Materials Science and Engineering
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Lecture – 15
Eutectic Phase Diagram

Hello friends, now we will go further in the phase diagram and come to the next type of phase diagram which are one of the most important system which is called eutectic phase diagram. So, the in the last slide is lecture, if you remember we were discussing about isomorphous phase diagrams or isomorphous system, in which the two component have complete solubility.

Now we will see the systems where there is no complete solubility, in that case what changes it takes place in the phase diagram. So, binary eutectic phase diagram is a Diagram phase diagram between 2 components having complete solubility in liquid phase.

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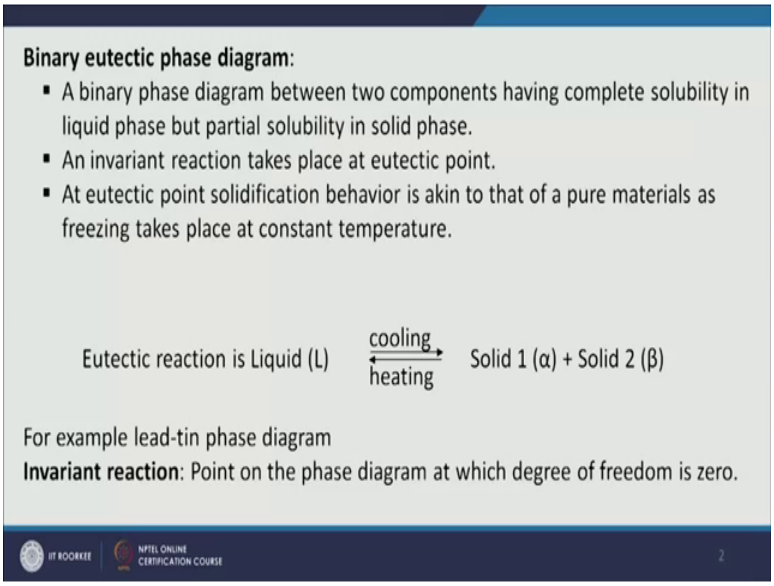

So, please keep in mind that they have come the two component have complete solubility in liquid phase, in liquid phase you can have all type of solutions. But when it comes to solid phase then they start having limited solubility or partial solubility and when this type of partial solubility happens you also get an invariant reaction at eutectic point. We will see what do we mean by invariant reaction and what is a eutectic point.

At eutectic point the solidification behavior is akin to that of a pure material is freezing takes place at constant temperature. So, if you again remember that when we said in a pure component if you plot the time temperature profile ok, the transformation will take place at constant temperature this is what we discussed ok.

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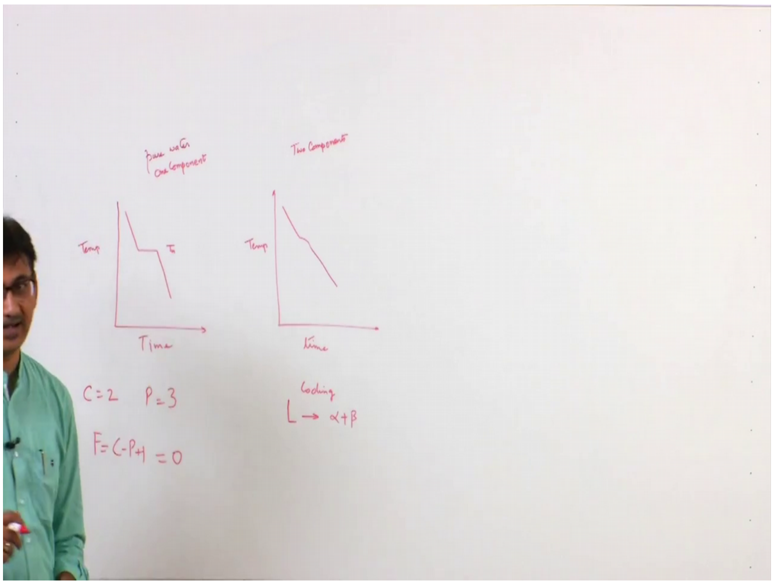

So, for a single component let us say I am want to see in pure water ok, this is temperature this is time. So, I will have cooling in the liquid phase, then the transformation at constant temperature and then cooling in the solid phase and that is why we call this as melting point or solidification point.

In case of two component system we said that the transformation happens at a temperature range. So, this is cooling in liquid phase then the transformation from liquid to solid then it is you have, so cooling in the solid phase ok. So, the transformation takes place over a temperature range if you have a more than 1 component suppose we say it is two components ok, this is one component. But in two component system also where they show eutectic behavior or at eutectic point again the transformation will be like this though we are having 2 component, but the transformation will be like this and we will see that why this transformation will be like this.

