip? Slip plane for tension, may be different from compression and we are not saying that we are talking about different orientations. So, even in the same orientation for same crystal orientation, this may be different and of course, the resistance on different planes are different, which would mean that shear stress to move dislocation is not same in forward and reverse direction.

So, originating from the threefold symmetry, we see that there is a symmetry of plane, which implies that the slip plane for tension may be different from compression. And, since different planes have different resistance shear stress that is required will be different to move dislocation in the forward direction versus in the reverse direction. And, that may also end up yielding, that you will have different shear strength in tension and different shear strength in compression.

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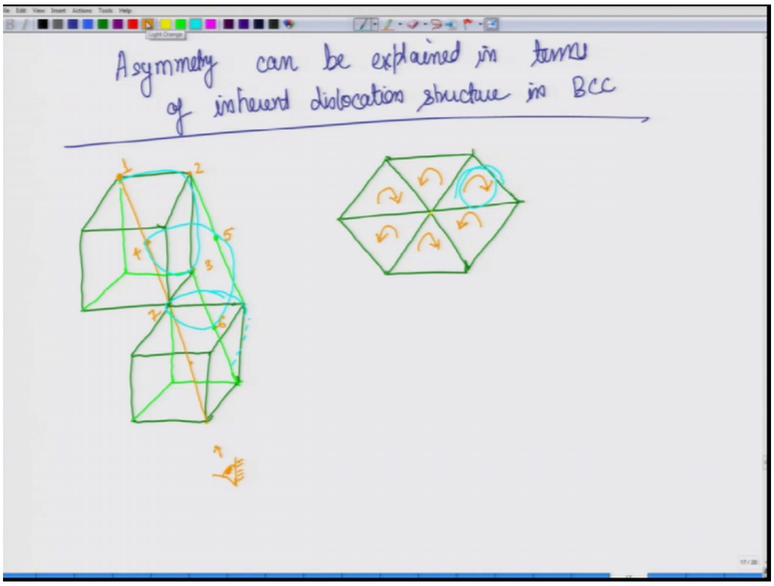

Now, this asymmetry there is another way, that you can explain this asymmetry let us look at this and this is related to inherent dislocation structure in the BCC. What is that inherent dislocation structure? We will see in a moment ok. So, let us let me start with again a simple drawing. So now, I will not draw just 1 cell, I will be drawing 2 cells together to be able to explain this concept and it will be much easier for you to understand, if you have if you can get hold of a BCC model.

Now here, which is the 1 1 1 direction? We know this is the 1 1 1 direction, now what I want you to visualize is how this atom would how this 1 unit cell would look like? If you have if you are looking along this direction; so, let us say you were looking in this direction. So, this is your eye, you are looking in this direction in a 1 1 1 direction, how would it look like? And if you get hold of a real system then, you would see that this is how it would look like in reality. The perspective image of this would be like this and let me try to explain what you are seeing here? What you are seeing here is that, this is one end this particular end and below this is the other end. So, this is your one side of it and over here this is your one face, which is something like over here this is one face and this is another face, this is square, this is another face and this is the face on one side, this is another face on one side this is another face on one side.

So, if you can imagine, you would be able to see that this is representing 1 cell, when we are looking down along the 1 1 1 direction. Now next thing that I want you to notice over here is that, if you take this atom as 1, this atom would you would see is just one layer above it. So, this becomes 2 and just one layer above it will be your third item 3 and just one layer above it will be your fourth item 4 and this will form like a spiral. So, we are looking at when you look through this will actually form one triangle and therefore, this triangle will turn out to be like this. So, there is a spiralness over here 1 and 4 are just one over the one over the other. So, this is equal to 1 full Burger vector and the distance along this direction between 1 and 2 would be 1 b by 3 the distance between 1 and 3 along 1 1 1 direction would be 2 b by 3.

