Introduction to Materials Science and Engineering
Prof. Rajesh Prasad
Department of Applied Mechanics
Indian Institute of Technology, Delhi

Lecture – 75
Eutectic, hypoeutectic and hypereutectic alloys

We are currently discussing the topic of phase diagram. And we have in particular now discussing Eutectic Phase diagram. So, yesterday we took the example of lead tin system, which is a eutectic system. And we talked about the eutectic composition and eutectic alloy; two related terms are the hypoeutectic and hypereutectic alloy which also we should be familiar with.

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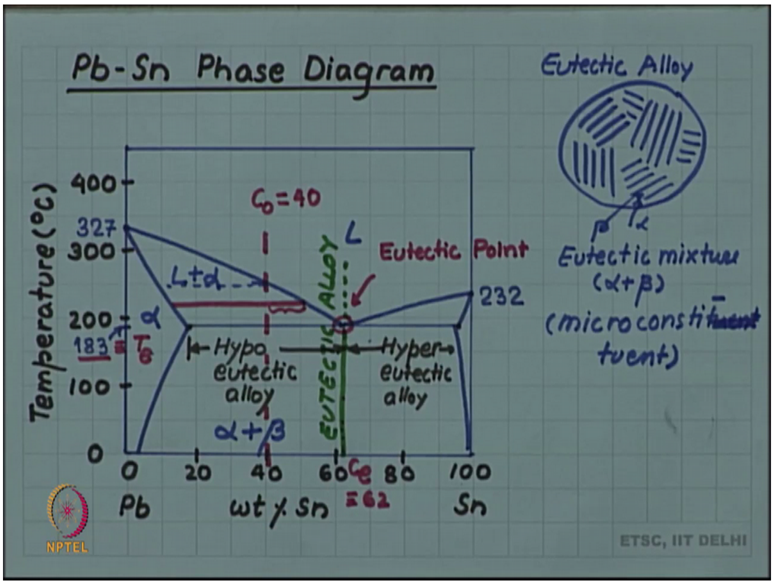

So, recall the lead tin phase diagram which is something like this. So, the minimum in the liquidus at 183 degree Celsius, which we call the eutectic temperature in particular this minimum liquidus point is an important point in the phase diagram and this is called the eutectic point eutectic point. And the temperature corresponding to this is called the eutectic temperature that is 183 degree Celsius, the eutectic temperature I am writing it as T e and the composition corresponding to this is the eutectic composition, I am calling that C e and we saw yesterday this was 62 weight percent tin.

The alloy of exactly eutectic composition that alloy is called the eutectic alloy. So, this alloy; I am drawing a vertical to represent that composition it is not a boundary on the phase diagram, this is a eutectic alloy eutectic alloy. And then alloys with composition less than the eutectic composition, they are called hypoeutectic alloys hypo eutectic alloy, means alloy with composition less than the eutectic alloy.

Alloys with composition higher than the eutectic alloy correspondingly called hyper eutectic alloy. This will be the hyper eutectic alloy. Now the question is how the microstructure evolves, we have seen how the microstructure evolves for a eutectic alloy. Since eutectic alloy is liquid right up to the eutectic temperature and, then solidification begins at the eutectic temperature and below eutectic temperature, it is a mixture of two phases alpha plus beta and, above that it was liquid.

So, liquid solidifies directly into two phases alpha and beta and, we saw yesterday that the eutectic alloy gave a microstructure, which was alternating plates of alpha and beta, oriented differently in different regions of the microstructure. The eutectic alloy, we have alternating plates of alpha and beta. This particular micro structure is called eutectic mixture, it is a mixture of alpha plus beta phase the eutectic mixture is not a phase, but a mixture of 2 phases. So, sometimes it is called a micro constituent. So, this is a it is not a phase, but a micro constituent I am going out of the so, micro constituent micro constituent. So, that was for eutectic alloy. Now the question is how the microstructure evolves for let us say a hypoeutectic alloy, or a hypereutectic alloy, you can quickly see if I take a hypoeutectic alloy. So, let us take a 40 percent alloy as our an example of a hypoeutectic alloy.

So, this particular alloy which has an alloy composition of 40 weight percent tin, and since this is less than the eutectic composition of 62, this will be a hypoeutectic alloy. This alloy as it cools you can see it will not directly form the alpha plus beta because, before it reaches the alpha plus beta region, it enters in the liquid plus alpha region.

