

**Defects in Crystalline Solids (Part-I)**  
**Prof. Shashank Shekhar**  
**Department of Materials Science and Engineering**  
**Indian Institute of Technology, Kanpur**

**Lecture - 30**  
**Glide+Kinks**

So, we looked at how the deformation takes place in a single crystal.

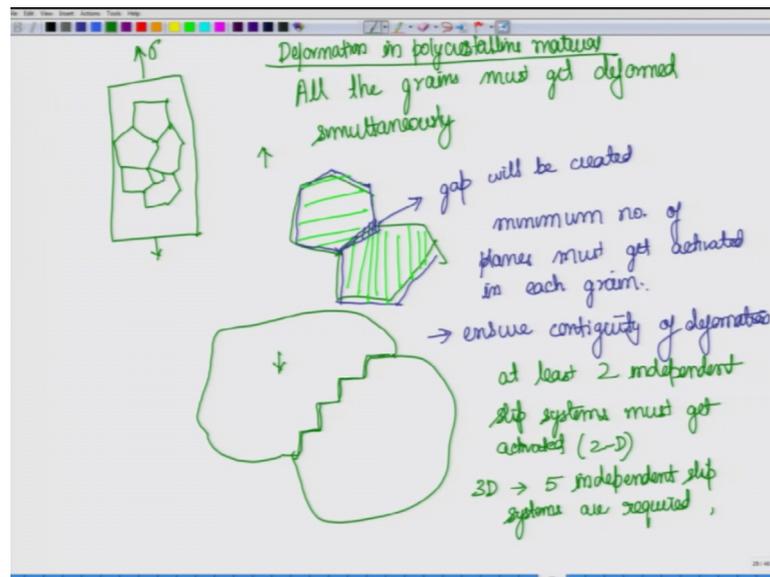
(Refer Slide Time: 00:20)

The whiteboard contains the following content:

- Crystallographic planes:  $[111]$  (011),  $[11\bar{1}]$  (101),  $[11\bar{1}]$  (110)
- Slip systems:  $-3 \times 7$ ,  $-3 \times 2$ ,  $-3 \times 5$
- Values: 21, 6, 15
- Equation:  $\sigma_{ys} = \frac{\tau_{crss}}{\cos\phi \cos\lambda}$
- Calculation:  $\cos\phi \cos\lambda = [111] (101) \rightarrow \frac{30}{A \cdot B}$
- Value:  $\sigma_{ys} \approx 20 \text{ MPa}$
- Text: What about polycrystals??
- Diagram: A cylinder with a vertical dashed line representing the axis. Three slip bands are drawn on the cylinder's surface, each labeled with  $\tau_{crss}$  and arrows indicating the direction of slip.

And I left you with the thought how this will what will be the scenario when we are talking polycrystals. What do you mean by polycrystal?

(Refer Slide Time: 00:27)



So, let us say we have cylindrical bar like this. So, these are different grains. Now, in single crystal it was much easier for us because  $\cos \phi$  and  $\cos \lambda$  term would be same for throughout the crystal but here the  $\cos \phi$  and  $\cos \lambda$  term would be different for each of these. So, what it would mean is that all the planes in fact, I should say all the grains must get activated or must get deformed simultaneously when you are applying a stress. So, we are applying a stress here must get deformed. Now, when that is the case, it would mean that in some particular one ones type, one slip system will get activated; in another one another slip system will get activated. But that is not all the complication.

Here for example, let us say we are talking about 2 different grains and when they deform, one of them let us a becomes along a so, the stress direction is like this. And let us say the other one gets deformed like this. So, what do you see here? It seems that there will be a gap will be created and this is when we have only one type of slip system. So, let us say there is only one type of slip system which was leading to this. In both of them, let us say there was. So, in both of them let say there was only one type of slip system and when it if only one type of slip system gets activated in both of these, they will govern and whichever way there it is possible they will let the deformation go. And in many cases in fact, in most of the cases what will happen is that at the interface a gap or a crack will get created.

