Defects in Crystalline Solids (Part- I)
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Lecture – 23
Glide Forces on Dislocations + Line Tension on Dislocations

So, coming back to where we left. So, we showed that the total energy for a dislocation can be given in the form E total equal to alpha G b square; where, usually alpha varies between 0.5 to 1.5.

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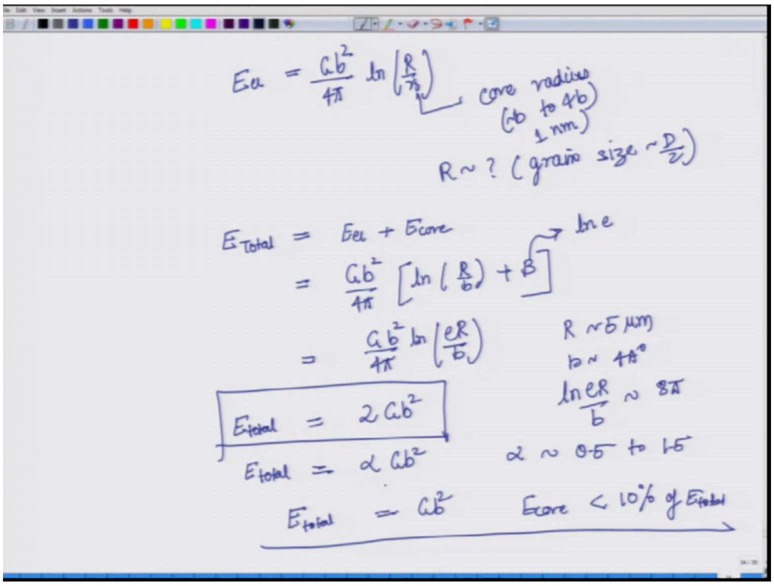

And this is total energy, we also have relation for just the elastic component. In the elastic component, you add a core component energy, core energy where the linear elasticity does not hold and usually this E core is less than 10 percent of the energy ok.

So, now we have this relation for E total as a first order of approximation, we said that E total is equal to G b square. Now, what are the implications for this? There are some implications regarding dislocation, association and dissociation which will see over here.

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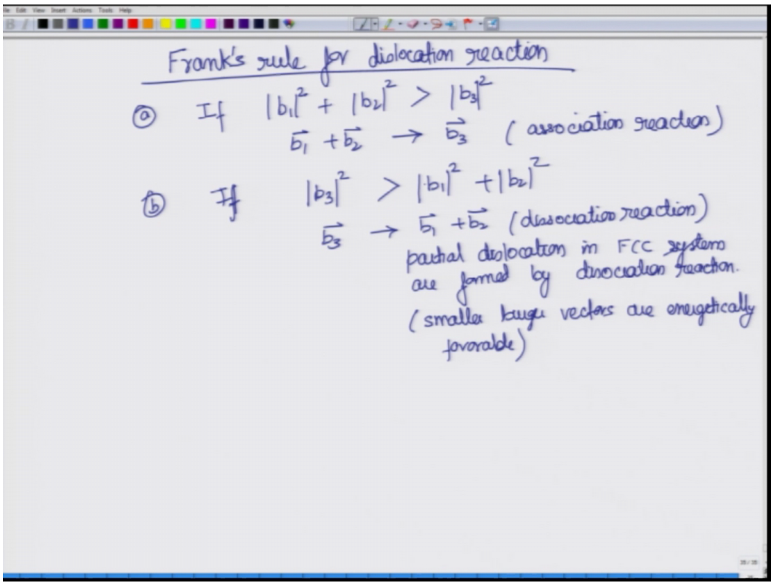

This is called Frank's rule for dislocation reaction. What it is? What this rule is basically describing is whether dissociation reaction of this location is possible or re-association of dislocations are possible. What that means? Let us says we have dislocations with 3 dislocation with burger vector b 1, b 2, b 3 and it is possible that b 1 plus b 2 can associate or disassociate into b 3. Now, which one is possible is what we are trying to understand using Frank's rule.

So, let us say if b 1 square plus b 2 square is greater than b 3 square. If this is something that you can know or derive, then what it means is that the overall energy for separately the 2 dislocations b 1 with the burger vector b 1 and b 2 is more than the energy for the dislocation word with burger vector b 3. And therefore, they will have a tendency to associate and it will become, it will become b 3; the dislocation will burger vector b 3.