First let me tell you what do we mean by eutectic, a eutectic reaction tells me that a liquid phase will transform into 2 solid phase simultaneously. So, in the binary phase diagram where you have partial solubility ok, you sometime have this type of eutectic reactions where liquid phase directly transforming to 2 solids and this is this type of 1 of the example of a eutectic system is a lead tin phase diagram or lead tin system. What is an invariant reaction point on the phase diagram at which degree of freedom is 0.

So, why at eutectic point you get this type of profile because, in this case the degree of freedom is 0 this is an invariant point, invariant means you cannot change anything or it remains same it remains constant that is what we call as invariant. So, in this case it is invariant means that I cannot change anything in this no variable can be changed because, my degree of freedom is 0. Why degree of freedom is 0 we are talking about a 2 component system.

So, my C is equal to 2 there are 2 components, phases as I told you the eutectic reaction the eutectic reaction is like this the liquid phase transform on cooling transform to 2 solids ok. So, there are 3 phases in equilibrium here liquid alpha and beta 2 solids ok. So, my 3 phases are in equilibrium and my relationship for the Gibbs face rule is C minus P plus 1 pressure we are taking as constant.

So, it will be 2 minus 3 plus 1 2 minus 3 will be minus 1 minus 1 plus 1 0. So, you have a degree of freedom as 0 that is why at eutectic point you will get a temperature profile like this and that is a invariant reaction means your there is no degree of freedom the degree of freedom is 0.

So, this is a typical eutectic phase diagram I this is drawn schematically. So, it may not be possible that maybe some system has some something like this I have drawn it.

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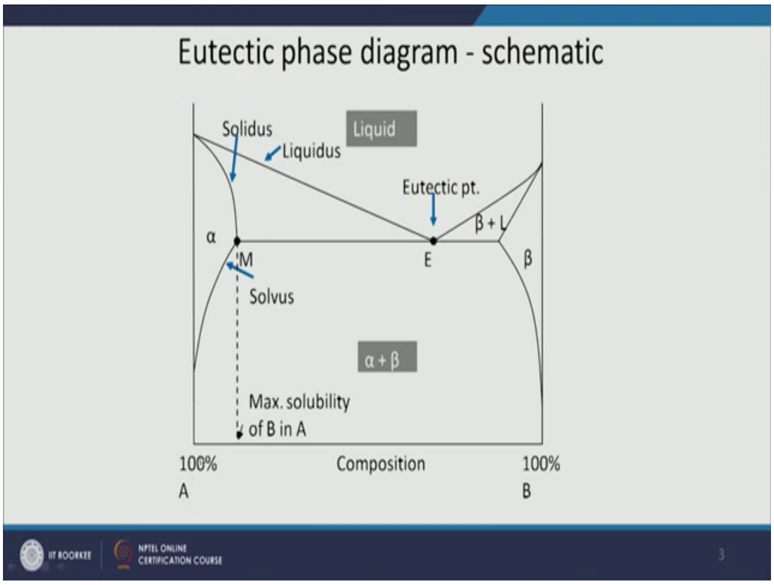

So, you can again see that you have hundred percent a at 100 percent B at the other end and the composition of B is increasing from left to right.

In the isomorphous it was very simple you had liquid you have liquid plus solid and then you have solid phase, here you can see that the it is more complicated now in the liquid phase you can see that there are there are no phase boundaries; that means, there is a complete solubility of a and B in the liquid phase ok. Now there is a very important point here which is shown by E it is called eutectic point ok. So, you can see that at this point above that you have a liquid phase, below that you have 2 phases alpha and beta.

Please remember there will always be a 2 phase region between the 2 single phase region. So, as you can see at the left hand corner you have a single phase alpha, at the right hand corner you have the single phase beta. So, any phase diagram between these 2 single phase will have a 2 phase region which will be alpha plus beta.

Similarly, you have alpha here at the left corner liquid phase above. So, any this phase region between these 2 single phases will have 2 phase region, which will be alpha plus liquid in this case and beta plus liquid in this case ok. So, let me draw it and show you all these things on the blade on the board. So, a eutectic phase diagram will look like this maybe take something else here better than the previous one.

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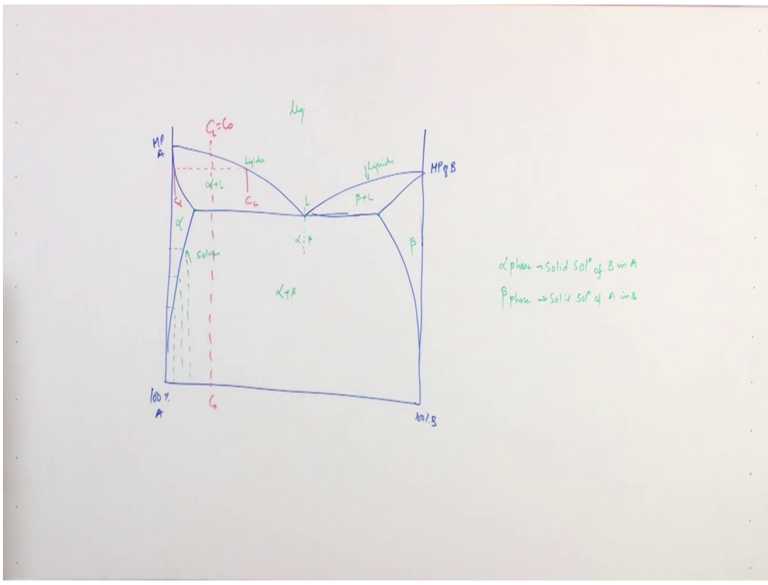

