Principles of Physical Metallurgy

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Lecture No # 11

Crystal Defects in Metals (Contd.)

Good morning, today we continue our lecture on crystal defects in metals. Last class we talked about few defects, which are present in the crystals.

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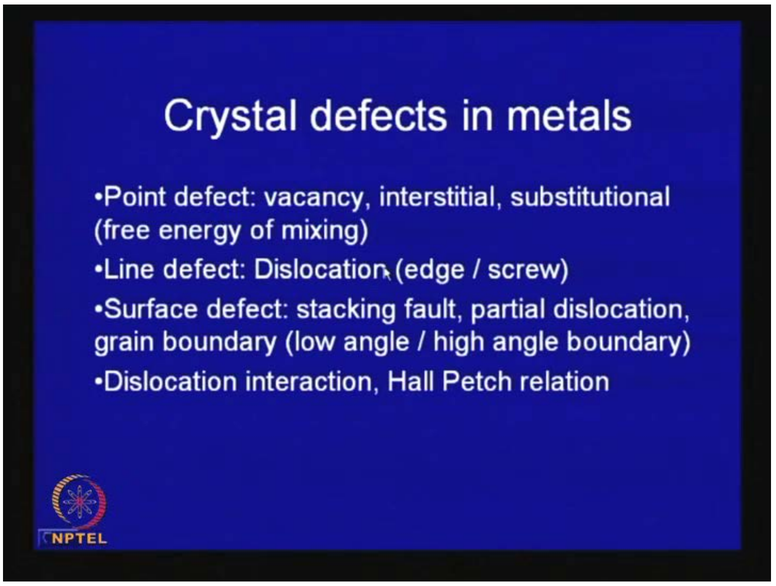

See, real crystals are not perfect; here, the periodic arrangement of atoms, there is a little disturbance. And last class we talked about few of these, like point defects, like vacancy. If there are impurities in the crystal, where do these impurity atoms go? We talked about interstitial type of impurities; we talked about substitutional type of impurities. And we also derived an expression for free energy of mixing for this point defects and we find that this defect concentration, particularly this vacancy is a strong function of temperature, higher temperature, you have more vacancy.

And then, we introduced the concept of a line defect, the dislocation and in fact, particularly the mechanical properties of metal are determined by the types of dislocations which are present in the crystal and dislocation-dislocation interaction, dislocation precipitate interaction, dislocation and this impurity atom interaction.

So, now, today we will look at this in little more detail and we will try and look at that, how, I mean, can we visualize an ideal configuration of the dislocation and if there is a dislocation what will be the nature of stress field surrounding the dislocations. And presence of the dislocation, as has been mentioned earlier, that it is because of the presence of dislocation, strength of real metal crystals is never as high as that predicted for ideal crystal.

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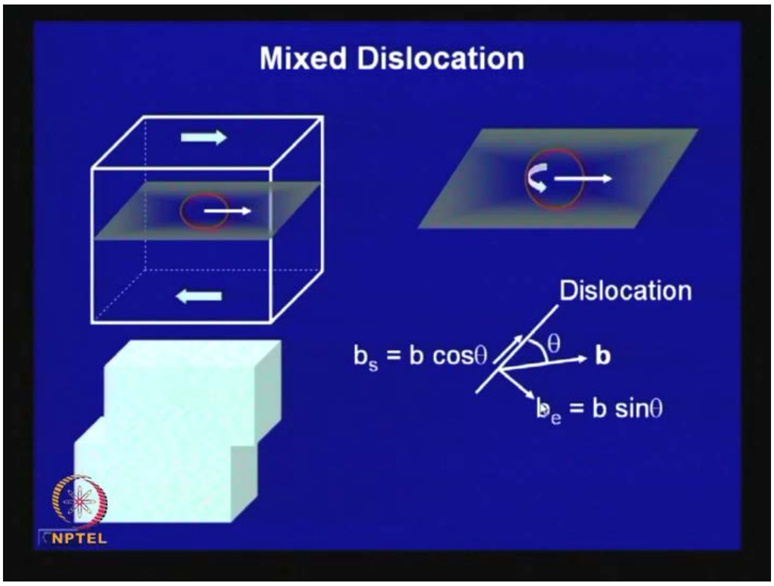

Now, we looked at the type of the dislocations, we talked about edge dislocation, we talked about screw dislocation, but basically in general a dislocation need not be a perfect screw or a perfect edge dislocation, it can always be a mixed dislocation, so which is shown over here.

Suppose this is a crystal and you apply (( )) crystal and this is a 03:20 slick plane on which you have a dislocation. So, here this dislocation line, you know, it, either it will, that would not be any end, if it ends, it has to end on the surface of the crystal. So, this is the continuous dislocation line. So, dislocation line also is a vector, say suppose we say that this is the dislocation direction. You look into the crystal, say this is the positive direction of the dislocation and this is the (( )) and when this dislocation moves out, it will create a step like this, step on this side.

So, when this goes out here, you know the dislocation, you look at the sense of the dislocation as, so here if you say the dislocation is positive, here it is coming out, you can say, that sense of the dislocation. So, you have to follow the proper convention. Say, suppose we say, that one end will be positive and another end will be negative. And here this part, it is a positive edge dislocation and this part, it is a negative edge dislocation. And say, point is, if it is a positive dislocation, this upper part moves ahead; if it is a negative bottom part, you have an extra display atom and which, when it comes out, it forms a step like this, whereas this two parts are the screw dislocations.

Now, screw dislocation also, one will be positive and the other will be negative and the step here also will form along this, it is easy to visualize. Now, suppose this is the sleep plane, you look at the dislocation. Now, take a segment of this, say suppose, this is a dislocation direction, the line representing this dislocation, this is the vector that represents dislocation line and this is the (( )) vector. If it obtains an angle theta, you can see, that the part that is component b cos theta, is the screw component of the dislocation. This is the Burger vector for screw; this is the Burger vector for an edge dislocation.

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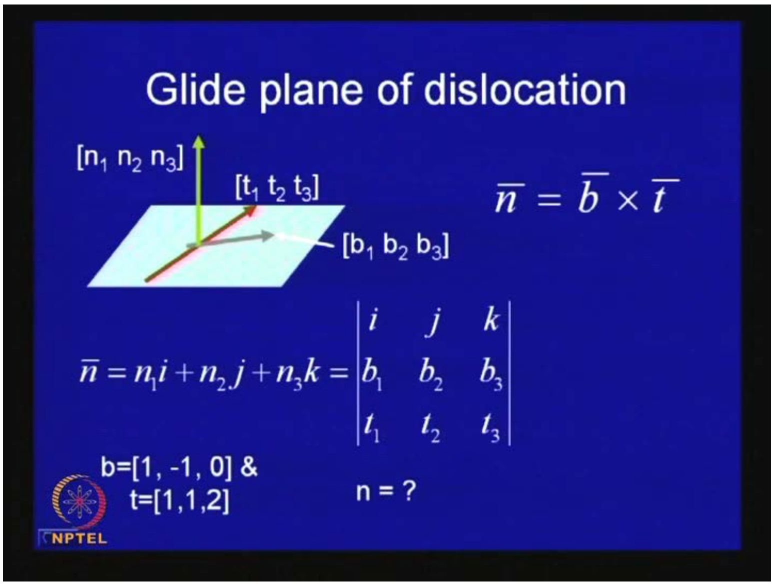

Now, obviously, a dislocation, if I go back here, this dislocation, this lies on a particular plane and this glide movement, is actually the movement along the plane. So, this is possible only within this plane. And how do you determine if you know the Burger vector, know the dislocation direction. The plane, the glide plane is fixed. If it has to move through slip, it has to move, can move only in this plane. And this is the method, which describes, you know, how can you, last class I did give an example and where we solved it intuitively using the, I mean, the shortcut roots.