So, it will look like this. So, for the b 3 square must be smaller than b 1 square plus b 3 square for this reaction to take place and this will be the association reaction. On the other hand, if you are if you can find out derive or it is given that b 3 square is greater than b 1 square plus b 2 square, it means that the overall energy which will be proportional to b 3 square for this dislocation b 3 with this location with burger vector b 3 is higher than when the dislocations are separate individual, as dislocation is burger vector b 1 and b 2. And therefore, it will like to remain individual because that way the energy is lowered for the system and this will lead to a dissociation reaction.

And it is this particular dissociation would be very well known to you if you have had any course in mechanical behavior. You would know that partials in FCC, partial dislocations in FCC type of system or formed by this dissociation. Here, it is saying that smaller burger vectors are energetically favorable. When will come to the BCC and FCC lattices systems, you would see there are also examples where b 1 plus b 2 goes to b 3 meaning association reactions take place.

But, the dissociation reaction is much more commonly known and that is for when a full dislocation in FCC system dissociates into partials. And, there is another small aspects is your talking about energy and we said that what we have looked at is only the pure edge dislocation energy, pure screw dislocation energy. But we also said that at the same time that most of the dislocation would be in a mixed form. You will you will see only at a particular point it will be other pure edge and at a particular point it will be pure screw, but on the whole it will remain a mix dislocation.

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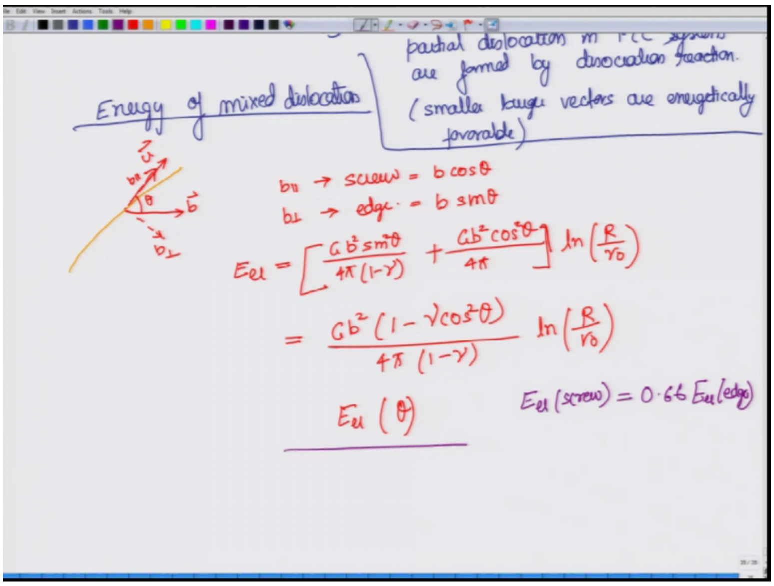

So, how do we find the energy and we showed that you can dissociate or you can find resolve b into edge and screw components; so, the using that we will be able to find the energy of a mix dislocation. So, using the same plot; so, our topic here right now is Energy of mix dislocations. So, let us say the burger vector is like this, which is at an angle theta. And therefore, you have b which is perpendicular to the line vector, which is somewhere over here and similarly you have a b component of this; this is the real b. This is b perpendicular. This is b parallel.

So, b parallel denotes the screw component because in screw, dislocation vector and b perpendicular represents edge dislocation. And therefore, the elastic energy can be given as. So, what is b parallel equal to? This is equal to b cos theta. This is equal to b sin theta. And therefore, we have G b square for the h component, we can write it like this. So, this is the burger vector for edge dislocation which is b sin theta is taking square of it. It becomes b squared sin squared theta and rest of the components remain same and energy is can be simply added. So, this is the edge component energy. Now, will at the screw component energy. If it were vector quantity or tensor quantity, we would not can be in a position to add it is directly like this. Thankfully, these are scalar quantities and we can simply add it.

So, here b cos theta is the screw component and will write the equation rest of its just like that. It will be equal to l n R by r naught and if you want to simplify it further, you can write it like this. So, what we see is that this E e l is a function of theta and why it is like that because, screw dislocation and edge dislocation have different energy. If you remember we said that elastic energy of screw dislocation is actually lower than the elastic energy of edge dislocation and assuming that nu is equal to 0.3, then we can get 0.33, then we get the factor as 0.66.

So, screw the energy of screw dislocation is 66 percent of the energy of edge dislocation which would mean that a system if you take a material system that, then it would prefer every like to have only the screw dislocation or it will like to have higher density of screw dislocation because that weight has lower energy.