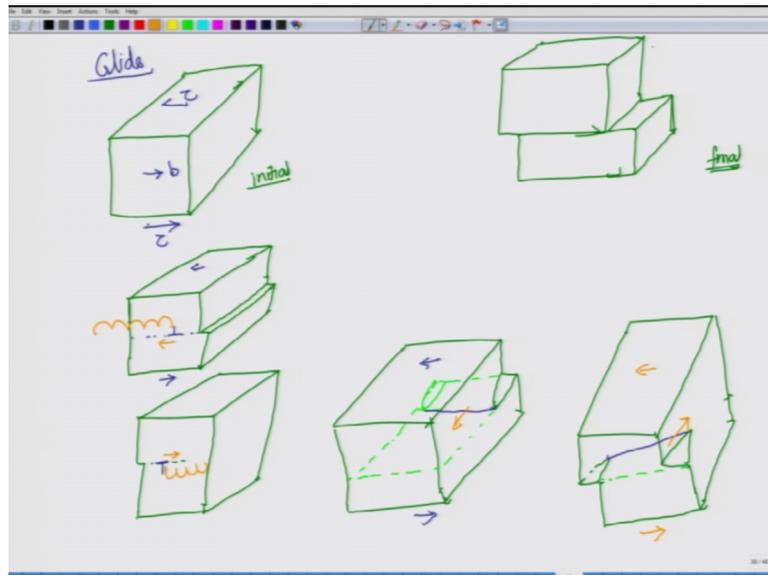
But we know that does not happen. It means what is that mean is that, there must be minimum number of planes must get activated in each grain. What it will do? What will this two what it will do is that it will ensure contiguity of deformation. In this 2 dimensional space, it is very easy to realize that what you would need is a two in set of independent slip system.

So, we are talking about one grain over here, one grain over here; both them are getting deformed. So, both of them should be compatible at the interface with each other. And therefore, at least two independent slip systems must get activated and this is when we are looking at in a 2 dimensional model. When you are talking about the 3 dimensional model, similar contiguity principal must be held. So, that deformation homogenous deformation does not lead to crack initiation at the interfaces. And for 3 dimensional system this implies 5 independent. We are not in a position to derive this.

But there are several classic journal articles we show that in 3 dimension, 5 independent slip systems are required. So, in three dimensional system this is what you will read at most of the places that 5 independent slip systems ok. In one particular plane you will get 3 or 4 slip system, but that does not mean all of them are independent. In fact, in a plane you can get only two independent slip system. In 3 D similarly, you will lead 5 independent slip systems.

So, 5 independent slip systems are needed to ensure contiguity of deformation and to ensure that all the grains get homogenously deformed. So, this is how we are not in a we are not quantitatively deriving anything, but this is the basic information that you must have regarding deformation in polycrystalline material. In the second half of the course, we will when we touch upon plasticity will probably also describe this part in more detail. But for now it is time that we start move on to another aspect of glide; in this glide of the dislocation.

(Refer Slide Time: 06:46)



So, we have been discussing about dislocation glide. There we encountered Peierl Nabarro stress and now we want to picturise how this glide takes place when there are edge dislocations, when there are screw dislocations, when they are positive or negative as dislocation, when they are positive or negative screw dislocation. So, this is what will picturise in this particular slide.

So, let us say that you have a bar like this. It can be inside a bulk material or somewhere and let us say you are applying shear stress. So, let me show the shear stress with a different colour. So, this is the shear stress and let us say the Burger vector is in this particular direction. So, this is the shear stress on the two sides being applied like this and simultaneously for balance, you will have to have the shear stress on these two planes, but which we are not right now describing.

Now, when this deforms the final shape you can imagine would be. So, let us say that one dislocation has moved. So, this will you one dislocation had moved, this would cost one  $b$  step in this bar. So, this is initial condition, this is final condition. Now what we will look at is what will happen if it were there was edge dislocation here positive as negative as positive screw dislocation and the negative screw dislocation. So, let us look at it. So, let us say when you applied the stress one edge dislocation got introduced which is now moving.