But here, if it is the general case, this is the way you will be able to find out the glide plane of the dislocation. This is quite important, in the sense, if the glide plane of the dislocation is not one of the common slip plane in the crystal, in that case we can see the dislocation is immobile, it will be difficult to move. In other way, the resolves (( )) necessary to move the dislocation on that plane will be very high, it will be difficult. So, for all practical purposes we can consider the dislocation to be immobile.

So, the thus to understand some of the subsequent lecture it may be important, so let us look at it little critically. Say, this is a glide plane and you have a dislocation line here and this line, as I said, say if it extends, say this may be the end of the crystal, it must end here. Similarly, other end, say, should end here. It cannot stop all by itself within the crystal. It is impossible because there will be some lattice distortion, maybe, this contain (( )) part of the dislocation or it could be an endless loop.

Now, let us represent this dislocation direction as t 1, t 2 and t 3 and let us see, this is the Burger vector of the dislocation. We represent in vector notation, these are the three components of the Burger vector with respect to the reference axis. So, b 1, b 2, b 3 and we call the unit vector, the reference axis, let us say as i, j, k. The unit vector, say, along x axis, along x axis is i unit vector, along x 2 axis is j, x 3 axis is k. And then, in that case, say, if this is the dislocation direction, if this is the Burger vector, then obviously, the cross product of the two will represent the slip plane normal and this slip plane normal here is represented as a vector n 1, n 2, n 3. So, n is actually a b cross t. So, here is a case where you can look at this. How do you find this out?

So, this in, in terms of, in terms of, you can, it is possible, it will show, that this cross product in terms of this kind of a vector representation is represented like this. These are the components, the vector is n 1 I, n 2 j, n 3 k and this will be equal to this determinant. This is i j k, then you put three component b 1, b 2, b 3, t 1, t 2, t 3. So, this determinant gives this plane normal. Now, let us look at the case, say if b is equal to 1, bar 1, 0 and if this direction t represents (( )) this as 1, 1 and 2. In that case what will be this glide plane? Now, this is, if you can simply substitute and find out the determinant and in fact, possibly, this was done in the last class.

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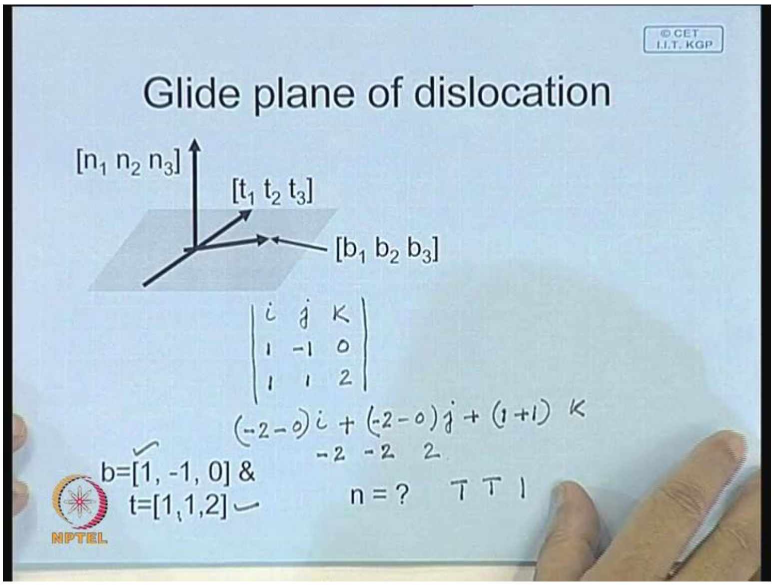

So, if you write the determinant, say basically, what it comes, this i, j, k, then 1, minus 1, 0; next one is 1, 1, 2. And so, this determinant, if you break it, so it will be minus 2, minus 0, i, plus j. So, this will be minus 2, minus 0, plus k, this is 1, plus 1. So, if you solve, this it actually come minus 2, minus 2, 2. So, basically, this n comes out to be 1 bar, 1 bar, 1. So, now you can check, so this is also to verify, this is normal perpendicular to the, and this is also perpendicular to this direction. So, that means, you can say, that this is the very easy way of finding out glide plane of a dislocation.

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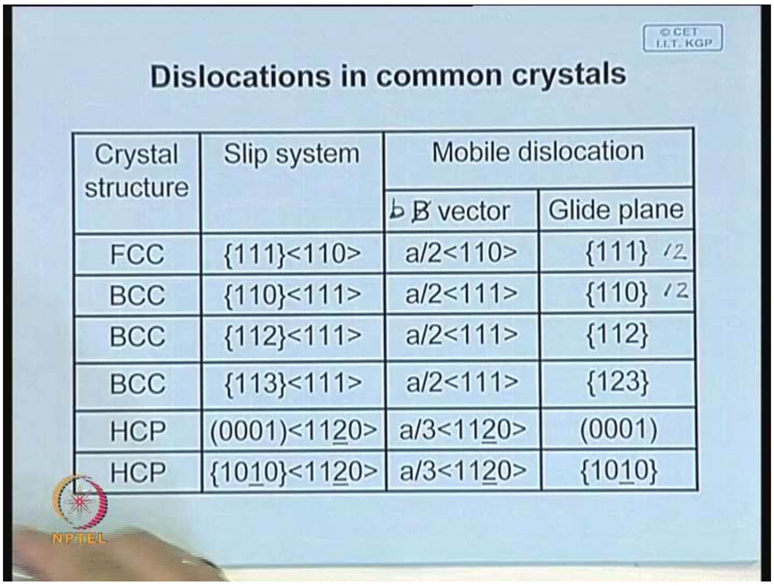

Now, here are some common slip system and which gives the glide plane and the Burges vector. This should be small b, Burges vector. So, basically, so these, some of these are listed and we also looked at how many of these are possible, like in this case FCC, here you can have different combination of slip plane and this Burger vector. So, on each of these slip plane you will have 3, so you can calculate, this will be 12. So, similarly, here also this type is 12. So, maybe, try and find out what will be this possible slip system or glide planes for the dislocations in these crystals.