So, as soon as it hits the liquidus at this temperature alpha starts forming. And as it gradually if you cool, then you will draw tie lines at lower temperatures if I draw a tie line at this temperature, more of alpha will form and the amount of alpha will be given by the opposite liver arm that is this much. So, as you cool more and more alpha will form and this process will continue till it reaches the eutectic horizontal. So, let us continue this discussion on a different diagram.

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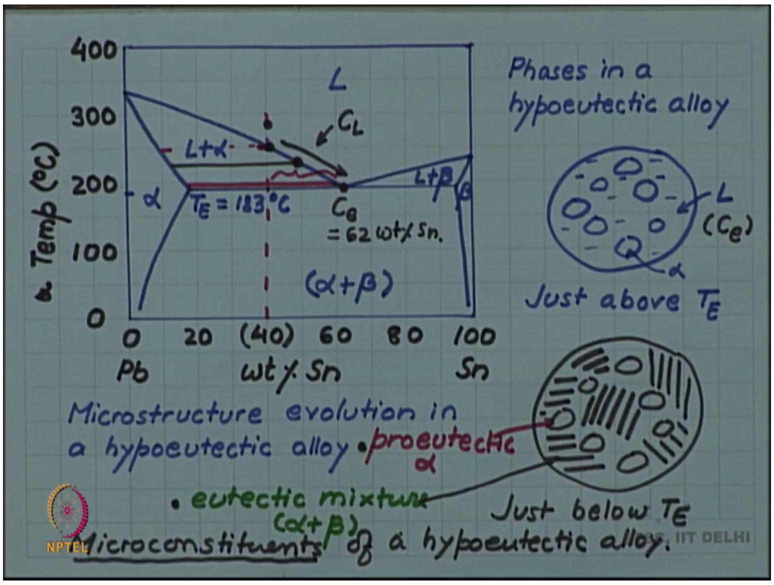

So, we are considering this alloy 40 percent alloy which is our hypoeutectic alloy, the phases in this diagram you are here knowing that is liquid alpha, alpha plus beta liquid plus alpha liquid plus beta and beta.

So, at the liquidus temperature, or rather just below it the first solid starts to form that is alpha starts to form. So, let us try to draw a micro structure corresponding there. So, you had liquid and just some alpha started to form and, as you will lower the temperature more alpha will form and you can see the maximum amount of alpha will be just above the eutectic temperature. So, at a temperature just above the eutectic where I have drawn this red tie line, you will have the maximum amount of alpha forming. So, let us make more alpha to represent this situation. So, this is all alpha and the remainder of the alloy is liquid alpha and liquid. So, this is a situation just above the eutectic temperature, which I am calling T e which for this diagram is 183 degrees Celsius, just above the eutectic temperature we have maximum amount of alpha which has formed and the remaining is liquid.

But the question is as we cool further what will happen to this alloy? So, what will be the microstructure just below T e when we cool it? So, you can see just below T e all liquid should disappear because, the equilibrium phase is only alpha plus beta; beta has not yet appeared. So, this means this liquid should now transform to both alpha and beta and that is because, weight will transform to both alpha plus beta.

Let us first look at what is the composition of this liquid, we have a we are at a temperature just above T e how the composition of the liquid was evolving initial liquid was of the same composition of our alloy composition which was 40, but when you hit the liquidus and cooled further, then the equilibrium composition of the liquid is given by the tie line you know and, it is started evolving as the liquid end of the tie line gives you the liquid composition.

So, initially it was 40, but then it is started increasing and it started following this liquidus line. So, this is a evolution of how of liquid composition how the liquid composition evolves. So, finally, just above the eutectic temperature the liquid composition will reach exactly the eutectic composition C e which is 62 weight percent tin. So, which means this liquid just above T e is exactly of the eutectic composition the composition is exactly eutectic composition and, it is exactly at the eutectic temperature. So, on cooling this liquid will undergo the eutectic reaction, which we have discussed that a liquid of eutectic composition, if it is cooled at eutectic temperature, it will transform into mixture of alpha and beta.