So, this is 1 b by 3 2 b by 3 and this is 1 full b now the fifth atom, it will come right above 2. So, it is actually if you take if you join this atom through this atom, that the next atom along this line, which is parallel to this would be the body centered atom over here. And this becomes our fifth atom, the sixth atom likely similarly would be the item that would lie above 3, which would if you join this one and this one and there will be a body centered atom over here. So, this will become your sixth atom. So, 1 2 3 4 5 6 and again you can come over here, which will be your sorry this one, this is six, this is the next one 7.

So, this is forming a spiral and this is a screw dislocation type structure and if you look carefully, there are this kind of structure in all these this is not of course, by symmetry you know that it will not be only for one triangle that, we are seeing here it will be true for all, but only that the screw dislocation character would be different. It is in fact, changing from one cell to another cell. So, these are the 6 cells and each of them have different crystal or not sorry they are not crystal, but different spiral orientation and this is the, and let me try to draw a connecting line to say that this is a. So, I will just leave it at this. So, this is a spiral character that, you see and this is what I am trying to draw over here.

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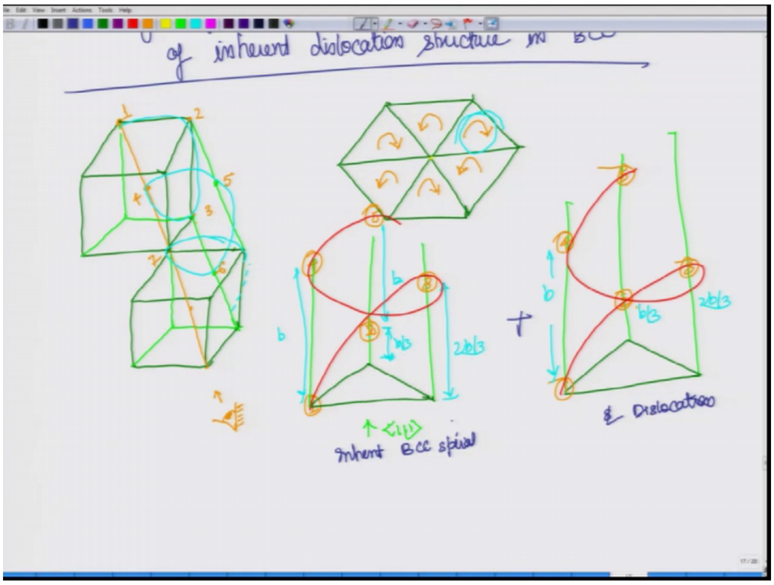

So, this is the spiral and this is parallel characters over here and now that if you are able to see this next, I want to move on and draw just one of this triangle. So, this is the BCC. So, these are straight lines along 1 1 1. So, this direction is remember 1 1 1 1 and so, the first atom lies, let us say somewhere over here and this is moving clockwise. So, the second one is over here, I will mark it 2, the third one is over here and the fourth one is over here and fifth one will be over here.

So, if we talk in terms of Burger vector, what is the Burger vector over here? Sorry what is the length in terms of burger vector? So, this one will be equal to b by 3, this one will be equal to 2 b by 3 this one will be 3 b by 3, which is 1 full b and. So, on again if you go from the bottom it will be 4 b by 3 or if you go from here to here it will be 1 b and so, you are again seeing a spiral this is what the spiral character, I was explaining.

So, this is the inherent dislocation that you see in the BCC, now what does it do how does it have a role to play? So, let us say I have a dislocation, which is also clockwise. So, we will assume that the core of this dislocation is limited to 1 cell or 1 atomic spacing. So, in this particular case also we will have a dislocation and I will draw these 3 lines and it will be very similar not similar in fact, it will look exactly same. So, we will have 1 over here, 2 over here, 3 over here, 4 over here.

So, this will be equal to b by 3, this will be 2 b by 3, this is b and so, this is the spiral character this is the dislocation. So, let me keep this, label this is dislocation sorry not dislocation. So, this is a screw dislocation and this is inherent BCC spiral.