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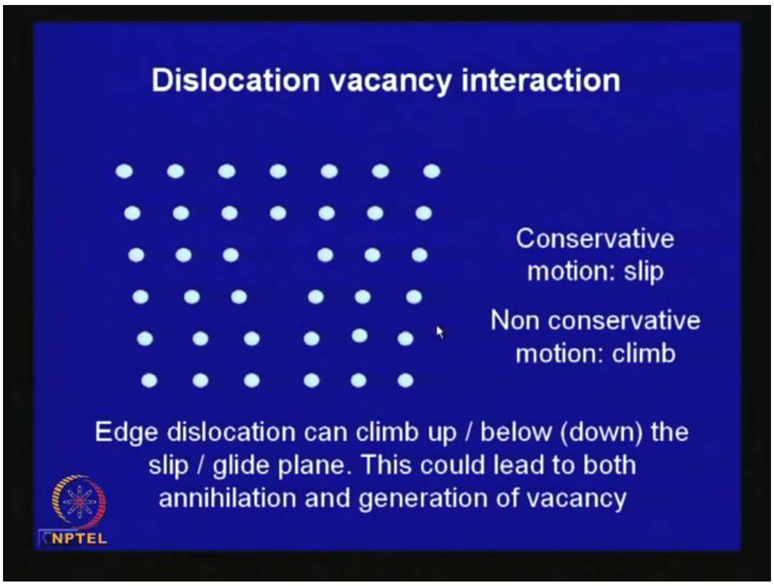

Now, we looked at the glide movement of the dislocations. Now, edge dislocation can move in another way because edge dislocation, you can visualize as an extra plane of atom above, let us say, positive dislocation extra plane of, there is an extra plane of atom above the slip plane and beneath the slip plane, it is basically the space is vacant. And we also know that crystals at any temperature will have some amount of vacant spaces or vacant lattice side. How will these vacancies interact with edge dislocation, which is shown here?

This is the dislocation, I mean we will try and show this edge dislocation and vacancy interaction. So, now, this is the gap. So, now, if there is a vacancy in the lattice here and then what happens? This, depending on the temperature it has some mobility, it does not remain stationary, it keeps moving through the lattice at random. And say, suppose next time, next (( )), it comes here and it might as well as come here as well. So, that will be a very stable configuration. So, in that case what is happening, that this edge dislocation has moved up. So, this is called a (( )) motion of dislocation. So, this is actually, we call this as a non-conservative motion of dislocation.

So, why, and we will say, suppose in this particular case this is a vacant space, so what happens? So, normally edge dislocations are represented as an extra plane of atom. So, this is the glide plane. So, this is that extra plane and when vacancy comes here, say right now the slip plane is this, when a vacancy comes here it moves up. So, that means, it comes here, so now it can move on this plane, which is parallel to this.

So, what happens? This gives an additional possible movement for this edge dislocation. If somehow there is edge dislocation encounters an obstacle here, later on we will see what will be the nature of obstacle, it cannot move through the obstacle. So, that is, when this vacancy can help this dislocation move? So, if the vacancy comes here it moves up and this plane, there is no obstacle, so it can; it is free to move here. So, this movement is called non-conservative motion of dislocation, whereas glide is called the conservative motion of dislocation. So, this is, we say this is a non-conservative motion, which is a slip process and non-conservative motion is a climb process now, which dislocation can climb. So, it is, definitely we explained it with respect to edge dislocation.

Edge dislocation is only associated with extra plane of atom and beneath the plane you have a lot of vacant space. So, it can, it is only edge dislocation that can climb. It is screw dislocation, cannot climb, but screw dislocation, there are multiple slip plane screw dislocation, can have multiple slip plane, whereas edge dislocation will have a specific slip plane. And this dislocation and vacancy interaction is quite important. Say, in this case, we considered the case of climb motion of the dislocation through climb motion, what is happening?

Vacancies are getting annihilated, vacancy in the rest of the part, if one vacancy from here, comes here. Vacancy in the rest of the part decreases. Similarly, there is a possibility, if this location climbs down, in that case it can generate vacancy. Dislocation. edge dislocation act as both, as source and sink for vacancy.

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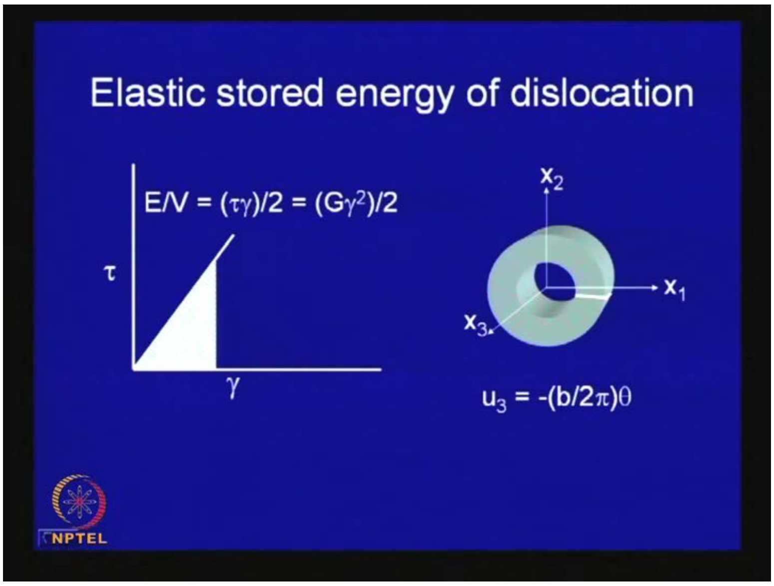

Now, to understand many of our interaction with the dislocation with the point defect dislocation with solute atom, it is necessary to know about the nature of stress feel, which is generated when a dislocation is, when a dislocation, when there is a dislocation in the crystal. And the best way to visualize is, this is like, this we consider (( )), say a hollow cylinder here and suppose we make a cut over here, one part of this we cut here and let us say, this cut portion, this is the sleep plane and what we try and do? We try to move it slightly and then we weld it. So, what happens? A step will form here (( )). If it is a, if you are trying to generate an edge dislocation, a step will form on this phase if we are trying to generate a screw dislocation.

So, what happens if we weld the two phases together? It will not be able, it will not be, that part, this part will not be allowed to come back to its original position. So, therefore, there will be an elastic stress field surrounding this defect. In fact, what we can see, that this hollow area is where this defect is located and the reason we consider it hollow is, that you can find out the stress feel only if this deformation is elastic and within this your elastic or Hook's law will no longer be valid.

So, it is a convenient way of assuming, that you have a hollow core where we do not know there will be a disturbed lattice structure, but here the stress will be too high. We can say this, let stress over here be equal to the theoretical strength of the crystal. So with this assumption it is possible to apply the theory of elasticity to calculate, not only the stress field, but also the elastic stored energy of the dislocation and we know, that to move this dislocation you have to apply a shear stress. And the shear stress and shear strain relationship is linear and the energy per unit volume is given by the area under the curve. So, in one way you can say, that if you multiply the modulus shear strain square over 2, this, the elastic stored energy per unit volume.

Now, let us try and visualize the process of generation of this dislocation, say, say suppose you take, try and explain it with this. Say, suppose if you take a piece of paper, fold it like this, now you try and displace it like this and then you fix it, so I will try and fix this here. So, what happens in this case and you join these two faces. So, what happens? You are creating a step over here. So, this is, you can say, that this simulates an edge dislocation, edge dislocation is line along the axis, along the axis and this is the step vector, this is the step vector forms in this surface.

