Introduction to Materials Science and Engineering
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Lecture - 81
Diffusion: Introduction

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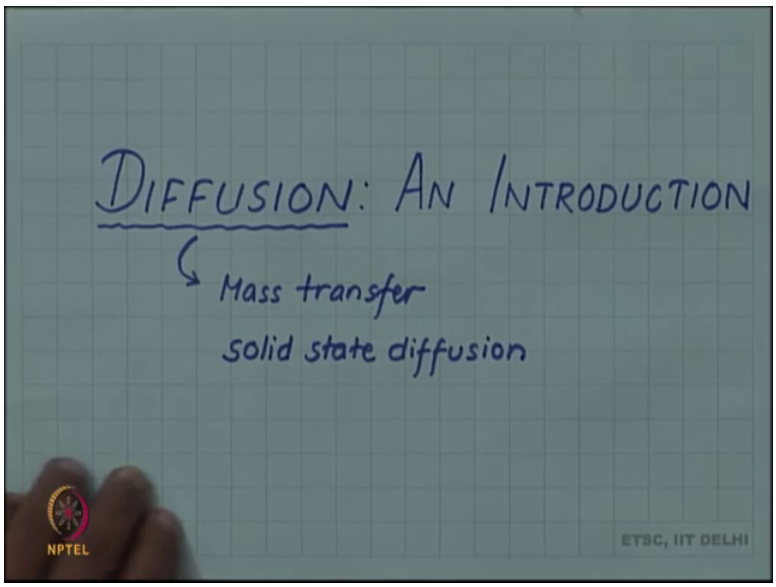

Let us begin with a new topic diffusion. This is a very very important topic in material science because in material science, we are interested in controlling the microstructure and micro structures are controlled by phase transformation and phase transformation often involves diffusion. So, we will talk about diffusion. Diffusion is essentially a mass transfer and we are in particular interested in, it can happen diffusion can happen in solid, liquid or gas. Our main interest is in solid state diffusion.

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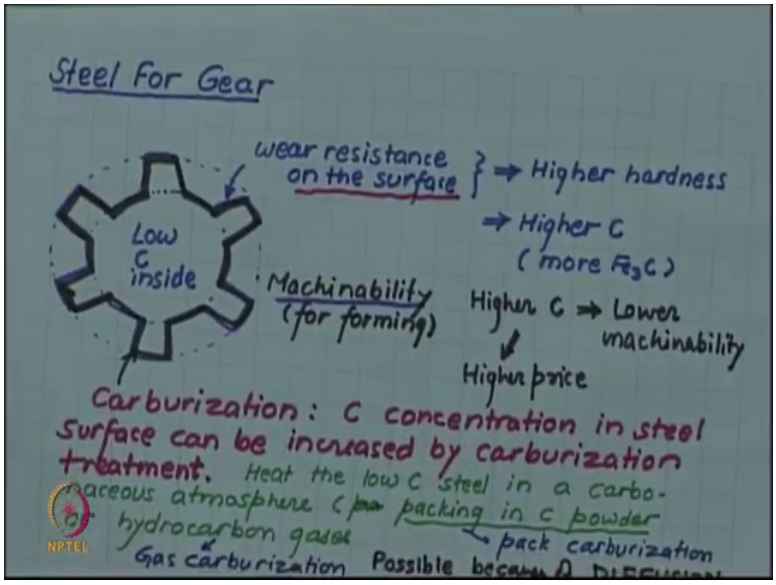

Let us motivate the topic with a particular application for diffusion and that is steel for gears. So, now, as engineers you all of you are familiar with gears. Let me try to draw one for you.

So, trying to draw a gear which has teeth; so, and this is gears of course, are can be made of many materials. Steel is a one common material of which gears are usually made in engineering and what kind of steel should be select for this gear? Now one thing one thing you can see very clearly that a gear messes with the teeth of other gear. So, there is lot of wear and rubbing on the teeth faces. So, these faces should be wear resistant. So, wear resistance is one of the requirement.

Now wear resistance requires harder the steel higher is the hardness higher is the wear resistance. So, this implies that we should choose a steel of higher hardness. And we have looked at in the phase diagram that higher hardness comes from higher carbon. So, we should select higher carbon steel because higher carbon steel will have more F e 3 C for example, and this will increase hardness. So, quite often higher hardness can be achieved by higher carbon, but we also because we want to machine the gear in the forming process we require machinability. But machinability goes down with higher carbon; higher the carbon implies lower machinability.

and also higher carbon also implies higher cost. So, both the cost of the steel as well as the cost of processing will increase higher the carbon we choose. So, you can see then there are two contradictory or two opposing requirements are there that of wear

resistance which tells us to choose a higher carbon steel. And that of machinability which indicates that we should go for low machinability as well as price which tells us that we should go for lower carbon concentrations. Now optimization can be done if we note that wear resistance is required only on the surface. So, we do not have to select a high carbon steel for the entire gear. The higher carbon concentration is only required on the surface.