So, this is the relation for E l and that is the reason why energy elastic energy of dislocation of make dislocation will change with theta. So, if you go from one point to another point, the energy per unit length is changing. So, with that we come to end for the energy component. Now, we will move to another aspect of dislocation which is Motion of dislocation.

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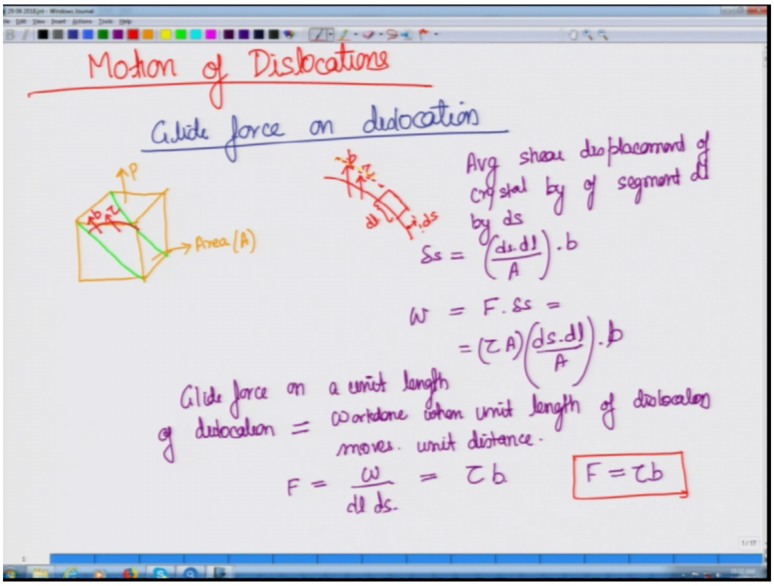

So, our next topic is Motion of dislocations. So, we have now looked at stress, strain and energy components. Now, with these informations, we are equipped to understand a little about the motion of dislocation and we have not mentioned it earlier, but you would see that there are they can be 2 possible kind of motion for dislocations. One is called the Glide motion which is in the plane and the other is the Climb motion which is perpendicular to the plane.

So, in the Glide motion the dislocation move in the same plane in which the line vector and the burger vector lies. The dislocation moves perpendicular to the plane which contains the burger vector. It is only define like that and there will be implication of that that there will be restriction on the plains on we edge dislocation can move; while for screw dislocation, it will have plenty of planes to move on to. Any of coming back to motion of dislocation, the first aspect that we would want to study that we want to discuss here is Glide force on dislocation.

Now, assume that you have a material that is a let me draw it like this. We are looking at a small section of it. Now there can be external or internal load applied onto it. So, let say this is the load. This load if we are since we are talking about small section, this particular load which is shown by P, it could be arising because of some external load or it could also be arising because of some internal configuration. So, that is something will leave it open right now. With can so, whatever we derive will be independent of whether this load that is coming onto this is from external load or internal load.

Now, let us say that there is a particular plane on which dislocation is moving. So, let us say the dislocation is. So, let us say the straight line denotes the dislocation and over here, it must have burger vector which will be constant throughout. So, let us say the burger vector is like this. So, this is the burger vector. Now, this burger vector also denotes the slip direction. So, the shear stress must be resolved along this burger vector to find out how much stress is acting on this dislocation which will cause its motion.

So, let us say the resolved shear stress is given by this tau and you see that I have drawn it parallel to be. So, the resolved shear stress from sum of external and internal load is coming out to be tau. Next, let us say that the area on to which this shear stress is acting is area is equal to A. Now, what will do is will see a in assumed direction how this dislocation is moving. So, let us say this is the dislocation that we do; this is the burger vector and this was the dissolved tau and let us say this, this is the new position for the dislocation. Since, it is this is not appearing here, let me draw it by ok.

Now, let us consider a small length d l and let us it has moved a small distance d s. So, you are look talking about. Now, the average shear displacement of crystal by Glide of this segment d l can be given as average shear displacement of crystal. So, we are talking about this crystal which is the section shown over here by Glide and since, it is moving only by glide, we are assuming that the dislocation is moving in the plane of segment d l by a distance d s, this will be given by. So, the del divided by area A because this is where, the shear stresses acting and multiplied by burger vector v to normalize it.

Now, since this is the shear displacement. So, what will be the work done? Work done will be some force which has acted on to this into this displacement. So, this is let us say delta s force into delta s is equal to and what is this force? Force is nothing but shear stress acting on the area A. So, this is force and delta s is d s into d l by A into b. Now, this is the total work done. So, the Glide force if you want to talk about the force which was acting on to the dislocation, then we have Glide force on a unit length of dislocation; it can be defined as Work done when unit length of dislocation.