So, same way you can also visualize edge as screw dislocation and screw dislocation, the displacement is along, along the axis, displacement is along the axis. So, here is the step that is forming. So, you have, this axis screw dislocation is along the axis of the cylinder and this displacement is the Burger vector.

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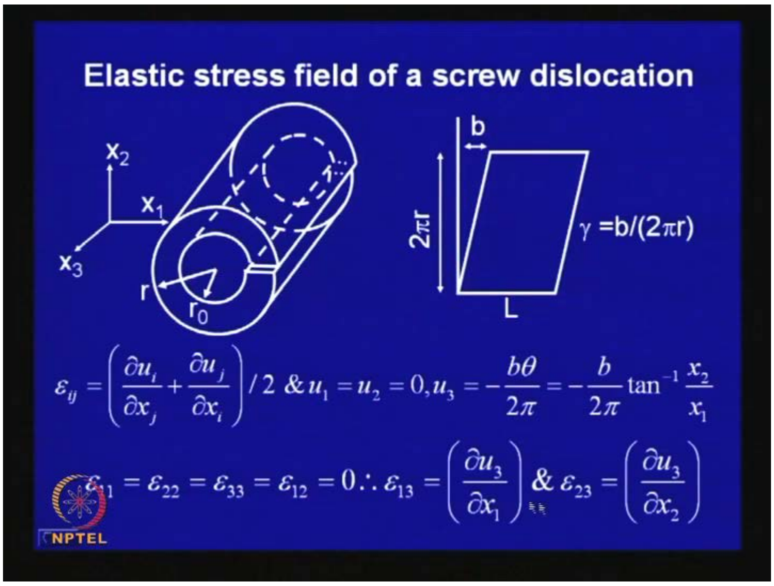

So, with this and so, let us look at edge dislocation. The estimation of this stress is very simple. So, this is the hollow cylinder we have displaced, we have formed a screw dislocation and this is the hollow core. This is the reference axis, X 1, X 2, X 3 and let us say, the core radius is r naught, and let us take a thin shell and this part is r. And now, you can also open and visualize it, so there are two ways you can do it. You look at like this, if you go round an angle 2 pi, what happens and if you go around one angle, that is twice pi, what happens? You move through a displacement along X 3 axis, along this displacement is, along this X 3 axis and this displacement ise.

So, if I go back what you can write therefore, if you move not through 2 pi, but as angle theta, then most general expression for u 3 displacement is minus b over twice pi theta and the displacement, there is no other displacement along X 1 and X 2 axis. So, that means, there is no displacement along u 1 and u 2 is 0 and this u 3 equal to b theta over twice pi. And this theta you can also write in terms of this Cartesian coordinate, this will be tan inverse X 2 over X 1, and in earlier classes we have seen this is most scientific as a physicist definition of strain.

We made a distinction between the shear, pure shear and simple shear. Simple shear is one, which is the slip process and pure shear actually, which is the pure shear strain, which represents shape change, so pure shear. And if you, with pure shear if you add a rotation component, then you get a simple, simple shear, which represents the process of slip.

So, here you can visualize it like this, as if, if you open it and cut it out, open and then you spread it. So, you, you will feel that this is the length of the dislocation L and this part. So, this end is over here, this end, come, goes there and this length, which is the circumference, this is twice pi r. So, in a way you can say, this is a major of shear strain. So, gamma is b over twice pi r. So, if you multiply by the modulus you should get the shear stress (( )). So, better way of doing it you can do it as a more rigorous analysis by this, you, you have written this expression.

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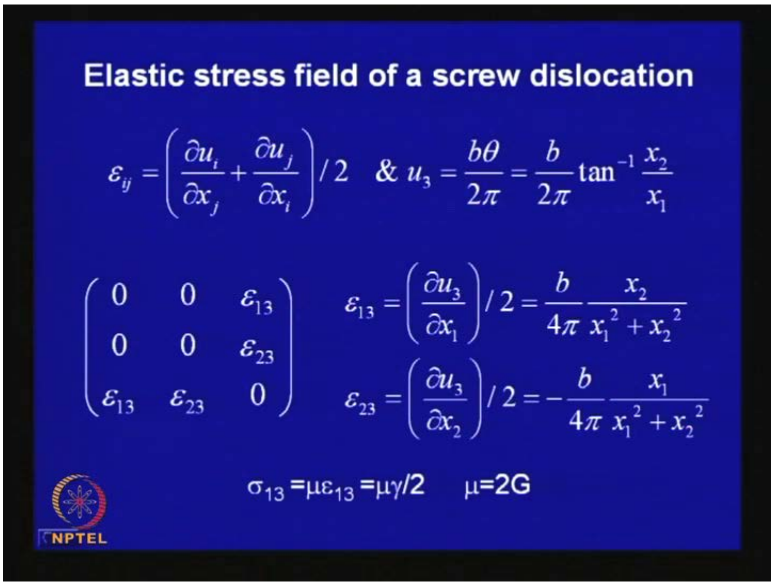

Now, what you can do by differentiating this. you can get the two shear strain component, epsilon 13 and epsilon 23, which is shown over here, this. So, this, this you can do leisurely, but I have written this expression over here and what it shows is a large number of components. This is that full strain picture, the strain at that point. So, you have six component of the strain, but we know, that we, these are representing the plastic strain and the sum of all these will be 0. And here, in any case, it is 0 because each of these component themselves they are 0. This is because there is no displacement, u 1 is not non-existing, u 2 is also non-existing and because of the volume comes (( )).

The other one, if there is no tensile strength along this, along this axis. Obviously, there would not be any tensile deformation along z axis as well. So, these three are 0, these components are also 0. So, only there are two components of shear strain and which are described over here and you can multiply this by G. In fact, what we will do here, because of that kind of representation we made a distinction between shear, basically pure shear and simple shear and so therefore, there is a two way you can make this correction.

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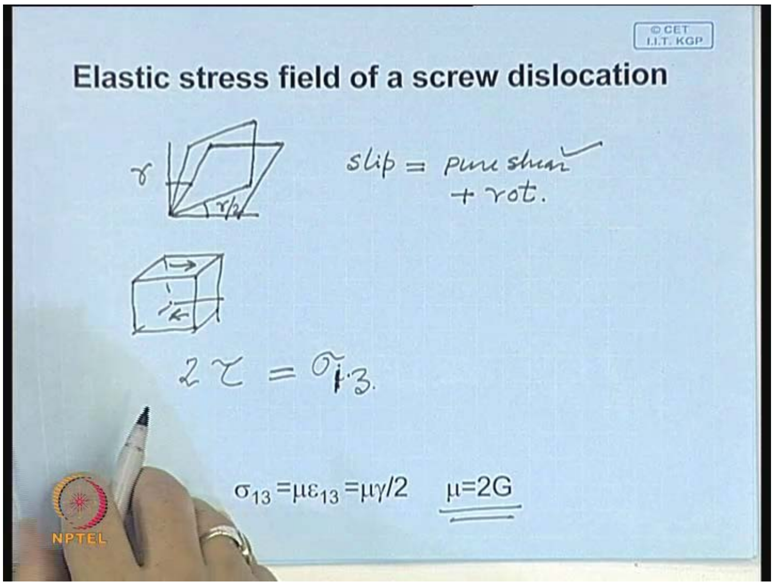

So, one, we have seen that this pure shear is actually, this is simple shear, the process of slip. Now, if you rotate it like this, so here this is gamma, whereas if you rotate as gamma by 2. So, simple shear is a process of that means, slip or glide is a process of pure shear plus rotation. So, whatever stress, which you are applying on the crystal, say, here you are applying a shear stress here, part of the shear stress is used in changing the shape, shape of the crystal. That means, here the shape has changed from, let us say, a square to a parallelogram and a part of the sheer stress is, is used in rotating the crystal.

