Phase Equilibria in Materials (Nature and Properties of Materials - II)
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Lecture – 33
Methods of measuring phase diagram: PbMg2

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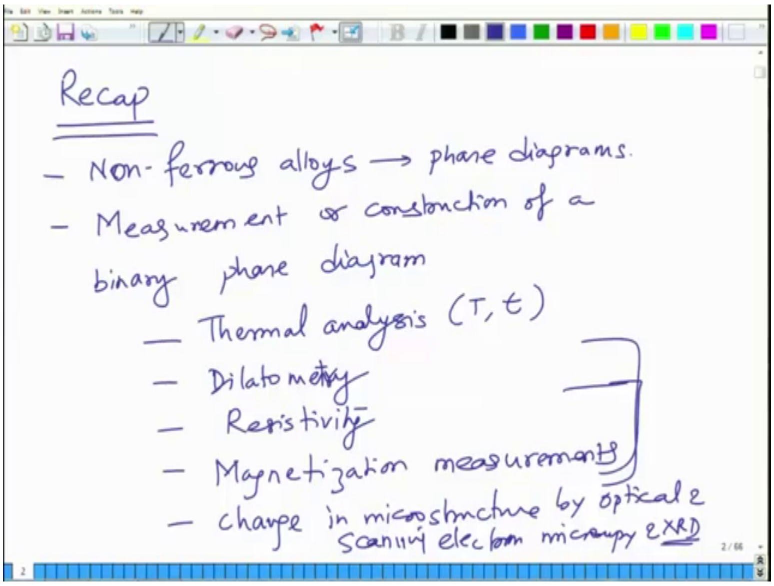

So, welcome again, we start with a new lecture number 33 in this course on Phase Equilibria. So, we will first recap the contents of last lecture. So, in the last lecture we discussed things like, so, basically we were looking at non ferrous alloys their phase diagrams and what sort of micro structures that one can evolve and then this is what we discussed 2 3 lectures back. In the last lecture, we basically looks looked at measurement of or construction of a phase diagram, basically experimental by experimental means.

So, the tools to do that, is one is to carry out the thermal analysis, which is basically drawing time versus temperature plots for various compositions and then stitch together the points representing start and end of solidification of melting and the second aspect of this was to carry out other measurements such as you can do dilatometry, by looking at a change in the volume, you can look at you can do resistivity measurements, because resistivity changes as a function and of composition as well as temperature and it is particularly useful in solid state and then you can do magnetization measurements.

So, these are basically you can say, the last 2 are basically indirect measurements and the thermal analysis is a very good method and this is all have to be accompanied by a change in microstructure by you have to examine this by optical and scanning electron microscopy as well as XRD X ray diffraction. So, basically you have to examine composition microstructure and phase analysis to correlate the results of time and temperature dependent phase transformations with the results of thermal analysis as well as a resistivity magnetization or a electrometry measurement.

So, all these put together can give you construction of a phase diagram of a given material. Now what we are going to do in this lecture? Is we are going to just take up a problem of suppose, you are given certain amount of data and how can you construct a phase diagram?

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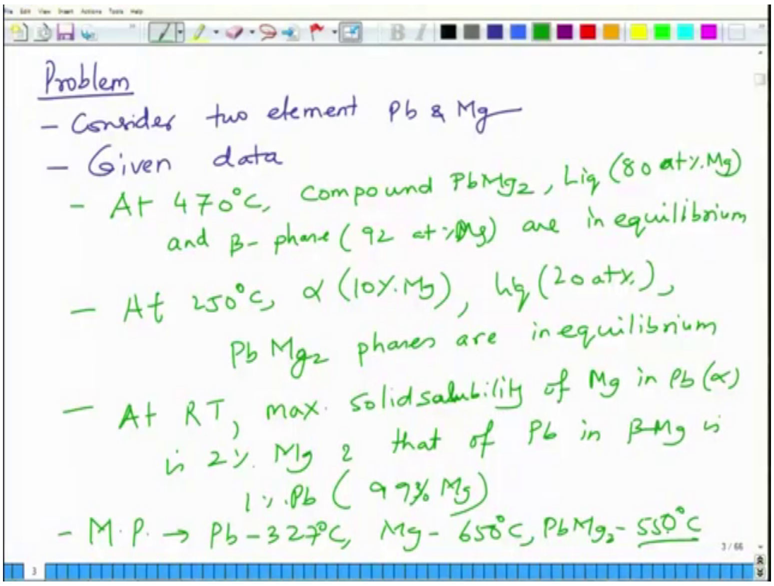