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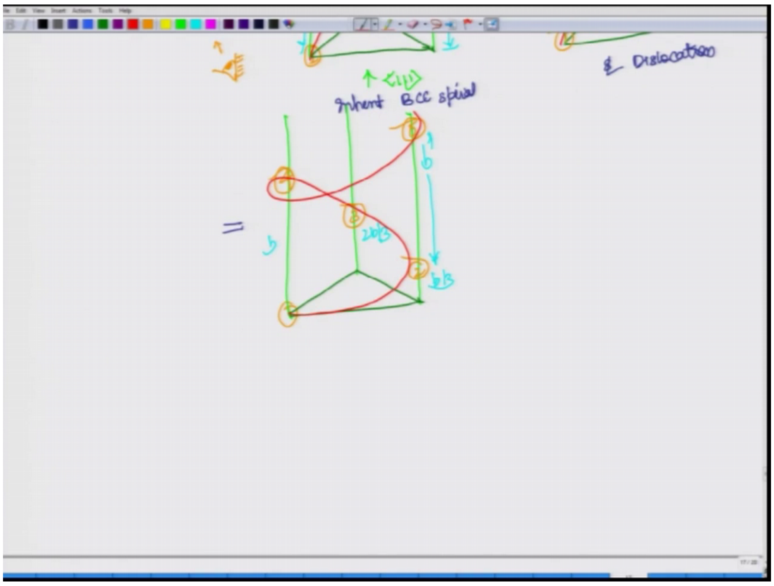

So, this is not a dislocation remember this is just a spiral inherent in the in the BCC structure and when you combine these, let us say if these two come together they are move. So, let us say, this is the screw dislocation, this somehow happens to fall in this one, what will happen? This particular position it would remain like this, but here it is b by 3 and this is b by 3. So, this one will get displaced by another b by 3. So, this will become 2 b by 3, here this is 2 b by 3, this is 2 b by 3. So, this becomes 4 b by 3 and then another atom, which was over here it will also come over here. So, this will become b by 3.

So, let us see, what I am trying to say. So, the final outcome would look like this it means that, the spiral now you can see and let me mention the dimensions. So, this is now 2 b by 3, this is b by 3 and this is b and this hole is 2 b. And therefore, a spiral character is still there, but now the direction of the spiral character has changed. So, these two summation is possible, this when this comes with closer to this becomes our spiral of different kind and therefore, this is the still a dislocation structure present over here and this is a possible scenario.

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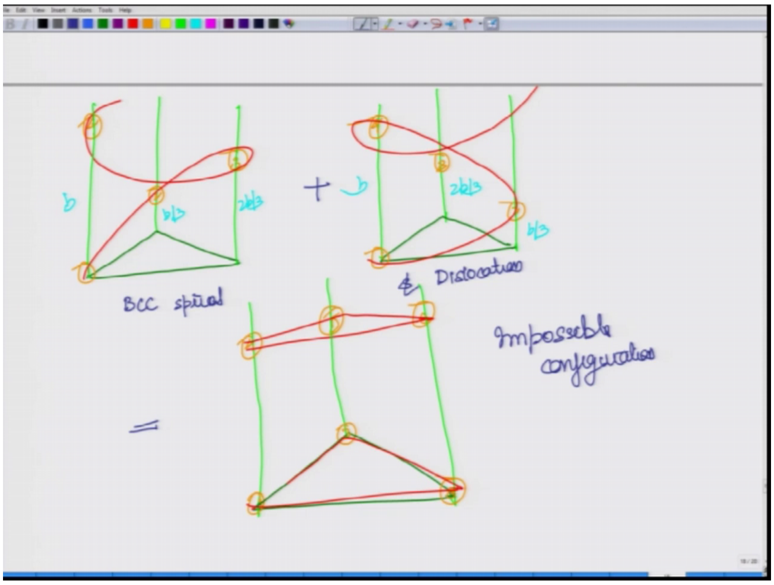

But let us say you happen to add something like this. So now, I will start with the same spiral of the inherent BCC. So, this is one this is at so, this is the spiral now, what I would do? I want to do is add a dislocation of opposite character into this. So, this was the clockwise, I want to add anti clockwise dislocation in this. So, let me first clearly say this is BCC spiral, this is screw dislocation and this time I am adding with a different character, 1 2 3 4. So, this is now this is b by 3, this is 2 b by 3, this is 2 b by 3, this is b by 3 this is b, this is b

