Introduction to Materials Science and Engineering
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Lecture - 87
Diffusion paths

Let us conclude that discussion on diffusion, by discussing various diffusion paths. We have till now assuming tacitly again that; the diffusion is happening inside the lattice, both the interstitial diffusion and sub substitutional diffusion we were thinking as happening inside a lattice.

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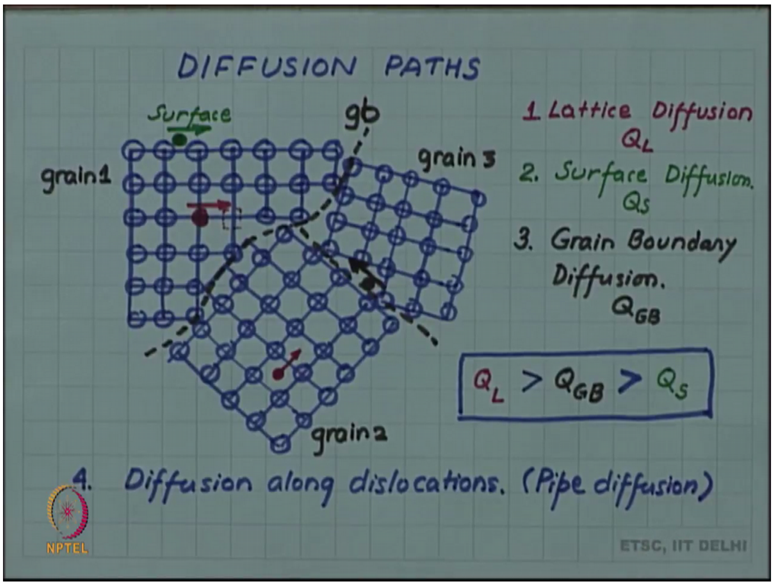

So, that is here I have shown a substitutional red atom, you can think of this two dimensional diagram as showing a poly crystal with three grains: grain 1, grain 2, and grain 3 with these black dotted line outlining the grain boundary. And our substitutional atom was sitting inside the lattice and with help of some vacant site, which I have shown here can jump from one lattice site to another causing substitutional diffusion; or if we had an interstitial atom, then that also will jump from one interstitial site to another interstitial site inside the lattice.

So, this is what is called a lattice diffusion. So, the red atoms are diffusing inside the lattice, that is one possible path and that will be called the lattice diffusion. And this is what we have been discussing till now. But atom can be present on the free surface of a crystal, in fact, during crystal growth and all the new atoms, which are coming will always join the surface and they will move along that surface.

So, it is possible for a atom sitting on the surface to move to the next neighboring site on the surface. So, this will be a diffusion along the surface and this will be called surface diffusion or an atom can be very often you can see from this diagram also that there will be little bit more open spaces around the grain boundary, because atoms do not match the crystals do not match properly, so they leave some little bit more open a space it is not as tightly packed the regions around the grain boundary will be not as tightly packed as a region inside the grain.

So, there is more open space along the grain boundary and an atom can sit in those open spaces. So, there can be an atom present at the grain boundary. So, this black atom which I have shown here, is sitting on the grain boundary; and it may jump from one grain boundary side to another grain boundary side marked by this black arrow.

So, this will be grain boundary diffusion. And of course, each of this diffusion will have their own activation energy. So, for lattice diffusion, there will be an activation energy; let us call that QL for surface diffusion the activation energy will be QS; and for grain boundary diffusion it will be QGB. And usually a it can be it is found and intuitively also you can feel that the lattice diffusion will be the most difficult one, because it has to displace all the surrounding atoms to move from one side to the other side.

So, Q lattice will be very high. So, the activation energy for the lattice diffusion is highest, then grain boundary although there is more open a space, but then still there are grains on both sides of the grain boundary. So, the grain boundary activation energy is less than the lattice diffusion, but it is still higher than the surface diffusion, because in the surface diffusion the binding is only from the one side on the crystal side the other side there is no bonds.

So, it is a most easiest for atom to move along the surface. So, that has the least activation energy. So, this is a useful order of activation energies three kinds of activation energy. So, we will not go into the details of all these processes, we have mainly discussed the lattice diffusion, but just for the completeness sake; we wish to mention that these other paths like diffusion along grain boundary or diffusion along surface is also possible.

In fact, if crystal has dislocations which we have seen in our defect chapter, then diffusion may happen along dislocation also. So, we can I have not shown it in this diagram, but we can note it as the 4th mechanism as diffusion along dislocations; sometimes this is called pipe diffusion.