Introduction to Materials Science and Engineering
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Lecture – 73
Eutectic system

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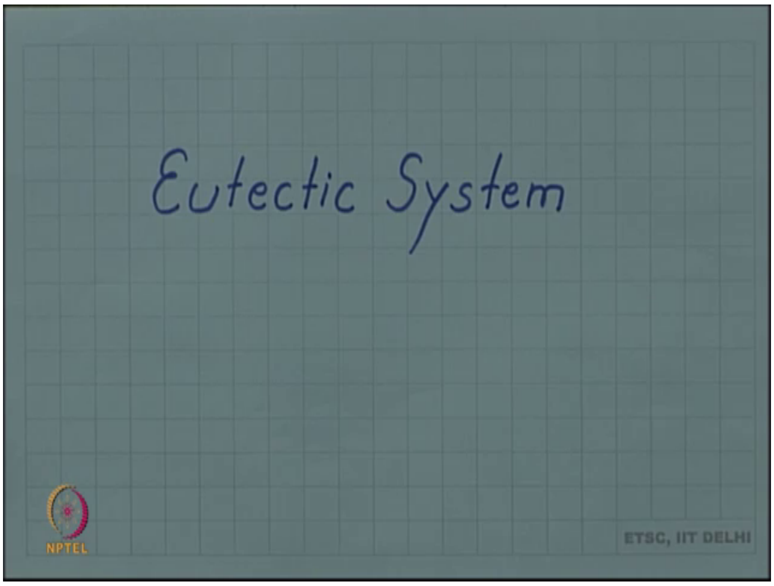

As an example we take up the lead tin solder alloy.

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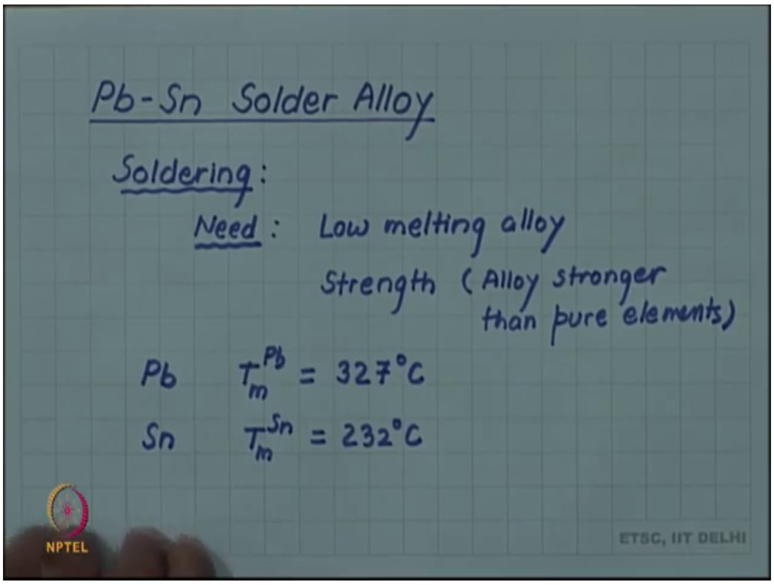

So, this is used for soldiering and conventionally this was the most common solder alloy of course, now because the concern of toxicity of lead it is being phased out in many contexts. But still for the study of phase diagram it constitutes a nice system or a nice alloy to look at. So, basically in soldering if you think of soldering, you need an alloy which can melt easily; what you need is a low melting alloy. And you need alloy rather than a pure component or a pure element because you also need a strength, and you will see during the development of this course that alloys always have better strength than pure elements.

This is a general rule, this is called solid solution strengthening and we will have more time to discuss that later in the course. So, lead in it makes a nice candidate for this because lead itself has a melting point of 327 degrees Celsius, which is reasonably low if you compare it with your previous example of copper and tin which were both having more than 1000 degrees Celsius as their melting point, lead has only a melting point of 327 degrees Celsius. And it still to strengthen it we have an alloying addition and we select another alloying addition which is even lower melting point. So, the melting point of tin is only 232 degrees Celsius.

So, hopefully since we are adding a lower melting point alloy in a higher melting point system, probably we will get an alloy which may have even lower melting point, which will be even better on the point of view of soldering because you want to heat it to melt it and this heating will be easier or melting will be easier if the melting point is low. So, let us look at what the lead tin phase diagram looks like.