So essentially, problem solving in that sense: So, let us look at; so, it is a problem basically, the problem a statement is you have consider, 2 elements. Let us say, lead and magnesium ok. Now data that is given is first, you are told that at 470 degree centigrade is you form a compound, a compound Pb Mg 2 liquid of composition 80 atom percent magnesium and beta phase of composition 92 atom percent magnesium are in equilibrium. Another data that is given is at 255, would at 250 degree centigrade, alpha phase with 10 percent magnesium.

So, when I say percentages atomic percent in this problem, liquid phase of composition 20 atom percent and Pb Mg 2 phase are in equilibrium, then we have third scenario at room temperature. Maximum solid solubility of magnesium in lead, is that is alpha phase is 2 percent and that of Pb in beta Mg is 1 percent lead, that is 99 percent magnesium and then another data point that is given is melting point of lead is 237 degree centigrade, melting point of magnesium is 650 degree centigrade and Pb Mg 2 has a melting point, which is 55 degree centigrade.

Now, if this is the data that is given to you, how will you construct, go about constructing a phase diagram? So, let us do that. So, let us first see. So, we see that for if you, if you look at the first data point at 470 degree centigrade, the compound Mg 2, which has atomic, which basically means 66.7 percent magnesium a 10 percent wise, liquid of 80 percent magnesium and beta phase of 92 percent magnesium are in equilibrium.

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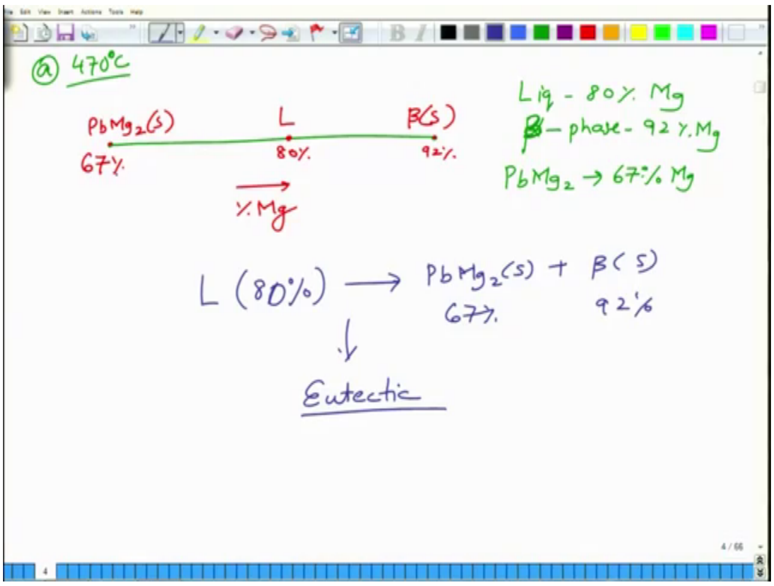

So, this is basically 3 phase equilibrium and our 3 phase equilibrium and binary phase diagrams happens, on a occurs on a invariant line, which means now, if I draw the line now. So, let us say this is the line. So, let us first draw, the extreme points the. So, you have liquid phase of 80 percent Mg.

All beta phase of 92 percent Mg and Pb Mg 2, which is essentially 67 percent Mg ok, let us say it, 67 instead of 66.7. So, this is at temperature 470 degree centigrade. So, if I mark these points, let us say this is. So, highest point is 92 percent. So, this is 92 percent, lowest point is 67 percent. So, this is percentage Mg and then in between somewhere, we have 80 percent magnesium. So, we have liquid of composition 80 percent ok. Pb Mg 2 of composition.

This is solid phase and beta phase of composition 92 percent. So, if you have such and now beta is a also solid. So, if you now based on the knowledge of phase diagram, we know that if liquid composition on this invariant line lies in the middle and there are 2 solids on either side of lower and higher composition then, we know that this reaction is nothing, but liquid of 80 percent because, liquid is the high temperature phase converting into Pb Mg 2 solid plus beta solid of 67 percent and 80, sorry 92 percent and we know that this reaction is eutectic.