So, now then this to get added this becomes 2 b meaning the item built in behind this lower than, this comes at this position 2 b by 3 plus b by 3 another item comes over here not here, but 2 b by 3 b by 3 it comes to b. So this, another atom will also take a position here 2 b by 3 and b by 3. So, b it becomes b and again this atom will move here and another atom from bottom will come over here. So, this structure would look like; so, there is no more spiral actually and all the atoms have formed in one plane. All the patterns would be on one plane, this is not possible that all the atoms are like this for all of the structure. So, this is a impossible configuration.

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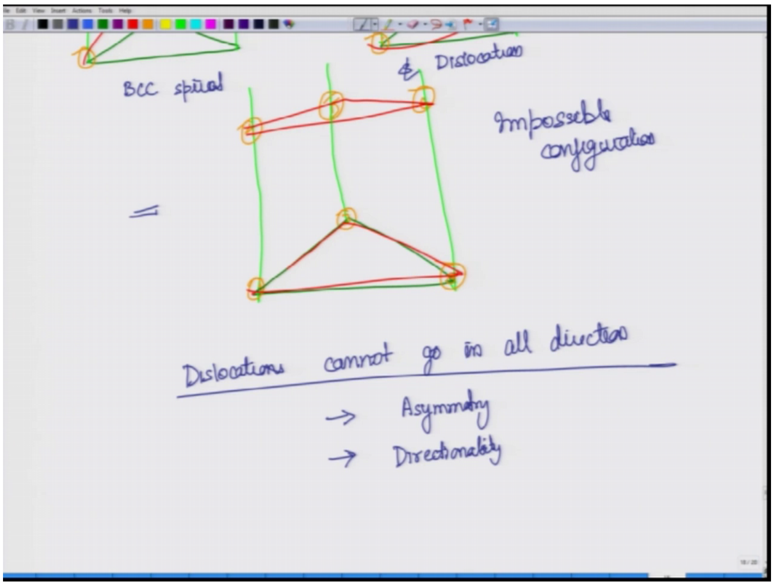

So, what I have shown you is that the dislocation cannot go at all places inside a BCC. So, that is the bottom line dislocations cannot go in all directions, even if it is one of the slip planes or the slip directions it cannot go in all directions and this is what leads to asymmetry. So, this is a simple way to visualize, why this asymmetry is arising. Asymmetry, directionality all these aspects can be seen or can be understood using this terms.

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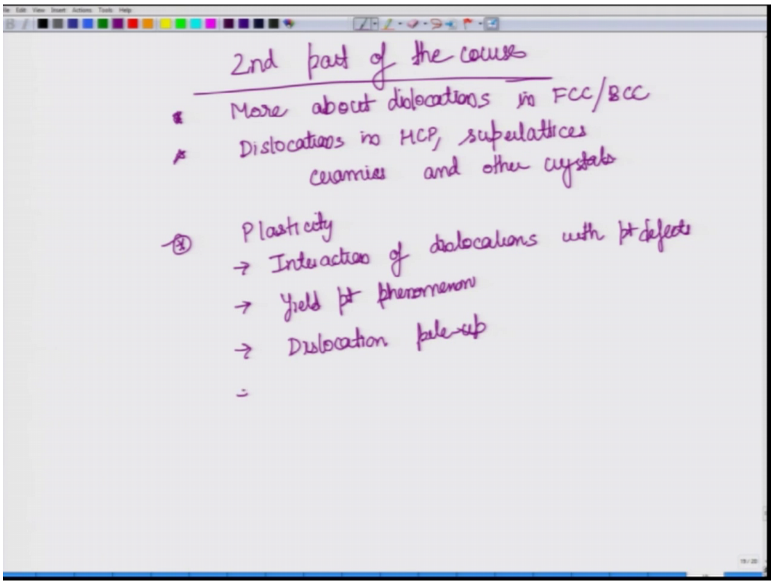

So, now, I have given you enough understanding by fundamental understanding about FCC and BCC dislocations, but there are lot more things that are still remaining in this particular topic and let me list out some of those topics. So, the second part of the course it will contain more about so, far we have seen we have just taken a glimpse at the dislocations in BCC and FCC, we will look at more about.