So, that is why this two kind of representation, either you can take that shear stress is twice tow, which is equal to (( )) shear stress, that kind of representation, that is, sigma, and so, 13, this kind of a representation I have just made it because this is a material, say, put that mu equal to 2G. So, the final expression, nevertheless, for the stress, will remain same.

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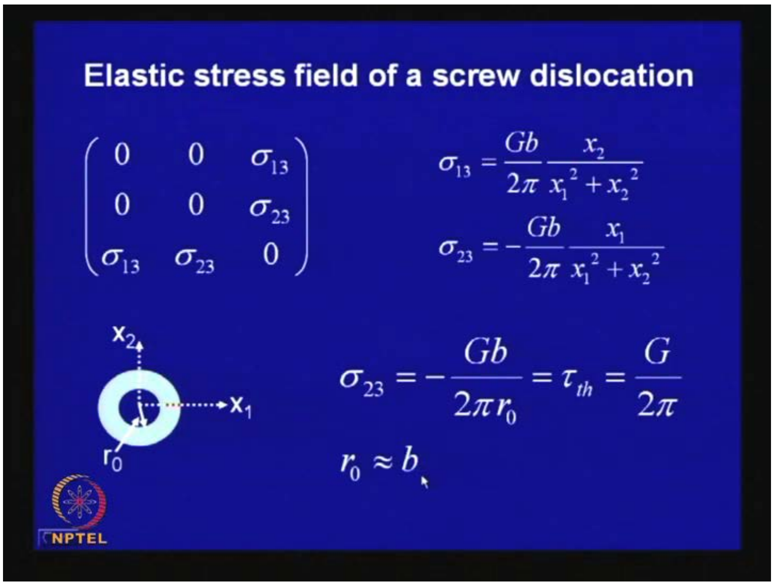

So, what you do here? This gives you the state of stress for around screw dislocations. So, all these components, these are 0 and if you add these, one-third of this is called the hydrostatic stress field. So, which means, that here the hydrostatic stress field is 0. So, this also explains why the vacancies do not interact with screw dislocation because if you create a lattice vacancy around the vacancy, there is a volume change and here you see that there is no volume change here.

So, therefore, there is no volume strain here. So, therefore, screw dislocation cannot interact with vacancy and now it will be interesting to know what will be the size of this core, core of this dislocation. Because within the core the deformation is so large, that is, the elastic laws will not be, that is, Hooks law will no longer be valid. And therefore, what we can see, that within the core we can see, that the strength or the stress field is equal to the stress field of the ideal crystal. So, ideal crystal we have determined, this is G over twice pi. If you substitute here, then what it gives, that b over r naught is nearly equal to 1. So, that means, the dimension of the core is around of the same order of the slip vector or the Burges vector.

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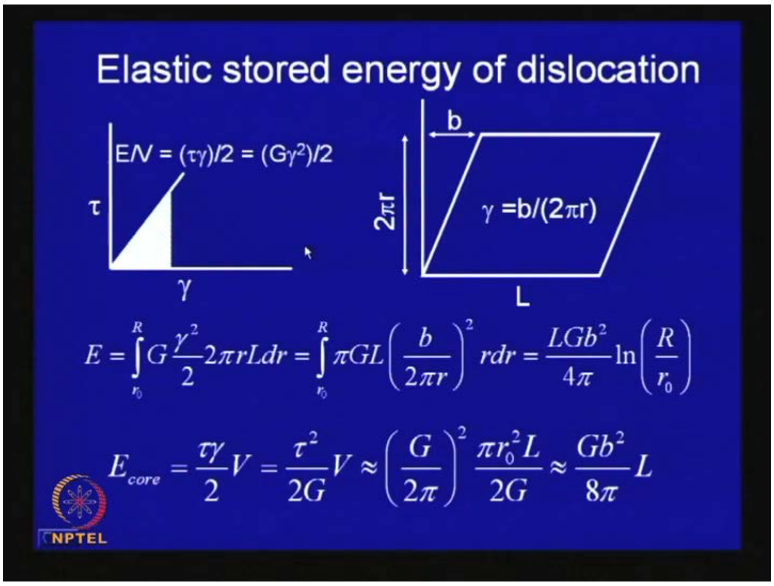

Now, from this we can go a step further and try to calculate, that elastic, stored energy and which is shown over here, that elastic stored energy will be given by this. So, what you can think about, that Consider, because this strain energy if you look at, look at the previous, here the stress field changes, you know, as you move outward. So, that means, at a definite hour the stress is same, but as you go beyond, the stress or strain it keeps on changing.

So, in order to calculate the stored energy per unit length of the dislocation what you have to do? You have to consider a thin cell like this of thickness, let us say, dr, and then repeat this calculation and which is shown here and integrate. So, this is twice pi r dr is the area, surface area in which this is, this stored energy and here you substitute, that expression for gamma, which is over here and then if you integrate, you get an expression this. And what is important, that we will, we try to calculate what is the energy per unit length, length of dislocation is the, which also features here.

And now, let us try and find out what is the energy, which is stored at the core of the dislocation. So, here we can go to the previous logic, that if the stored energy is tow gamma over 2 times volume, you calculate this, I think you change it to shear stress and then we can assume, that shear stress and the core is equal to the shear strength of an ideal crystal. If you sbstitute this, this, you get of the order of Gb squared divided by 8 pi

L. So, basically, what it amounts, that it is more or less, I mean, it is much less compared to this factor.

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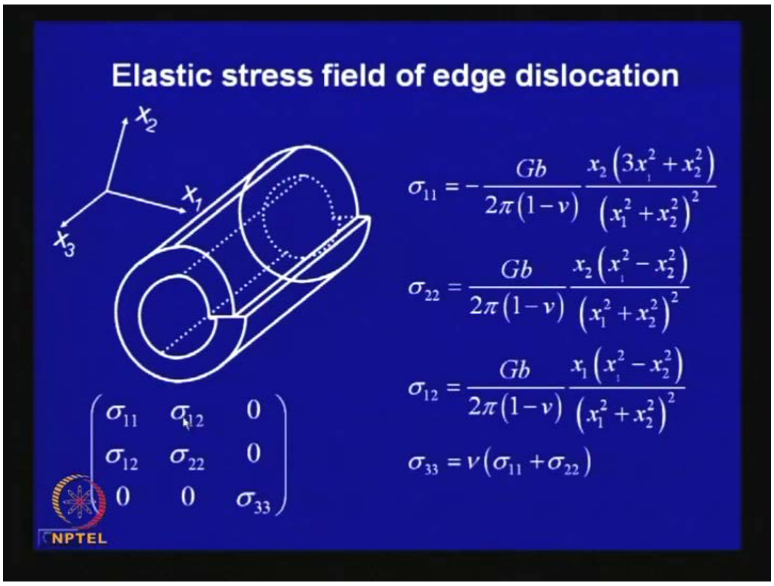

Now, similar calculation it is possible to do for edge dislocation, but edge dislocation, the displacement is, which occurs is little difficult to calculate and you have to have a clear conception of the geometrical distortion that takes place. So, that way we will not go through the total derivation, but we will give you the elastic stress field of the edge dislocation, which is given here. This is how you visualize that.