So essentially, what it means from the given data that at 470 degree centigrade, your liquid of composition 80 percent has given rise to 2 solid phases beta and magnesia let Pb Mg 2 and whose compositions are 6 in 92 percent in beta and 67 percent in magnesium. So, this is the eutectic reaction that happens in lead magnesium phase diagram at 470 degree centigrade between compositions 67 to 92 percent.

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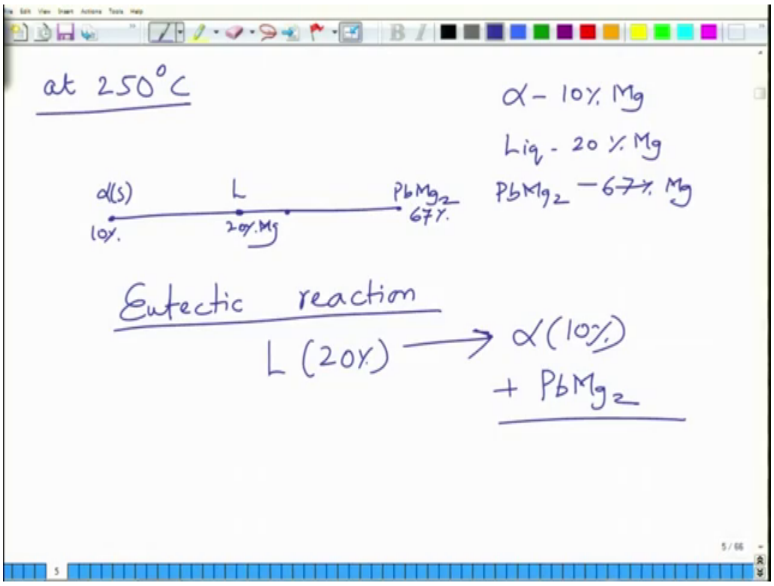

So, this is first piece of information that, we have derived. Second piece of information is at, 250 degree centigrade, we are given. So, I again draw a horizontal line. So, this is at 250 degree centigrade.

Next so, it says that alpha phase with 10 percent magnesium liquid with 20 percent magnesium and Pb Mg 2, which is with 67 percent magnesium. They are in equilibrium. So liquid, so alpha I have with 10 percent magnesium solid phase, Pb Mg 2 with 67 percent and then liquid somewhere in between is that, 22 percent. So, this again seems to be a eutectic reaction. So, this is again a eutectic reaction, where liquid of composition 20 percent transforms into alpha phase of composition 10 percent plus Pb Mg 2, this is again both of them are solid phases.

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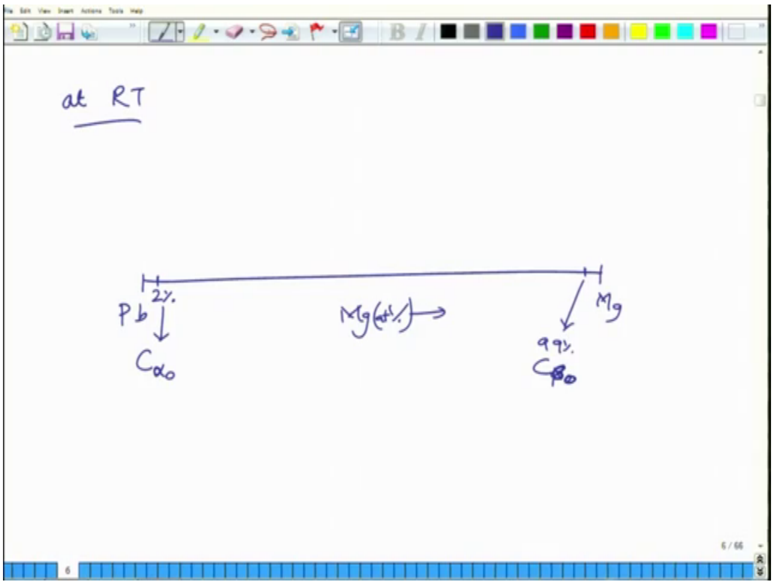

So, again a eutectic reaction that takes place, now the third data point was the solid solubility. So which means, at room temperature, if I draw the horizontal line, so let us say, this is Pb, this is pure Mg, this is percentage Mg atomic percent. So, it says that at the maximum solid solubility of magnesium in alpha, where that is alpha our lead is 2 percent. So, somewhere at 2 percent, this is you can say C C 0 in C 0, C alpha 0 and this is the maximum solid soluty of lead in magnesium is 1 percent, that is 99 percent. So, this is C alpha C beta 0 ok. So, beta phase is basically magnesium rich, it contains only 1 percent lead alpha phase is lead rich phase, which contains maximum of 2 percent magnesium at room temperature.