So, we have to talk about a unit per unit length, the force will be calculated as force per unit length that is the general known when we are whenever we are talking about dislocation because this locations are long lines. We cannot calculate the total force; we can only calculate force per unit length; when unit length of dislocation moves unit distance. So, the force can be what it means is that the force will be equal to work divided by unit length divided by the unit displacement. So, this comes out to be tau into b and now this is a very important relation.

So, this is telling us how much force is acting on the dislocation. So far we were talking in terms of shear stress which is acting only along burger vector. However, now we have well down to force that is acting on to the dislocation which means when we are and the dislocations since it is moving in normal directions. So, this force will also be acting normal to the dislocation. So, where have come know to a quantity force which is acting on the dislocation in the normal direction and it is given by shear stress times the burger vector b. Now, what is the meaning of this?

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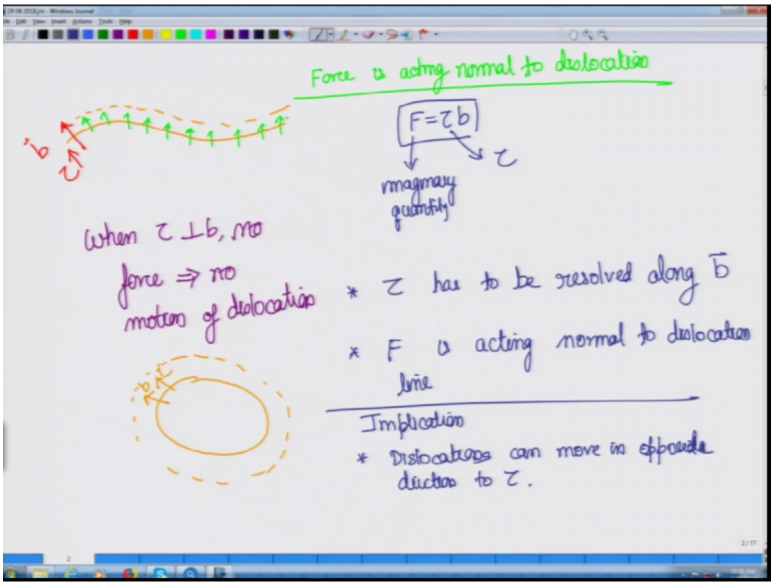

If we have, let us say a dislocation like line like this and let us say this is the burger vector. Similarly this is the tau. So, shear stress and burger vector are acting in this particular direction. However, the force that we are talking about which is equal to tau times b, this is acting normal to the dislocation. So, here are here we have the relation F equal to tau b; where, tau is the resolved stress which we can easily find from the given condition with their it is from the internal stresses or from the external stresses and from that, we can save how much force is acting on per unit dislocation length and that will be just shear stress times b. So, this is very power full relation which gives us the force that has to be acting.

Now, you have to also realize that this force that we have talking about is actually imaginary quantity. What is really applied here is only stress. So, force you must keep in mind is imaginary quantity. This is only useful from the point of view of understanding how the dislocations are getting moved the real quantity is tau. So, if you look at here tau is like this; but that would mean that the dislocations are moving like this. So, that dislocation is moving even direction indirection which is perpendicular to tau or maybe even in words of tau.

Because, as long as there is a resolved stress, along burger vector, there will be force acting normal to the dislocation; this is the implication of this relation, the only time when are resolved stress will not be able to move a dislocation is when tau itself will not be per when tau itself is perpendicular to b. So, when tau is perpendicular to b no force implies no motion of dislocation. But as soon as you get the tau some resolved stress along the burger vector, then what it is also doing is that even if your let say a burger you dislocation is like this with burger vector like this. This as if the burger vector is like this meaning tau is like this.

Now, in this particular case, the dislocation the dislocation can expand depending on the sign. If the tau is in the same sign the dislocation will expand. So, if you see the dislocation is moving in the direction opposite to the applied shear stress, why? Because as long as there is tau along b, there is force acting on the dislocation; on the other hand is tau as in the opposite direction like in the inverse direction, then it would have probably been contracting the dislocation. So, that is something that we learn here that tau has to be resolved along burger vector b.