So, here the step is unlike screw dislocation. The step is here in this phase, but here also we assume, that the, it is hollow core and we would not try to repeat any calculation for the hollow core, and if you do this you will find out, that here the stress field is like this.

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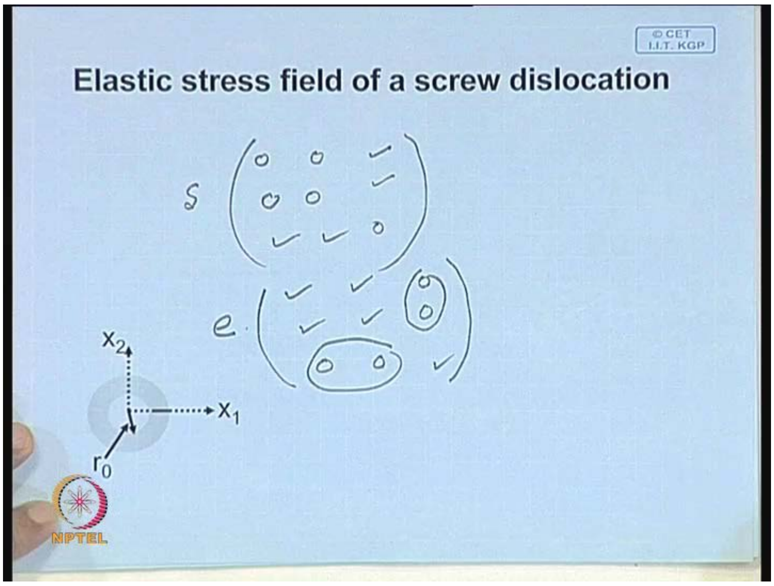

So, you look at, if you try and compare the stress field you will find, in one case the screw dislocation, see number of these are 0, whereas this existed, this existed, this is 0, this is 0, this is 0, this is there, this is there. So, this is the case of screw dislocation. Whereas, in this edge dislocation this, whereas the components, which had a value for screw dislocation, they are 0 in case of edge dislocation, but in reality or from the dislocation we will have a mixed character.

So, in that case we can say, that we can superimpose this two stress fields. So, in that case, all these components will be present, all these components will be present in case of a screw dislocation and here you see, this is hydrostatic stress field edge dislocation, has a hydrostatic stress, stress field. So, upper part, you will find out the upper part, you know this is compressed, you have a compressive stress and the upper half where, you have an extra plane of atom. So, it is compressed, whereas bottom half, it will be, nature will be, where X 2 will be negative. So, you will have a tensile component.

So, therefore, you can see easily, that a vacancy will also have an elastic stress field, but nature of stress field will be hydrostatic. So, the vacancy or a point defect; both will have hydrostatic stress field. So, both interstitial solid solution atom and vacancy, they will be able to interact with edge dislocation and this interaction will be quite strong, whereas in case of a screw dislocation, particularly that vacancy, that interaction will be very weak.

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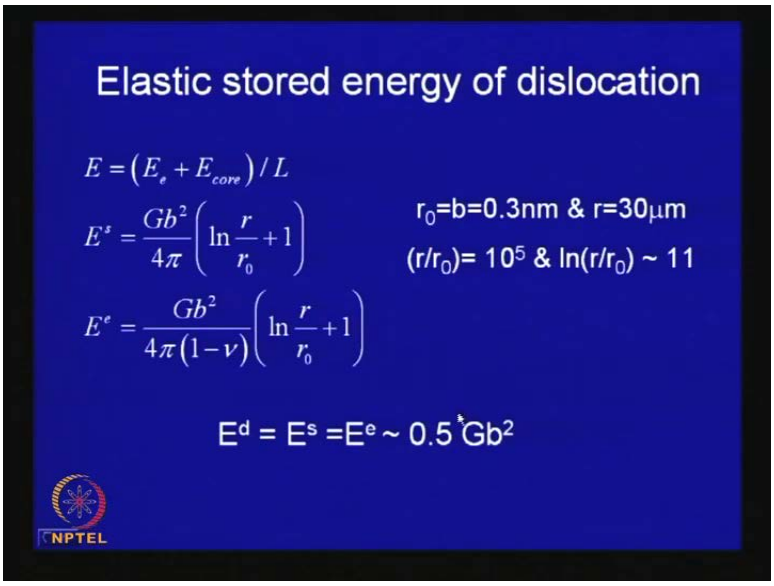

Now, a few points on that elastic stored energy of the dislocations. Now, therefore, when you look at elastic stored energy of the dislocation there are two complete parts, a part of the energy is stored inside that hollow core, say within the core also there is some stored energy. If we see within the core, core of the dislocation, there is some amount of energy stored and apart from the core, you know, from the core to the boundary of the crystal there will be some amount of energy stored. Now, in most of the calculation it will be quite interesting to know what is the level of this total energy, and we always try to represent this energy as per unit length.

So, for, let us say, that this is elastic energy, the total elastic energy of the dislocation plus the elastic energy of the core over L. So, this is the energy per unit length of the dislocations. So, if you do this, this we have derived for screw dislocation. Edge dislocation, you have more components of stresses, like normal component, so that is why you get a factor 1 minus nu and interestingly, that nu, this is Poisson ratio. So, if you assume this Poisson ratio for many metals, it may be about one-third or 0.3. So, this is, so basically what you can see, that energy, stored energy in case of an edge dislocation will be little higher than that of screw dislocations, but what is the order of this energy.

And it will be interesting, say suppose we look at this dimension of the core, we looked at the dimension of the core and we found out, this is of the same order as the Burger's vector and let us say, this Burger vector is, for any FCC crystal, say copper, this may be of the order of 0.3 nanometer and the average grain size of the metal may be of the order of, say we assume, that 40, 60 or around that kind of, so we say half of that is the radius. So, we say, that 30 microns, that means, if the grain size is 60 micron, we take the radius as 30 micron and assume that the dislocation is present at the centre of the grain, so r is 30. Therefore, if you find out this ratio, r over r naught, this will come of the order of 10 to the power 5. So, if you calculate it, this factor lnr over r naught, this will be around 11.