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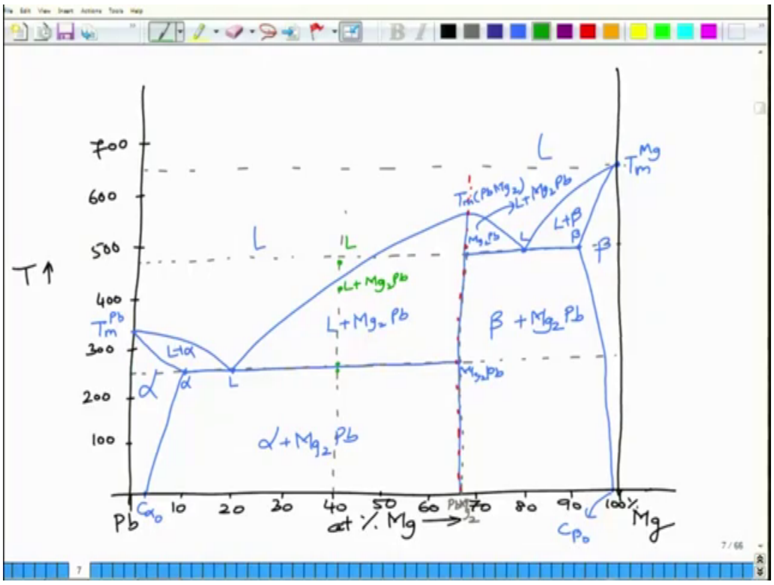

So now, let us is join, these pieces of zig saw puzzle. So, let us say. So, I draw this phase diagram here. So let us say, this is percentage magnesium this is Pb, this is Mg right. So, somewhere in between, we have 50. So let us say, 10, 20, 30, 40, 50, 60, 70, 80, 90 and we can remove this line, a little bit to the left. So let us say, this is 100. So, if I draw a vertical line. It is going to be something like this. So, this is 100 percent magnesium, this is 100 percent lead. So, this is 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 percent magnesium and this is atom percent magnesium on the y axis, we have temperature, we have the maximum temperature of 5, 650 degree centigrade.

So let us say, this is 100, 200, 300, 400, 500, 600, 700. So, 100, 200, 300, 400, 500, 600 and 700 degree centigrade ok, now what I am going to do, now is just to superimpose the previous information. So, the previous information was that, first at what temperature at 470 degree centigrade, which is somewhere here ok. So, 470 will be somewhere here. So, let me draw a horizontal line here, 470 degree centigrade ok. So, at 470 degree centigrade we said that. So, we draw a few critical points, we know that magnesium Pb Mg 2 has a composition here. So, this is the composition of Pb Mg 2 ok. So, this is Pb Mg 2 67 percent. So, what we are saying is at this temperature Pb Mg 2, 92 percent of beta with 92 percent of magnesium.

So let us say, 92 percent is somewhere here and then liquid of composition 80 percent. So, we say 80 percent is somewhere here, let us say this is 80 percent all right. So, this is

80 percent, this is 92, this is 67. So, this is invariant line, now eutectic line. So at this point, you have liquid at this point, you have Mg 2 Pb and at this point, we have beta all right. Second information is at 250 degree centigrade. So, that is a 250 degree centigrade. So, let me draw 250 degree horizontal line at 250 degree centigrade. So, we say that at this temperature, you have alpha phase of composition 10 percent. So, this is alpha phase of composition 10 percent, we have liquid of composition 20 atom percent. So, this is liquid of composition 20 atom percent and we have Pb Mg 2, they are in equilibrium. So, we have this as a tie line and then we have maximum solid solubilities.