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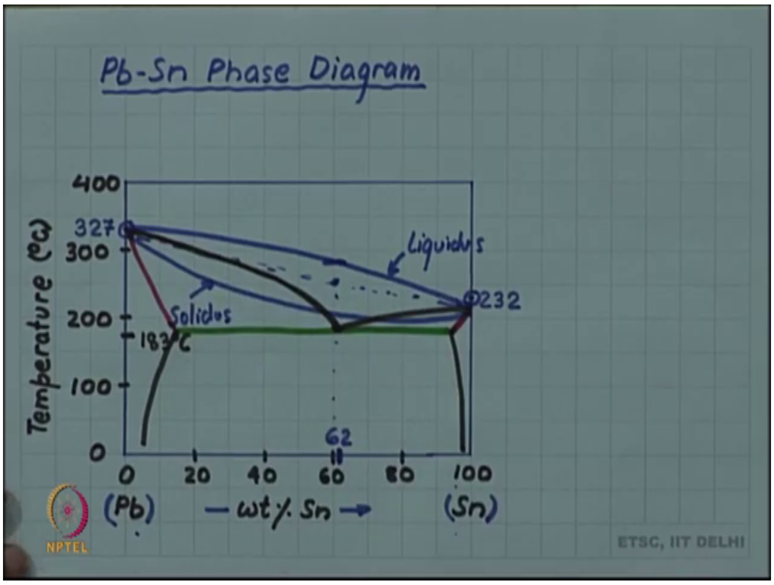

So, here I am going to draw a lead tin phase diagram for you, you are now familiar with this box for our binary alloy the x axis is components. So, since its a lead tin alloy. So, the components are lead and tin, and we decide to use weight percent tin as our x axis.

So, since its lead tin system 0 percent tin denotes led, 100 percent tin denotes pure tin and we have the temperature axis. Now we do not have to have temperature axis running in 2000 degrees Celsius, highest temperature the melting point is only 327 that is of pure lead. So, we have that on the lead axis and we have 232 which is the melting point of tin on the tin axis.

And you have already seen that now we remember that if we want let us say if we want the melting point of alloy of 62 weight percent you will soon see why I am selecting something odd like 62`, but suppose I want a melting point of 62 weight person tin alloy. Then we have already seen that our first approximation which was a linear approximation was not very right my line is not very straight. So, excuse me for that maybe I will try something, but at this time. So, if I draw a straight line and if I try to predict a melting point I get something close, but that is not the truth because now you know better that for alloy the melting point is not happening at or melting is not happening at one unique temperature, but over a range of temperature.

So, you see you saw in the copper nickel diagram, that there was a liquidus and solidus. So, you can predict something like this that you here also you will have a liquidus and solidus and this gives you an alloy which will melt at a lower temperature than the higher melting component lead. And this is intuitively obvious because we are adding tin. So, we are we were thinking that we are adding low melting component to a high melting component and that is bringing down the melting point from 327 to somewhat lower temperature. However, in reality you get even better result you get more than your expectation and the liquidus is not a continuous line like this in the lead tin system if you see, the liquidus reaches a minimum at 183 degrees Celsius.

The liquidus is not a continuous line, it comes in two parts one is starting from the melting point of lead and one is starting from the melting point of tin and both converging at to a minimum point which is 183 degrees Celsius. So, this is very very interesting, this is more interesting than a continuous liquidus like that and what does the solidus do? Solidus also makes an interesting term and solidus actually breaks into two different solidus instead of a continuous solidus.

Now, you have two different solidus and they end at the same temperature of 183 degrees Celsius. And then at 183 degree Celsius you have a horizontal line going through this minimum of the liquidus from one solidus end to another solidus end and finally, to complete the phase diagram, you have two more lines two new lines which you have not seen in an isomorphous diagram extending from this end to this end.

So, you can see this is a somewhat more complicated, but at the same time more interesting phase diagram than the simple isomorphous diagram. So, since the earlier isomorphous expectation is superimposed on this and is confusing the diagram let us look at the diagram in its own.