So, basically, and if you say, suppose if this becomes double, I will leave it as an exercise, you will find since because it is logarithmic, that increase is very slow, see it may find 10 to 15 percent increase in the energy. So, roughly, what we can see, that even if this crystals, see even if it is, right now if it is 50 micron is the grain size, it becomes double, 100 micron. There will not be much change, there will be some change, no doubt, but this change will be very small, maybe within 10, 15, 20 percent.

And broadly, in this when we consider dislocation-dislocation interaction, often we do not go through such vigorous calculation, we make approximations and always any dislocation will, no doubt will have a part screw character, part edge character, each will have different level of energy and approximately, a good approximation is irrespective of the character of the dislocation. We can assume, that energy per unit length of the dislocation is equal to 0.5 G b squared, G is the shear modulus, b is the Burger vector. So, obviously, say as a thumb rule what we can see, that b represents the strength of the dislocation and b squared roughly expresses the energy because shear modulus is a constant for the crystal.

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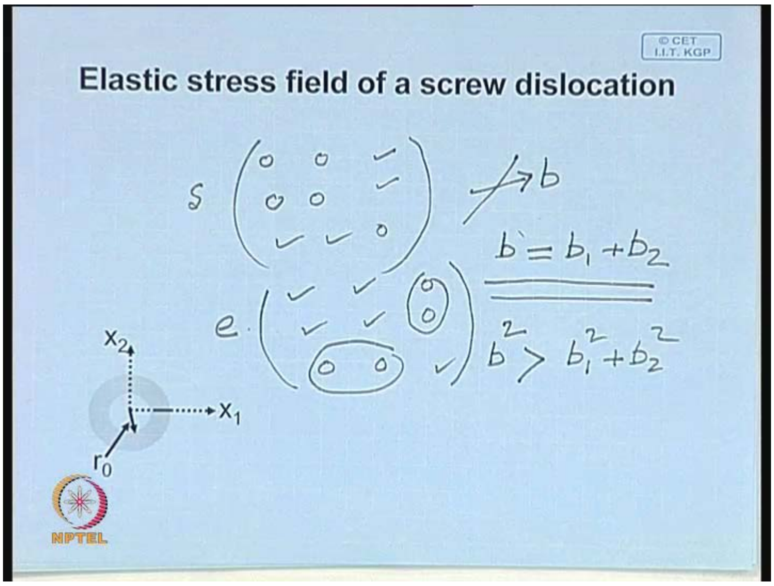

So, to understand, in many of these dislocation reactions we often approximate, that what is the dislocation, that energy….Say, suppose a dislocation Burger vector b, whether it will break into two, so b breaks into b 1 and b 2. Now, will this be energetically favorable? What we try and do, we check if b square, which roughly will give us the energy of this dislocations and the product dislocation energy also we can find out, b 1 square plus b 2 square. So, if we find there is a reduction in energy, if b square is greater than this, then the reaction will be favorable and we will often use this concept to explain dislocation-dislocation interaction.

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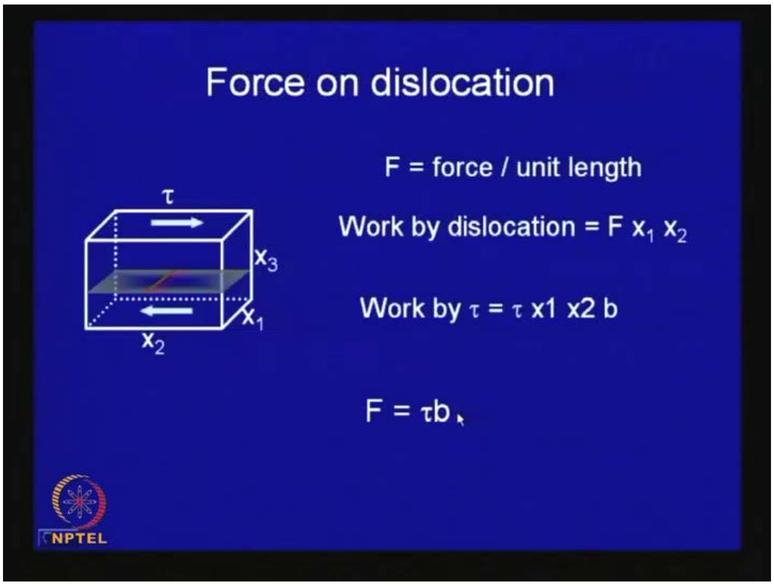

Now, dislocation can move only as a result of applied shear stress and when you apply a shear stress on the crystal on the slip plane, you can imagine, that means, as if the dislocation is there as a line and on that line a force is acting and this force will have a relationship with, have a direct relationship with the applied shear stress.

And let us look at how can we calculate this? So, and now here is the crystal, here we have applied shear stress tow here and this is a slip plane on which you have a dislocation; this red line, this represents a dislocation. Now, let us say, that force per unit length, of the dislocation, on the dislocation, acting on the dislocation is f. So, then, what we can do? We can try and find out what is the force required to move the dislocation, maybe over the slip plane, may be from here to here and this is possible to calculate, that is, this dislocation length. So, this dislocation lies along axis x 1, so length is x 1. So, force on the dislocation is F times x 1 and the displacement it undergoes when it moves through the slip plane is from here to here, which is equal to x 2. So, this is the work done by the dislocation.

And what is the work done by the applied shear stress? Now, this applied shear stress, when you apply this applied shear stress, what you do? You move the upper part of the crystal over the slip plane by a distance b.

So, when you apply the shear stress we look at, we find out what is the area of this, what is the area, area of the slip plane. So, area of the slip plane is x 1 times x 2. So, this is the force acting on the slip plane and the displacement is b. So, if you equate the two, then it is, force is equal to, you equate this two, x 1 and x 2, they cancel out. So, the force acting on dislocation is equal to tow b and this is the very important expression and we will be often referring to this in subsequent lectures.

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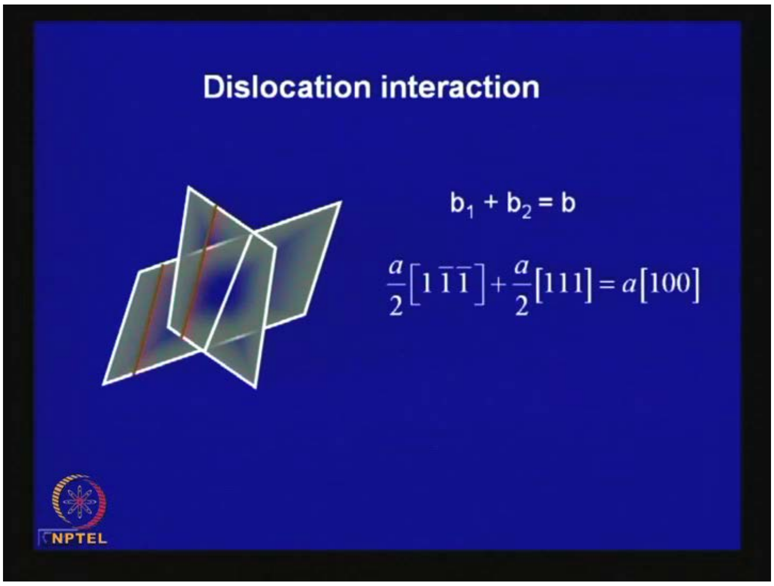

So, now, let us look at some of this dislocation-dislocation interaction and here, it is quite important to, we take an example, which is over here. Say, we have taken, say, this is one slip plane on which there is a dislocation, it is moving along this. This is another intersecting plane and this, these two plane, they intersect along this line. This is the line of intersection, so there is a possibility when this dislocation is coming here, this also reaches and the two can react and will it form and can form another dislocation with a different Burger vector and these are all vector notation.