We can mark them. So, 2 percent magnesium in lead is somewhere here. So, this is 2 percent and then we have 1 percent lead in magnesium, which is somewhere here ok. So, this is C alpha 0 and this is C beta 0 and then we need to mark the, melt melting point. So, we say that the melting points of lead is somewhere here, which is 327 degree centigrade. So, melt. So, this is melting point of lead. So, this is Tm Pb and the melting point of magnesium is 650 degree centigrade so which is somewhere here. So, let me just draw a line, horizontal line on this point. So, this is the Tm Mg and the melting point of Pb Mg 2, which is a line compound, line compound means it has a single composition and it has a it is it has a fixed composition.

So, its melting point is 550 degree centigrade, which is somewhere here, let us say, somewhere here ok. So, this is Tm Pb Mg 2. So now, we have to draw the boundaries to construct this phase diagram. So, we know that in the eutectic you have so; obviously, eutectic is going to look something like this and this compound is a line compound. So, as a result this does not have any 2 phase region, it is a single phase line. So, you connect this point with this point, this point with this point. So, when you connect these points, you construct a phase diagram, which has 2 eutectic reactions. So, this is the first eutectic reaction alpha liquid and Mg 2 Pb. So, this is liquid region all of it somewhere here, you will have liquid plus alpha, this is alpha, this is liquid plus Mg 2 Pb, this is alpha plus Mg 2 Pb and this is liquid plus beta here, you have beta region this is liquid plus Mg 2 Pb and this is beta plus Mg 2 Pb.

So, this is how you have a phase diagram basically, you can see it is a phase diagram, which consists of 2 regions. The first eutectic between alpha and Mg 2, lead and Mg 2 Pb, second is the eutectic between Mg 2 Pb and Mg. So, you just put them together to construct a bigger phase diagram between lead and magnesium and this is separated by as line compound Mg 2 P Pb, which is like a component. So, it is like a 2 binary systems, you are put together ok. So, this is the sharp phase boundary that, you have because of presence of line compound ok.

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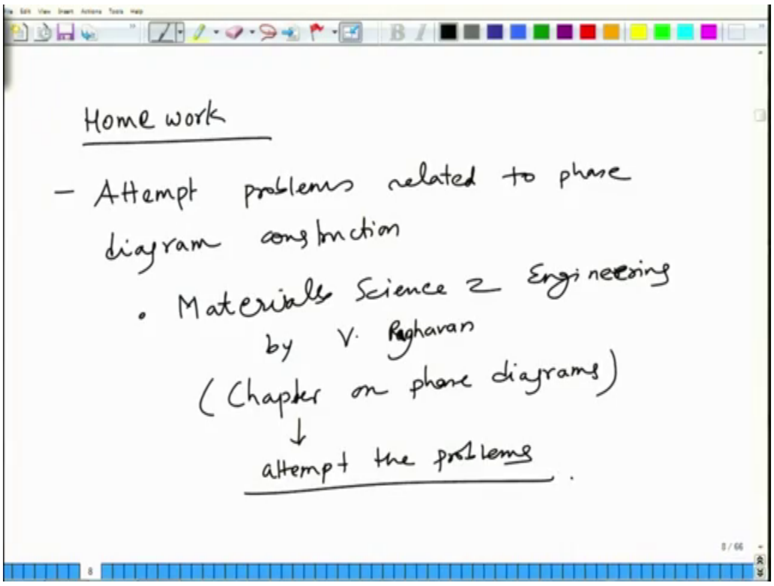

So, I would suggest you to do some homework problems along the similar lines. So, I would say So, your homework could be attempt problems related to phase diagram construction and one of the books I can recommend is, I would say material science and engineering by V Raghavan.

And in that there is a chapter on phase diagrams. So, attempt those problems. So, there is something that you could find useful to construct a variety of phase diagrams. Now using this information you can attempt a few more questions.