We have already looked at the fundamental points, but we can understand there motion behavior and with the help of examples in FCC and BCC. And so, far we have looked only at FCC and BCC cubic systems, but there are also dislocations in low symmetry system like HCP or there are something called a super lattices, which where the dislocations behave very differently, because of just because of the Burger size of the Burger vector.

Then ceramics because, there are anions again you get to see very different kind of behavior and many other crystals and then we will move on to the topic of plasticity. Now that we have looked at dislocations point defects, what is their role in plasticity? So, for that we will start with interaction of dislocations with point defects, which would help you understand particularly the yield point phenomena.

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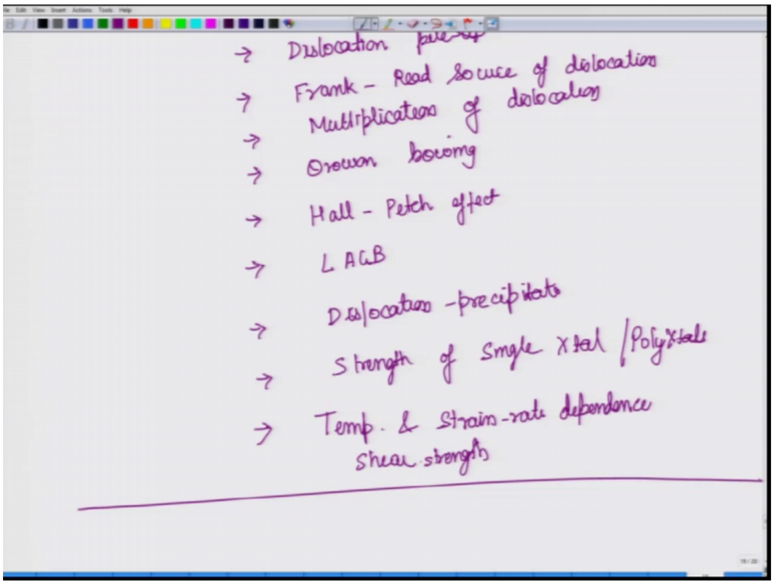

We will also look at interaction between dislocations like what is the what leads to dislocation pile up kind of behavior, we will also understand Frank Read source of dislocation. So, somewhere the dislocations must be generated and one of those is Frank Read source of dislocation and related to this we will also look at other mechanisms of multiplication of dislocation Orowan bowing, where because of the presence of 3 D defects like inclusions the grain boundaries have to bow around the obstacles. And, also how such phenomena can lead to hardening which is known as Hall Petch effect, then dislocations end up forming what is called as low angle grain boundary. When they get aligned they form low angle grain boundary, dislocation precipitate interaction, which leads to strengthening precipitation strengthening.

So, in aluminum alloy you would know that, you have under aged, peak aged and over aged samples, what is the difference in terms of precipitates? That we will get to understand when we look at dislocation precipitate interaction; and as a some of these you would be able to understand strength of single crystals, polycrystals and one important topic, you can say is more like a fundamentals to the dislocation is temperature and strain rate dependence. So, we know that the strength of a material is dependent on temperature and strain rate.

We will look at this phenomena from dislocation point of view, because in the end it is the motion of the dislocation, which is at the application of shear or sorry at the application of shear stress. But, at certain temperature you need to apply lower stress; at a lower temperature, you need to apply higher stress at higher strain rate again you need to apply higher stress. So, how does this shear strength depend on temperature and strain rate? So, these are some of the important topics that will be covered in the next part of the course.

And, I hope you enjoyed the first part of the course and I will strongly urge you to register for the exam. And, if there are some contents where you feel that there should be more clarity, then you are welcome to send feedback to us and we can put tutorial sessions on that, which will help you understand this concept; so happy learning.