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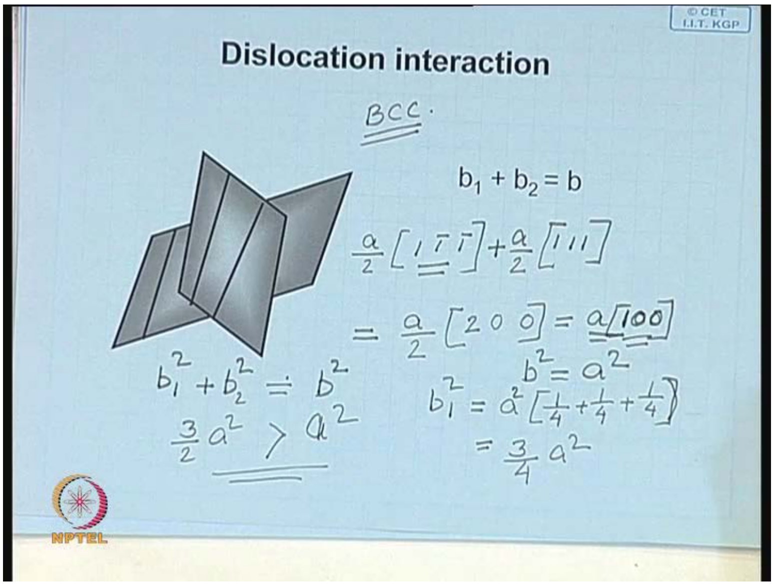

So, you can add them up. So, basically what you see, that if you try and do it, this is a over 2, 1, 1 bar, 1 bar, plus a over 2, 1, 1, 1. Now, if you add up what you get? So, a by 2 you add this and this you get 2, this is 0, this is 0. So, basically, what you get is a 1, 0, 0. Now, with this reaction if is energetically favourable, how do you know? See, this product you can find out, that is, b square is the energy. That means what you have to find out, b 1 square plus b 2 square and you have to compare with b square. Now, b we have to find out. Now, b is this, so basically, that is, b square is actually equal to a square and what is b 1 square? b 1 square is this, we can say is a square.

So, this is one-fourth, one-fourth, one-fourth. So, basically, this will be 3 over 4 a square. So, there are two 3 over 4. So, basically b 1 plus b 2, this will become 3 by 2 a square. So, that means, this is greater than a square. So, this type of reaction it will be difficult to form, whereas you can say, that the reverse is possible. So, that means, this dislocation, which is not common. So, this is basically, when I have written a dislocation like this that means, we are talking about a body centered cubic structure. In a body centered cubic structure the Burger vector is of type 1, 1, 1. Now, in a BCC structure this is not mobile dislocations, but if it splits into these two they can move on the slip plane.

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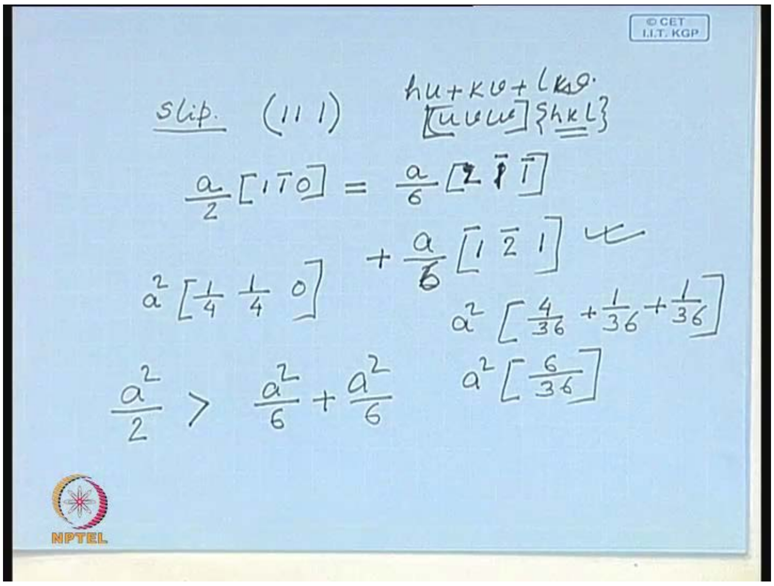

Now, let us look at another case. Say, suppose we look at phase centered cubic structure, yes, phase centered cubic structure and look at slip, look at a slip plane 1, 1, 1. Now, on this slip plane, let us say, we have a dislocation of type a, mobile dislocation. So, this is

1, 1, bar 0. So, this definitely, it will be lying on this. So, now, suppose can this breakdown into these two.

This is 2, 1, 1, so, but it has to be 2, 1, 1, it must lie on this. So, you have to do it like this, we make this. Another, a by 6 is a 1, 2 bar, 1; this also we say a by 6. So, what we are saying, that is this reaction possible? Now, you check here, you must check here using this relationship, say hu kv plus lw, say, where u, v, w represents the direction and this represents, h, k, l represents the plane. Now, you check that this must lie on this, this also lies on this. Now, is this reaction possible, how do you find out? You again do the same thing, this will be a square one-fourth, one-fourth, 0. So, this is, and in this case it is a square, 4 by 36, 1 by 36, 1 by 36. So, this comes, a square over 6 by 36. So, basically what it comes out to be is here, your, here it is a square over 2 and in this case, it is a square over 6, and you have two of this a square over 6. Now, if you add this up you find that this is greater than this. So, this kind of splitting is energetically favorable.

So, today in short what we looked at, we looked at edge and screw dislocation little more critically. We looked at the movement of the edge dislocation. Edge dislocation can move both by glide, as well as, by climb, whereas screw dislocation can move only by glide. But screw dislocation, we learnt in the earlier class, since it can lie on multiple planes, so there is a possibility, that screw dislocation can crossly point to another intersecting slip plane. We also looked at the interaction between vacancy and vacancy, and edge dislocation. We tried and just gave a physical insight why this interaction is possible, why similar interaction is not possible with screw dislocation.

We looked at the energy, energy per unit length of both, edge and screw dislocation and what we found, that the Burger vector is a good parameter for dislocation energy. b square roughly gives us an order of the energy of the dislocation and this can be used to find out, whether any types of dislocation interactions, combination of the dislocation or splitting of the dislocation will that be energetically favorable.

And next class we will go beyond that and try and understand few other dislocation-dislocation interaction and we also introduced the concept of (( )) or , some of the surface defects. Thank you.