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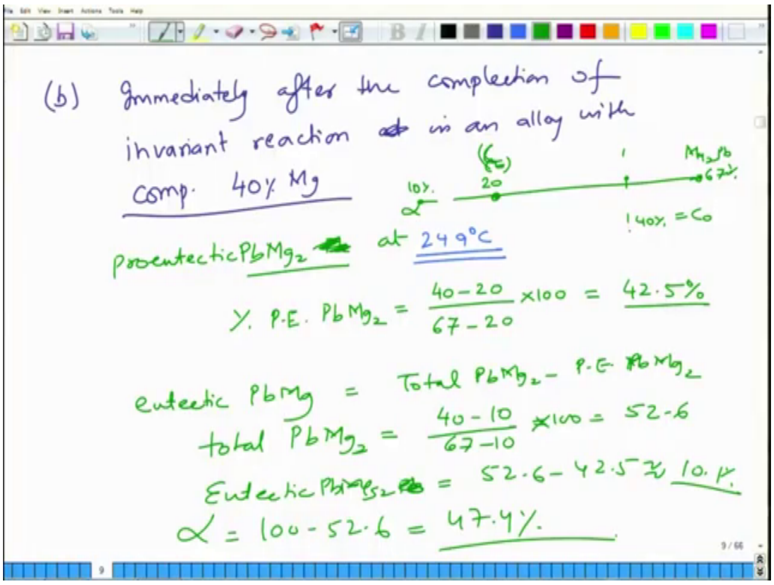

So let us say, the first thing somebody asks if there is a question, let us say there is a question that, what is the immediately after the completion of reaction? Immediately, after the completion of invariant reaction at in an alloy with composition, let us say, forty percent magnesium. So, calculate the phase fractions for instance. So, when you go to 40 percent magnesium. So, this is 40 percent magnesium. So let us say, we draw a vertical line. So, 40 percent magnesium lies on the left hand side of the phase diagram. So, what you do here is? What you see here is? First you have a liquid phase, this liquid phase converts into liquid plus Mg to Pb. So, you have some crystals of Mg 2 Pb starting to appear, when you reach this point just before the invariant reaction, you have liquid and Mg 2 Pb, whose proportions can be determined by lever rule.

And then when you cross over this line the liquid converts and the eutectoid mixture of alpha and Mg 2 Pb. So you will have Mg 2 Pb as a pro eutectic phase followed by formation of a eutectic of alpha and Mg 2 Pb. So, if you want to determine the, so for example, what is the proportion of pro eutectic Mg 2 Pb at? Let us say so eutectic temperature is, I am saying is at this composition the eutectic temperature is 250 degree centigrade. So, let us say at 249 degree centigrade ok. So, at 249 degree centigrade percentage, pro eutectic Pb Mg 2 or Mg 2 Pb, this is nothing but, the alloy composition 40 minus the solid solubility at that point, which is the alpha composition 40 minus 20 divided by 67 minus 20 into 100.

So, essentially it is this line ok. So, you have 20, you have somewhere here, you have a 40 percent, this is 67 percent and you your eutectic lies at a composition of 20 percent. So, this is the sorry, this is eutectic and your alpha will be. So, this is eutectic composition CE, this is Mg 2 Pb and your alpha phase has a composition of 10 percent. So, this is 10 percent that is alpha point. So, pro eutectic Mg 2 Pb at this point for this composition, so this is C0. So, this is the percentage of protective which is 42 point roughly. 42.5 percent atom percent, mole percent you can say. So, because the compositions are given in other percent, what you can determine is only atom percent or mole percent things, you cannot determine weight percent from this. So, you will have to convert the atom to weight percent to achieve that and then you can determine the eutectic Pb.

Eutectic Mg 2 Pb that is total of Pb Mg 2 minus of pro eutectic Pb Mg 2. So, let me write it Pb Mg 2, just to we consistent and here also we can write P b Mg 2. So now, what is total Mg 2 Pb? So, total Mg 2, sorry total Pb Mg 2, I am just upon writing this, which is nothing, but 40 minus 10 divided by 67 minus 10. So, this is total out of alpha and Pb Mg 2 present. So, this is into 100, this is equal to 52.6. So, eutectic Mg 2 Pb, Pb Mg 2 rather is equal to 52.6 minus 42.5, that is nearly 11 percent, 11, 10 10.1 percent and likewise you can determine the alpha phase, alpha phase is nothing but, total Pb Mg 2. So, it is like 100 minus 52.6, this will be equal to 47.4 percent will be the alpha phase. So, this is how you can find the phase fractions in eutectic information.