So, this is a positive edge dislocation somewhere over here because it has already created a ledge here and it will keep moving in on this particular plane. And this is the shear stress being applied and as you can remember from the Peierl Nabarro valley, it will move in steps like this, why? Because there are particular positions at which there is lowest stress required. So, it will kind of hop. So, there is a dislocation here. I will now have to show it with a different colour because it has got mixed up. So, in this particular case the dislocation is moving in which direction? In this direction.

So, this is stress and this Burger vector, if you have a positive edge dislocation; the dislocation is moving to this direction. Now let us look at a negative edge dislocation. So, negative edge dislocation has been introduced which is over here and which direction would it move? You can imagine it will move in this direction and again, it will hop like this because these are the reasons where it will have minimum stress or minimum energy configuration. So, the same stress is acting differently on the two positive and edge negative edge dislocations. There is one thing; now let us look at how it will behave when we have a positive and negative screw dislocation.

So, this is the slip plane and there will also be a step like this and it is where we have the screw dislocation line which I will show which I will keep showing by blue colour. So, this is our screw dislocation and when you are applying a stress like this which we had shown earlier ok. Here I made a mistake it should have been like this. This is; however, stress is always. So, here which direction would you think the screw dislocation would move? You can imagine it will move in this particular direction.

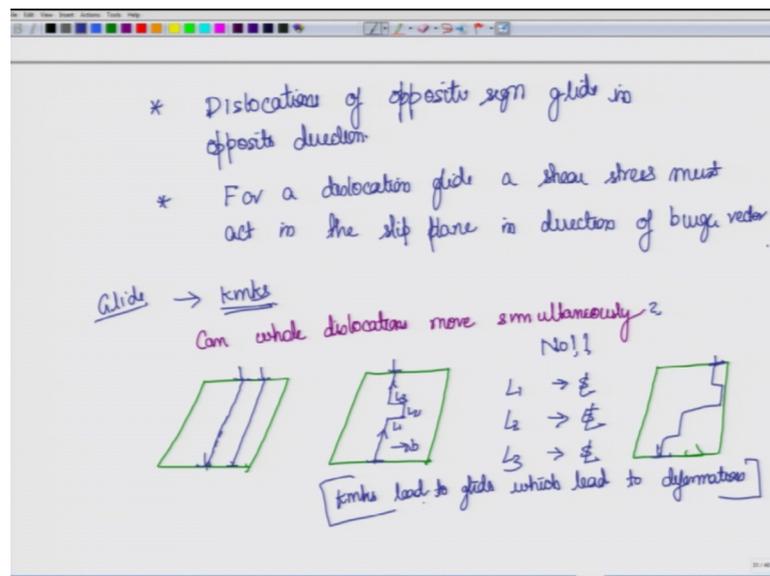
So, this particular type of screw dislocation is moving like this. Now will have still another kind of screw dislocation as we know we can have 2 different right handed, left handed. So, will can have still another screw dislocation. This is the slip plane and this is the screw dislocation. It has not come out very well, but you can imagine this is a screw dislocation. Just like this one, but here which direction this screw dislocation would move? This screw dislocation would move in this direction. So, the summary here is that in the glide even though the even though, we will have different types of dislocations take and they will move in different directions, but the final outcome would be the same.

And it that depends on what is the Burger vector and what is the direction of the shear stress applied. So, which ever kind of dislocation you have, depending on what is the

shear dislocation shear stress and what is the Burger vector the final outcome will be same and you will get different types of motions for the for the edge dislocation and for the screw dislocation. Another important aspect is the direction of motion for the edge dislocation and the screw dislocation. Edge dislocation you would see moves in the direction of slip.

So, it moves along the shear stress direction. On the other hand the screw dislocation moves perpendicular to the beam Burger vector and the edge dislocation move parallel to the Burger vector. So, again the motion of direction of the slip sorry motion direction of dislocation is also different from different kinds of dislocation and for different signs of dislocation. So, these are some two important take home messages.

(Refer Slide Time: 14:36)



So, let me write it over here. Dislocations of opposite sign glide in opposite direction. For a dislocation glide a shear stress must act, for the dislocation to move when we are saying glide it, but we are trying to say that for a dislocation to move a shear stress must act in the slip plane.