If I now try to draw the microstructure, just below T e just below the eutectic temperature, then whatever alpha has formed that will remain. So, I am trying to copy the alpha which I have drawn in that diagram, but what I had drawn as liquid, now will transform that liquid will transform into a mixture of alpha and beta. So, it will transform into eutectic mixture which we had talked about.

So, in this alloy you now can see that they are two kinds of region, one region is these alpha which formed before the eutectic reaction. So, they had already formed above T e. So, because of this they are called proeutectic alpha. Proeutectic alpha and the remainder of the alloy this region is eutectic mixture, eutectic mixture alpha plus beta. So, the proeutectic alpha and the eutectic mixture are the two micro constituents of the alloy.

So, this and this are micro constituents of a hypo eutectic alloy. So, notice that we are using two kinds of terminology, if I say; what are the phases in this alloy, I will say phases are alpha and beta, but if I say what are the micro constituents of this alloy and the micro constituents are proeutectic alpha and eutectic mixture. Because in microscope in an optical microscope you can see proeutectic alpha and eutectic mixture distinctly so, this terminology micro constituent is common while discussing the microstructure and phase diagrams.

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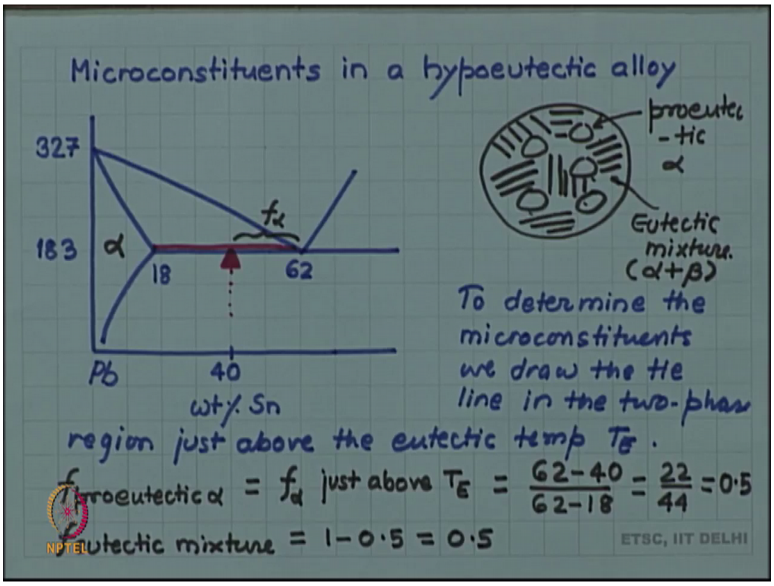

So, let us look at how to determine the micro constituent of the given alloy. So, if you wish to determine the micro constituents. So, remember we had alloy and we had some pro eutectic alpha and, we had eutectic mixture, proeutectic proeutectic alpha, eutectic mixture. So, we can ask for example, that how much proeutectic alpha and eutectic mixture is there in the alloy.

Remember that the proeutectic alpha formed just above the eutectic temperature, it formed in the range liquid plus alpha and, the maximum amount of it is just above the eutectic temperature. So, to find the amount of proeutectic alpha we have to take a tie line which is just above the eutectic temperature. So, let us note that to determine the micro constituent, we draw the tie line, in the 2 phase region just above a eutectic temperature T e.

And then of course, our alloy composition which we had selected was 40. So, that is the (Refer Time: 18:12) of our lever and then the proeutectic alpha, which we want to calculate. So, the fraction of proeutectic alpha in the alloy is nothing, but fraction of alpha just above T e. So, we have drawn our tie line just above T e. So, this fraction to alpha just above T e, remember, this is the alpha phase, which is on the left hand side of the lever. So, the right hand arm of the lever will represent the fraction of alpha. So, that in our diagram is 62 minus 40 divided by 62 minus 18, happily it comes out to be nice numbers so, this is 22 by 44, it is exactly 0.5. So, this means 50 percent of the alloy will be in the form of proeutectic alpha and, the remainder of course will be the eutectic mixture. So, the fraction of the eutectic mixture will be 1 minus the fraction of proeutectic alpha which will also be 0.5.

