Introduction to Materials Science and Engineering
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Lecture – 109
Slip

So we saw that in plastic deformation X-ray diffraction indicated to us that the crystal structure does not change and then the question of course, came that how can with without any internal change in the crystal structure, without such internal change external shape can change and then this was solved by proposing a model of slip; where unit cells slip over one another to give you a macroscopic shape change, without any internal crystal structure change. So we will look at little bit more details in the slip in this video.

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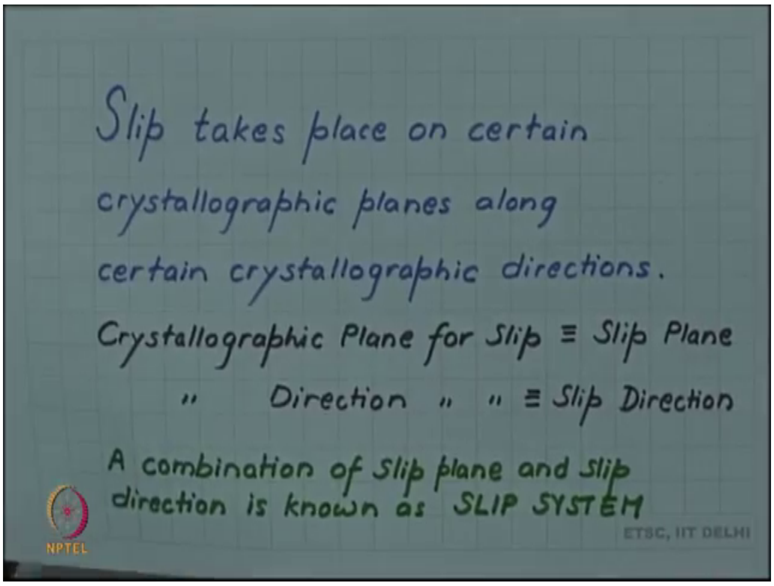

So, one of the experimental observation regarding slip, was that slip takes place only on certain crystallographic planes along certain crystallographic directions. So, when slip became important in the consciousness of scientists working on plastic deformation, they started doing careful experiments and these require lot of careful experiment on single crystals and with X-ray diffraction because, you have to find the orientations of the crystal before deformation and after deformation. So, such careful experiments umm then establish that slip is taking place in any given material in any given crystal, when you are deforming slip takes place on certain crystallographic planes along certain crystallographic directions.

By crystallographic I mean that certain a particular specific miller indices of the plane, particular orientation of the plane will be suitable for slip not all planes. And similarly certain crystallographic directions will be suitable for slip and not any arbitrary direction. Then the next interesting thing was that these slip planes which they found the crystallographic planes for slip, they were known as slip planes and the crystallographic directions was a slip direction. We also have a term called slip system; which is a combination of slip plane and slip direction lying in that plane. So, with this terminology slip plane, slip direction and slip system.

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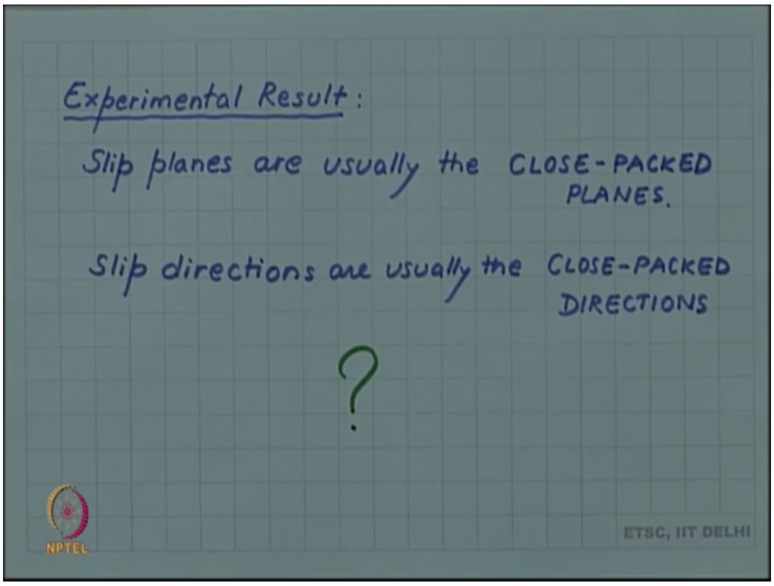

Let us look at the next interesting result, again an experimental result that slip planes are usually the close packed planes, we have seen various crystal structures and we have seen that particularly in cubic close pack and hexagonal close pack crystals, there are certain planes which are very high density of packing and they are the close packed planes.

And similarly certain directions are closed pack directions for example, in cubic close pack destruction the face diagonals are the closed pack directions. So, slip was happening when these experiments were performed, they found that the slip was happening on these close packed plane in these closed pack directions of course, so this again threw a question that why close pack plane and closed pack directions are being favored? We will look at it as we go along. But let us first note down what result they found for different crystal structures.