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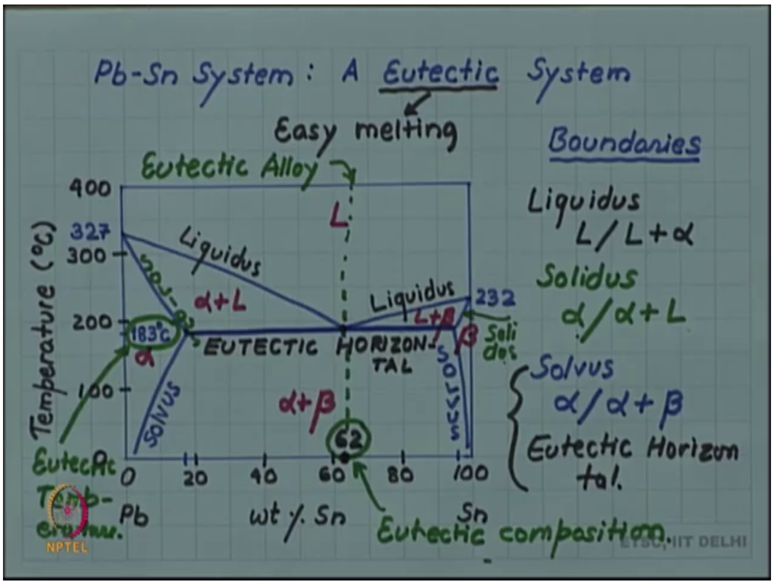

So, what we have seen is that you have liquidus in two components.

So, let us write down those boundary names. So, you have liquidus we have not yet defined liquidus, but we can do that. So, liquidus is any boundary which separates a single phase liquid with a mixture of liquid and solid. So, this is a liquid liquid plus alpha phase boundary. This is liquid plus liquid liquid and liquid plus beta phase boundary I have not yet mentioned the phases. So, let me first label the phases in this diagram.

So, above the liquidus you have a liquid. These two end triangular regions are solid phases and now you have two distinct solid phases. So, unlike isomorphous diagram where a single phase was extending from one end to the other end, now you have two different solid phases in the same alloy system. So, near the lead end you have alpha solid phase and near the tin and you have the beta solid phase. These are the single phase field and if you apply your lever rule you will get other two phase regions here. So, you can see here one end alpha another end liquid. So, this is alpha plus liquid region here one side liquid another side beta. So, this is liquid plus beta region and here one side alpha one side beta.

So, you have alpha plus beta region. So, all the phase fields are labeled and now I am labeling the boundaries for you. So, this is the liquidus boundary these boundaries are the solidus. So, this is solidus and this is also solidus. So, solidus is a boundary between single phase solid and solid plus liquid phase; so any boundary.

So, we had seen liquidus and solidus in the isomorphous system the copper nickel system, they are also the same definition is valid and when I say alpha not necessarily that it has to be alpha then you can see here that this is a boundary between beta and liquid plus beta and that is also solidus. So, alpha represents any solid. So, a solid with above a boundary between a solid and the same solid plus liquid boundary will be called solid as in any phase diagram. And finally, you have here these extra lines which was not there extra in the sense of in comparison to the isomorphous system, they were not there because you had a single solid phase, but now you have two solid phases.

So, there are boundaries which are delineating that these lines are called solvus. So, I have solvus which is a boundary between a solid phase and then the mixture of two solids alpha alpha plus beta. Of course, beta alpha plus beta is also another solvus there only one boundary is not yet labeled and that is this horizontal line which is a very important line in this diagram and this we call the eutectic horizontal eu tae tic eutectic horizontal. So, you have liquidus, you have solidus, you have solvus and you have eutectic horizontal the name eutectic comes from the meaning of eutectic is easy melting.

So, in this alloy system there is one composition and that is the 62 weight percent tin that is why I had started at 62 remember. So, at 62 weight percent tin you have an alloy which will melt at a very low temperature. So, if I take this alloy if I draw the composition vertical at that alloy, you can see that this is liquid up to 183 degrees Celsius and then it will become solid. So, this alloy solidifies although it is an alloy its solidifies as a single temperature. So, this is specific alloy is called a eutectic alloy eutectic alloy this particular vertical in eutectic alloy this composition. So, correspondingly this composition at which the eutectic alloy exists this is called a eutectic composition the temperature at which the eutectic alloy melts that will be called a eutectic temperature.

So, you have a eutectic alloy, eutectic composition and eutectic temperature and the phase diagram has a horizontal line at the eutectic temperature that is called the eutectic horizontal. So, in boundaries I have one more boundary, which is called eutectic horizontal. So, you had met liquidus and solidus in the isomorphous system also, the eutectic system gives you two more boundaries to new kinds of boundaries the solvus boundary and the eutectic horizontal.