So, if somehow we can make surface of higher carbon if we can make the surface of higher carbon then the wear resistance property will be satisfied. We need not make the entire steel of a high carbon, is this possible?

The question is, is this possible? And it turns out that yes there is an engineering process whereas, we can start with a low carbon steel. So, lower carbon in the interior. So, we can start with low carbon steel. So, this gives us good machinability. We can shape our gear and after shaping the gear we can by a process called carburization. We have a process called carburization by which the surface concentration of carbon can be changed or increased in the steel. Carbon concentration in steel surface can be increased by carburization by carburization treatment.

Essentially, what you do in carburization is to heat the low carbon steel in a carbonaceous atmosphere. Let us say we can achieve this by packing in carbon powder or we can use gaseous atmosphere, hydrocarbon gases. If you are doing a packing in carbonaceous powder, this is sometimes called pack carburization and if you are using hydrocarbon gases, this is called gas carburization. We will not go into the details of carburization heat treatment here, but it is, what we want to emphasize that, there is a process there is an engineering process available to us where we can start with a low carbon steel which has good machinability. So, we can shape our gears easily and then, but such a gear will not have good wear resistance because it is of low carbon steel.

Then we can improve the wear resistance by increasing the carbon concentration on the surface by a process called carburization.

But how does carbon from the atmosphere from outside the atmosphere get into the steel? And that is the process of diffusion. So, diffusion is required for carbon to enter into the steel and in enrich the surface layer. So, carburization is possible, this is possible because of diffusion. Let us look at this is a very classic example.

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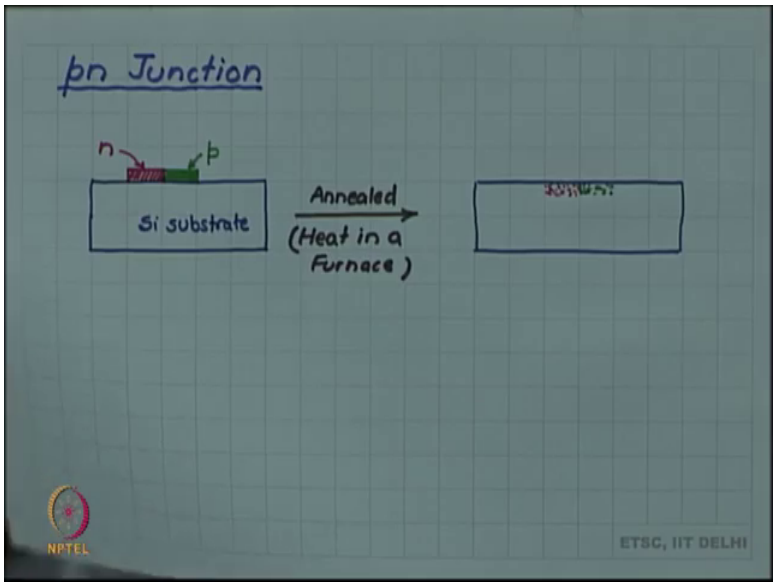

Let us look at a little bit more recent modern example and that is forming of a p n junction. When for electronic circuits a p n junction is formed. It is not formed by welding together a p type and an n type semiconductor. What is usually done is that you have a you have a silicon substrate and then you will deposit on it an n type region.

Various deposition techniques are there by which let us say this is n type and we have deposit this n type region onto this silicon substrate. And then next way we can deposit a p type region. Then the system is annealed which is just a term for heating in a furnace. So, this heating then leads to diffusion of n type and p type within the silicon substrate. So, what you will then have? What you had deposited on the surface will enter by the process of diffusion into silicon and you will have an n type region inside silicon and a p type region inside silicon giving you a nice p n junction inside.

So, this is the way actually the diffusion is an essential step in semiconductor industry for production of this kind of junctions and thus the production of any circuit because p n junction is basis for most electronic circuits. So, with this introduction we will continue the discussion of diffusion in the next video. Particularly, we will look at one important law discovered by Adolf Fick's called Fick's First Law.