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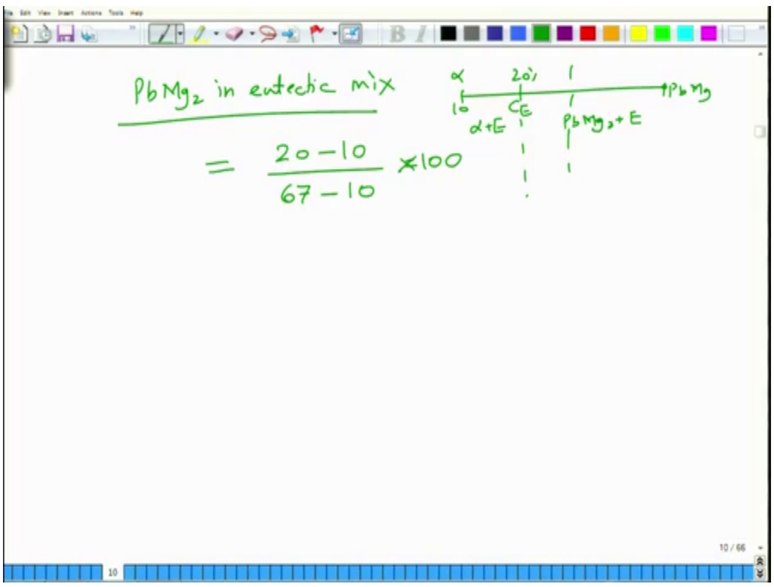

So, if somebody, you can also calculate, what is the fraction of Mg 2 P P b Mg 2 in eutectic mixture? So, if you want to find out, what is the Pb Mg 2 fraction in eutectic mixture? Then this is going to be equal to 20 minus 10 divided by 67 minus 10 into 100. So, this is how you going to determine the so, you have a eutectic line which is alpha is 10 percent, this is eutectic composition 20 percent, this is the alloy composition and this is the Pb Mg 2. So, you will have at this point alpha plus eutectic at this point, you will have Pb Mg 2 plus eutectic and the total amount of Pb Mg 2 in eutectic can be determined by so, let me just. So, the microstructure is going to look like this you sorry.

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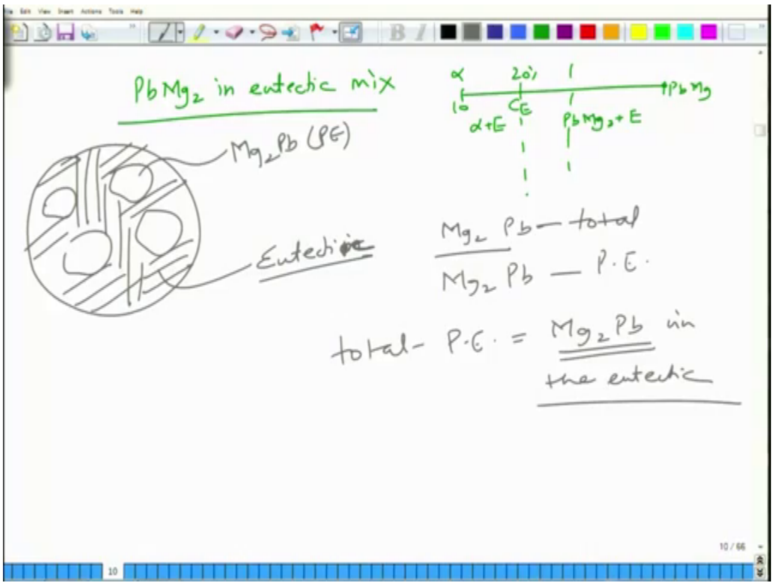

So, you have pro eutectic Mg 2 phase and then you have eutectic, this is the eutectic. So, this is Mg 2 Pb pro eutectic and this is the eutectic all right.

So, if you want to determine the. So, you know what is the eutectic? So, you can you have determined, what is the Mg 2 Pb proportion? Total Mg 2 Pb pro eutectic. So, total minus pro eutectic will be Mg 2 Pb within the. So, that is how you can determine the proportions. So, this is what we have discussed in this lecture. So, we have discussed basically, how to construct a phase diagram from the given set of data. So, basically it is a problem solving. So, I have, I would recommend you to. So essentially, what you need to do is that you first need to identify one of the invariant reactions, that occur and what are the various? So, you first determine the invariant reactions and the terminal points and then looking at the knowledge of your invariant reaction, you need to basically connect various phase boundaries by connecting the terminals and that is that is where your understanding of phase diagram comes into picture and invariant reactions. So, if for practice you should do the problems given at the back of chapter on phase diagram in Raghavan's book on material science engineering. So, you should do that to achieve a better knowledge of how to construct phase diagrams. So, we will finish here.

Thank you very much.