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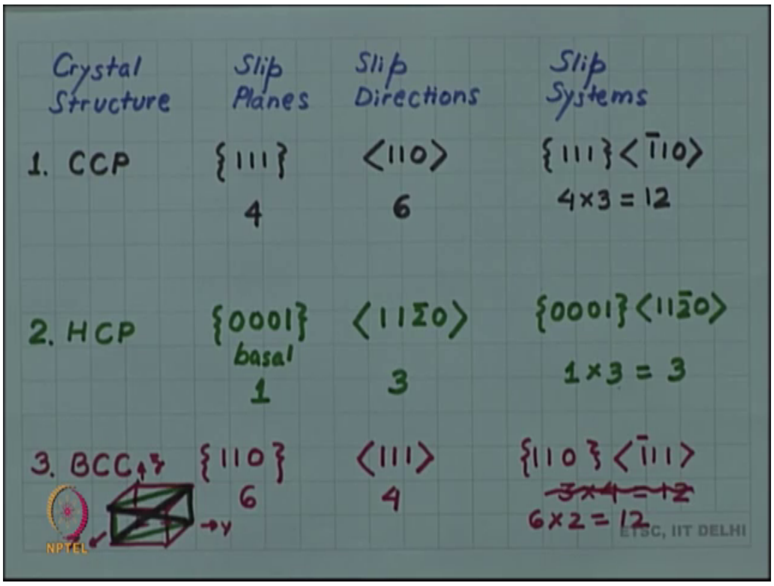

So, for cubic close pack structure as you know CCP umm the slip planes, if you if you want the close pack planes. The close pack planes in the cubic close pack structure are of the 1 1 1 type, you will need to review some of your crystallography videos which we have seen we have discussed these things. So, close packed planes in CCP are of the 1 1 1 type and the slip direction if it is a closed pack direction. So, that is of 1 1 0 type.

What is the use of brackets? I am using curly bracket because it is not 1 1 1 plane there are 4 such planes in the crystal and similarly there are not just 1 1 o jat direction this is a slip direction, this is a closed pack direction in the cubic closed packed structure and this is a face diagonal and there are 6 different face diagonals in a CCP crystal. So, the number here is 6.

The total number of slip systems and the way to write the slip system is to write the plane and direction next to each other. So, we will write 1 1 1 and 1 1 o, but recall that so, we have 6 directions and 4 planes so we may think that there will be 24 slip systems, but not really because out of these 6 directions all 6 does not lie on each of these 4 planes, in any given plane only 3 of the slip directions lie. So, for every plane we have 3 directions so, for 4 plane we have 12 directions; so 4 into 3 12 slip systems are there.

Sometimes if you really want to be careful you can insist that the direction lies on the plane. So, you can satisfy the particular choice which you have made using Weiss Zone law. So, I can write bar 1 1 0 instead of 1 1 1, but recall that bar 1 1 0 family is same as 1 1 0 family because, it also belongs to the same family and any member of the family can represent the entire family. Only here writing as bar 1 1 0, then satisfies the Weiss Zone law with 1 1 1 what I have written here. So, it shows that the slip direction should lie on the slip plane and that is why we have 4 into 3 12 slip systems and not 4 into 6 24 slip systems.

In the hexagonal close pack system, we have we have the o o 1 plane as a slip plane and 1 1 2 bar 0 direction as the select direction, so you have this as your slip system. Here if you think of 0 0 1 this is actually a basal plane. This is what is called the basal plane and there is only one set of such plane and in a given plane in hexagonal crystal there are only 3 such slip directions 3 closed pack directions. So, you have a rather limited number of slip system in hexagonal that is only 3 flipped systems.

It is an experimental observation that many hexagonal close packed materials are actually brittle whereas, many cubic close packed material are quite ductile and one reason leading to this sort of behavior is the number of slip system itself, you can see the paucity of slip system in hexagonal close packed system will lead to a lack of possibility of slipping and that is why lack of possibility of plastic deformation and if plastic deformation cannot happen the material cannot deformed and it will behave like a brittle material. Whereas, cubic close packed has a number of slip system and behaves in a ductile manner. This is a very simplistic exam the simplistic explanation, but this is one of the pointers towards this made difference in the behavior of CCP and HCP material.

Finally if you look at BCC, in the BCC there is actually no close packed plane. So, the nearest close packed plane is 1 1 0 and but there are well defined close packed directions that is the body diagonal; so it is 1 1 1. So, if you look at the numbers again this 1 1 0 comes out to 6 and this 1 1 1 comes out to be 4, you can see the situation is just reversed from that of CCP and then you have the slip system, I can again make it consistent with the Weiss Zone law and you will again have 12 slip system.

In fact, I am making a mistake here, although you have a 12 slip system, we have to look at it carefully, there are 1 1 0 6 such planes and in each plane there are only 2 directions.

So, I should write it as 6 into 2 12 slip system, I leave this as crystallographic exercise for you to work these out I have only given you the outline this you can do easily for example, what I said about the BCC can be seen in the BCC unit cell.

If you take this as your x axis, y and z; then a 1 1 0 plane will be this green plane and 1 1 1 kind of direction, the body diagonals are the 2 body diagonal which are lying in this plane like this. So, this green plane and these 2 directions give you the 2 out of these 12 slip system, I leave this as an exercise for you to find out other 10 slip systems and draw them for BCC as well as do that for HCP and CCP.