However, force is acting normal to dislocation line; implication that dislocations can move in opposite direction to tau ok. So, hopefully this has given you enough understanding to relate tau to be and this tau can be coming from any of the like as I said. It could be from external stresses or it could be from internal stresses. For example, there could be bunch of dislocations because of is there is stress getting generated and from there, there is tau getting applied on to this particular dislocation. So, here this tau, we have not said whether it is it has to be whether it can it has to external or internal; it can be a none of these things ok.

So, now let us move on to regarding the dislocation motion. So, now, that we know F there is a F equal to tau be relation, there is another implication for this which is in terms of line tension.

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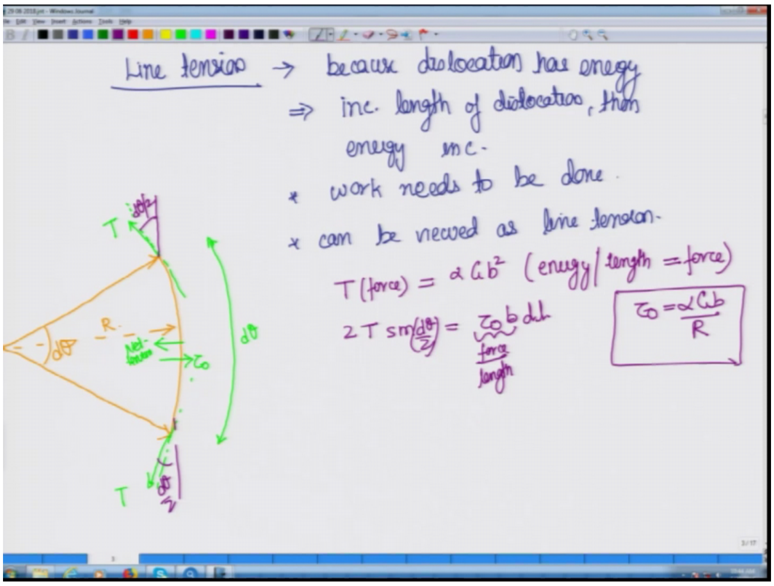

Now, first of all why should there be a line tension in a dislocation? Line tension exist because this location has energy. Now, if this location has energy, it implies that if you increase the length of dislocation; then, what happens to energy? Then, energy also increases, which implies that your it can be viewed as that work has work needs to be done to increase the length. Because when you do work, then energy will get added and therefore, the line dislocation length can increase. And therefore, this can be viewed as line tension.

So, now that we have defined this. Let us look at one particular application of this line tension which is to describe how much shear stress would be required, if you are if you want the line tension or sorry the dislocation line to have such sudden curvature. Let us say radius r. So, let us draw a line dislocation. So, let us say the line dislocation is like this. So, we have it has some curvature in a way we are drawing, we have zoomed in to a very-very small length ok.

So, this is a very small length of dislocation that we are talking about and the overall you can assume that the overall theta is very small over here. So, we are talking about a very small length which is d l and that theta is also small. So, this is d theta and that as there is energy associated with dislocation line. So, there will be line tension acting like this, which will be along the line direction.

Let us say at the edges of this, small segment of dislocation that we are looking at which means that since there is tension here, tension here. Therefore, there will be net tension in this direction and if there is net tension in this direction and if you still want to keep this curvature which has is we have I am not mentioned the radius. It is radius is, if it is still wants to maintain this curvature then there must be some applied stress tau naught which will be along the burger vector of course and this is the net tension.

Now, first of all, let us see what do we know. We know that this tension or the force is equal to alpha G b square. How do we know that? We know that because energy, what this was earlier defined as what energy per unit length and what is energy per unit length? Energy per unit length is equal to force. So, the tension that is acting along the dislocation segment along this direction and along this direction can be written as alpha G b square.

So, now we have one relation. Other relation is there is a net force acting like this and therefore, balancing stress must act along this direction and what is that net force here? If this is T, then you can find out that this is this angle would be d theta by 2; this would also be equal to d theta by 2 and therefore, this will become 2 T sin d theta by 2 equal to tau naught not b d l; where do we get this right hand side. Now, this is the force here acting here; over here, we should have total force.

Now, this is what is this force per unit length. If this is the tau naught is the shear stress, then best becomes the shear stress times burger vector base. This becomes force per unit length time's length. Therefore, this is the total force quantity. So, this is the force that is balancing in the other direction and this is the tension because of the line tension of the dislocation. So, using these 2 relations, we would be able to see will come back to the next in the next lecture. But what you will see is we should be able to get a relation like this.

So, what I would suggest is that you try and obtain this how to get this relation and will come back and I will show you how to come to this relation.