So, in this 40 weight percent tin alloy we expect to find 50 percent proeutectic alpha and, 50 percent eutectic mixture, recall that the fraction of proeutectic alpha is not the fraction of total alpha in the alloy. It is only the fraction of alpha which is as the proeutectic phase because, in the eutectic mixture also eutectic mixture is a mixture of alpha plus beta. So, total alpha in the alloy will be more than the amount of proeutectic alpha, total alpha is some of it is proeutectic alpha and some is part of the eutectic mixture. So, then you may like to know what is the total alpha and total beta in the alloy.

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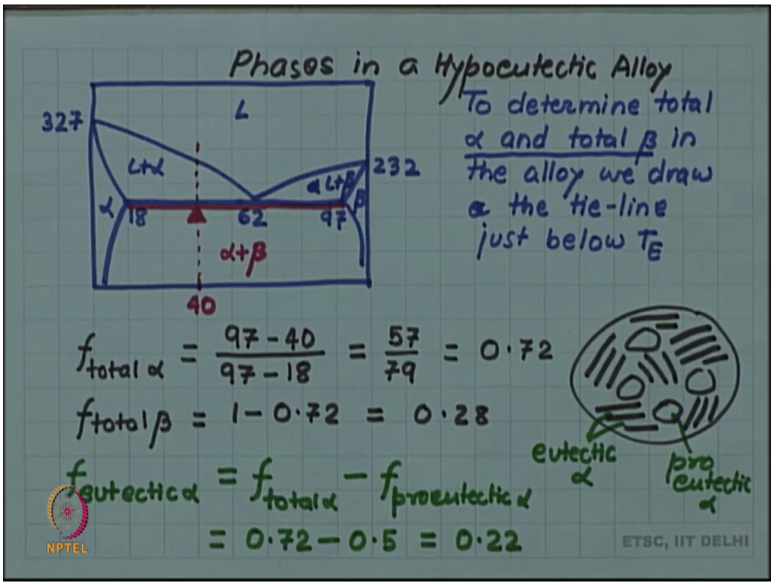

If you wish to do that, then you have to apply, the lever rule just below the eutectic temperature let me draw the diagram. So, this is 18 62 97 alpha liquid plus beta, beta and this is alpha, this is 327 and this is 232. So, we are familiar with this diagram by now, and all I am saying that we are talking of a 40 percent alloy a hypoeutectic alloy and, we want to know what is the total alpha and total beta in this alloy.

If we want to find total alpha and total beta, we draw a tie line just below the eutectic horizontal, in the two phase field alpha plus beta. So, to determine total alpha in the alloy, we draw our tie draw the tie line just below T e remember. So, when we wanted the micro constituents, we drew the tie line just above T e. Now we are interested in total alpha and beta which are the phases. So, we are now looking at phases in a hyper eutectic alloy.

So, once you realize that now we since we want total alpha and total beta, we have to take a tie line below the eutectic because, that is where we have alpha and beta. And if we draw a tie line like this tie line does not distinguish between proeutectic alpha and eutectic alpha, it will give you total alpha. So, once you recognize this it is easy to calculate now we are quite familiar, with your lever rule. So, we want total alpha the lever is this red line and, the fulcrum is at the alloy composition. So, an alpha is on the left. So, the right hand lever arm is the alpha arm.

So, which becomes 97 minus 40 is the lever arm corresponding to alpha. And 97 minus 18 is the total lever arm. So, this gives you 57 by 79. So, that is about 0.72 so, 72 percent of the total alloy is in alpha form. If total beta will be noise] 1 minus 0.72, it will be 0.28. So, 28 percent will be total beta, sometimes one wants to know how much is the eutectic alpha note the micro structure, that you have alpha in chunks, but you also have alpha as alternate plates, but now that since you have determined total alpha and you have also determined the eutectic the proeutectic alpha. So, you can find how much alpha is part of the eutectic mixture.

So, if we are interested in that number that how much of alpha is part of the eutectic mixture, we can call that eutectic alpha f eutectic alpha. So, since the total alpha is divided in as proeutectic alpha and the eutectic alpha. So, this proeutectic alpha and the alpha which is part of the eutectic mixture, this will be eutectic alpha. So, this we can simply find as difference between total alpha and the proeutectic alpha. We have determined total alpha here as 0.72 and the proeutectic alpha is 0.5. So, we take the difference of the 2. So, we get 0.22 as the eutectic alpha. So, if we are interested how much alpha is in the eutectic mixture? So, that is 22 percent.