So, the if you have look that the diagram you would see that there is shear stress on the surface, but that shear stress would also act on the slip plane in the direction of Burger vector. For at least component of it must lie along the Burger vector. If it is completely ninety degrees to it, then there will be no effect of the shear stress on the dislocation. So,

these are two important take home messages for this. Now let us move on to another important aspect of glide.

So, we have said we have always been saying that glide means the dislocation will move along a certain plane or something like this. Even in this diagram that we have shown, let us look at this

So, this is let us first look at the edge dislocation, this is the edge dislocation and it is moving in this. So, we said that this dislocation line is moving from here to here to here to here. Now the question is will the dislocation line jump all at once from one particular minima to another particular minima? All of the line which will which can very huge lens. Can all of it move at a time? In fact, it never happens. What happens is that what that glide takes place with the help of what is called as kinks. So, the question is can whole dislocations jump or move simultaneously.

So, if we have one dislocation let me draw it more clear cleanly. So, let us say if you have like this. So, this is one dislocation line, will it move all from this position to this position simultaneously? Remember we started with the question that can all of the plane of material shear simultaneously and we said no that it will happen by steps and what were those steps dislocation. Now, even we are breaking it down and we are asking, can whole of dislocation line move simultaneously and the answer is no.

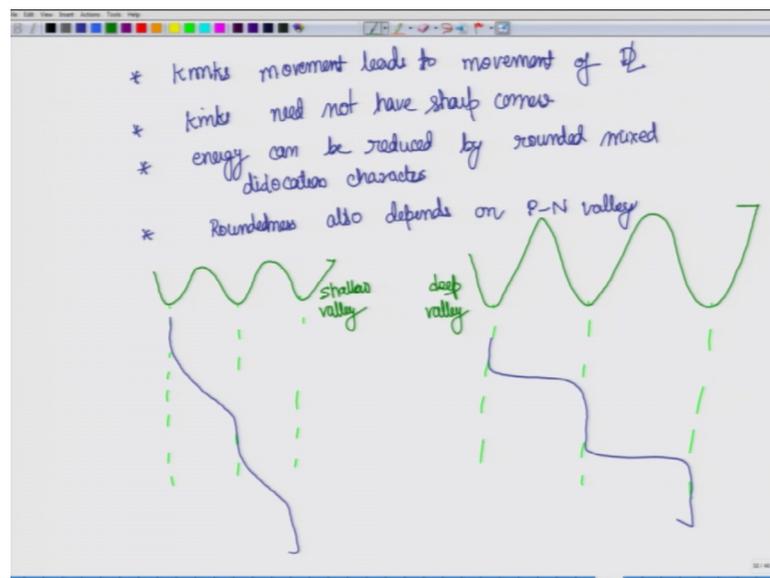
So, how does it happen? If it has to move from here to here, small step inside the dislocation line gets form. So, this is what is called as kink and if you look at it if this was the line vector originally and this was the Burger vector. So, what are the characters of these? So, let me ask you for L 1 L 3 L 3. For L 2, what is the line vector like this and what is the Burger vector like this. So, they are parallel. So, L 1 is screw dislocation, L 2 L 2 same as would have been here earlier

So, L 2 is edge dislocation. What about L3? L3 is parallel to L2. So, it is similar in characteristics. So, it is also screw dislocation. So, kink is found in a edge dislocation which has now partly different character. So, it was an earlier only a edge dislocation, but now what we have is a combination of edge, then screw, then edge the screw and then back to edge. And during the movement over the movement it is not that it is its primary purpose is to take all the dislocation simultaneously.

Now different positions may experience different amount of forces and because of that the motion may be slightly different for the whole section and what you will get

So, you start with the dislocation probably like this and different regions against different amount of forces. This one this particular region got moved furthest this is still a little kind of you can say pin and it is still over here, but overall there is there will be net displacement. And this net displacement for several dislocation would what is known as lead to the strain in the material. So, this is how the kinks lead to glide which lead to deformation. Meaning we started with the whole 3 D material and we said no only one plane would move at a time. Then we said no one whole plane would also not move at a time, only small section of it will move at a time and therefore, those small sections when they move they lead to this displacement of the old dislocation which in turn leads to the strain in the material.

(Refer Slide Time: 21:47)



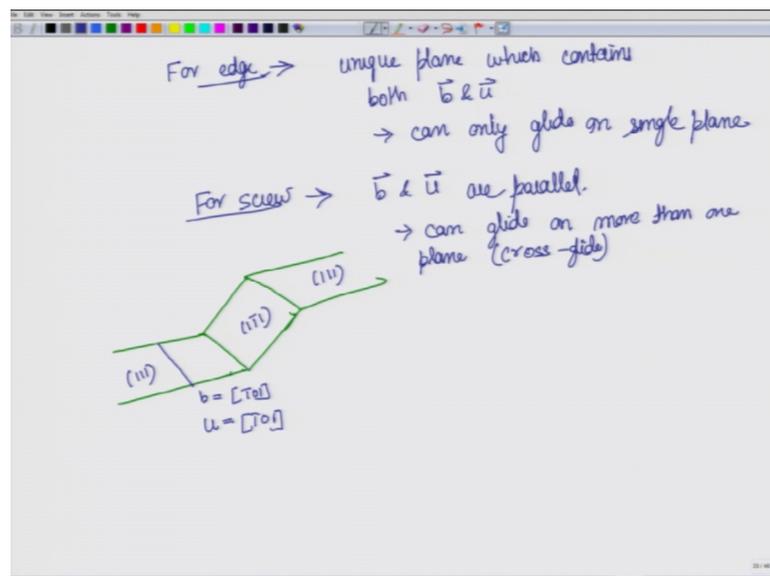
So, let me draw down some of the important for some of the important things that we observed or we understood. Kinks movement leads to movement of dislocation lines. Another thing that we will come to or we will explain in more detail is that so, far what we are seen that kinks had sharp edges. If you look over here, the way we have drawn it is edge clearly shear clearly screw, then pure edge, then pure a screw that need not an end with the case we said earlier dislocations can be can have mixed character even this kinks can have mixed character.

So, the kinks need not have sharp corners and what has been also analyzed is that energy of the system can be reduced by rounded mixed dislocation characters. Another thing that people have done you have studied dislocation in greater detail have found that this roundedness how sharp or how roundedness rounded these dislocations are, it depends on Peierl Nabarro valley. So, roundedness also depends on P-N valley and this will become clear when we look at.

So, let us say this is a Peierl Nabarro valley which is shallow and we have another one which is more deeper deep valleys. So, let me just draw just lines to the minima over here and over here the dislocation maybe something like this. On the other hand when you have very deep valleys, the dislocations would have sharp corners like this. So, we have what is the difference in these two conditions? That this one is shallow valley and this one is deep valley. So, this is another effect of Peierl Nabarro energy on to the dislocations. So, their roundedness character will also change whether you have a shallow valley or a deep valley.

Next what we will look at is the glide of a dislocation. How does the glide or the real glide of the dislocation take place? So, for that first try to understand what is the how will it be different for a screw versus and edge.

(Refer Slide Time: 25:25)



What will it be different for edge? What we have said is that for edge dislocation that slip or the glide must take place on the plane which contains both the Burger vector as well

as the line vector. And for that; that means, for edge this is a unique plane which contains both  $b$  and  $u$  which means that the edge dislocation can only glide on same plane.

What does this mean for screw dislocation? For screw dislocation Burger vector and the line vector they are parallel. So, what it would mean is that they can glide on more than one plane which is also known as cross glide. So, let us understand this with the help of a diagram. We drew this earlier in the day. So, let us say this is again 3 different planes. And now what will take is a screw dislocation which is like this and we say that the Burger vector here is  $\bar{1}01$ .

Let us say this plane is  $111$ , this plane is  $1\bar{1}1$  and this plane is  $11\bar{1}$ . So, this two have to be same that is what we saw in a on two lectures back. This is what we have observed that these two planes have to be same if we are talking about as dislocation moving from here to here to here. And if this is the Burger vector, the line vector will have to be either  $\bar{1}01$  or  $10\bar{1}$ . So, let us say this is  $\bar{1}01$  and will come back to this in the next lecture.