So, if I there will be 1 single phase here ok, then there will be constant temperature line, then there will be another phase line like this there may be something like this. So, this is hundred percent A this is hundred percent B, as I told you at hundred percent a this point from which the solid phase is going into liquid phase you will have melting point of A and here you will have a melting point of B or some more things we can quickly plot this is my liquid phase, complete solubility of a and B this is my solid phase.

But there are 2 new things coming up now you have 2 different solid phases 1 which is I am going to call as alpha and another 1 which is I am going to call beta. What is alpha B soluble in A, so A is solvent B is solute you have more of A less of B ok. So, the alpha phase now it I will call it as phase. So, alpha phase solid solution of B in a, so B is solute A is solvent beta phase is solid solution of A in B. So, A is solute B is solvent which comes here.

Now, as I told you between any 2 single phase there will be always a 2 phase region. So, if this is alpha phase this is liquid phase they are always going to be a alpha plus liquid phase in between this beta phase, this is liquid phase 2 phase region will be here which will be beta plus liquid; this is alpha phase this is beta phase region between them will be alpha plus beta and at this point you can see that liquid phase suppose I take a composition exactly of eutectic, liquid transform into 2 solids alpha and beta ok. So, you have the liquid is transforming into 2 solids alpha and beta, so that is the eutectic reaction invariant reaction where the degree of freedom is going to be 0.

Now, which we can see that this will be my liquidus line, between liquid and liquid plus solid this will also be liquidus line, liquid between liquid and to solid. Another line which is our boundary which is going to come here which we saw earlier is called solvus boundary or solvus line, this gives me the solid solubility of B in A.

So, at you as you can see that a different temperature the solubility's are different ok, as I am increasing the temperature the solubility of B in A is increasing. Now at higher temperature I can have more solubility of B in A and the maximum solubility will be given by this point, that this is the maximum I can have solubility of B in A, I cannot have more than this.

Similarly, this is the maximum solubility of A in B I cannot have more than this and this is a exponential dependence again the temperature dependence ok, that how the solubility of B in A is increasing as a function of temperature.

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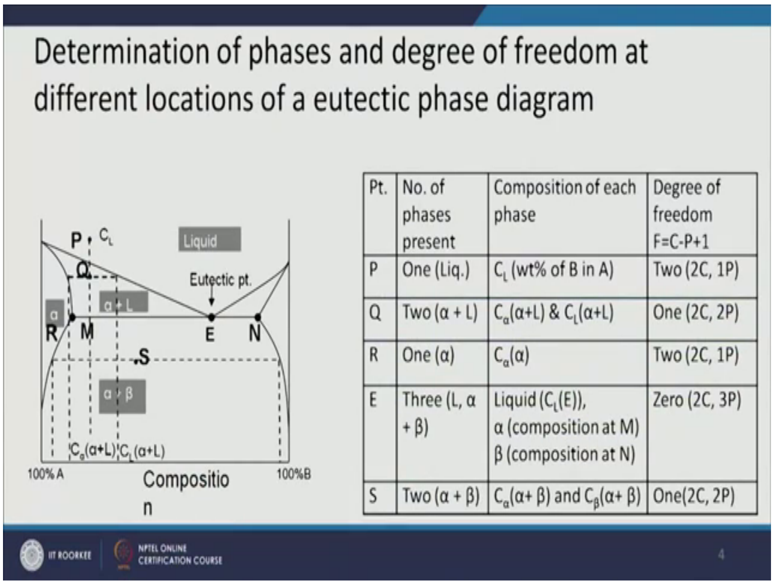

Pt.	No. of phases present	Composition of each phase	Degree of freedom F=C-P+1
P	One (Liq.)	C_L (wt% of B in A)	Two (2C, 1P)
Q	Two (α + L)	$C_\alpha(\alpha+L)$ & $C_L(\alpha+L)$	One (2C, 2P)
R	One (α)	$C_\alpha(\alpha)$	Two (2C, 1P)
E	Three (L, α + β)	Liquid ($C_L(E)$), α (composition at M) β (composition at N)	Zero (2C, 3P)
S	Two (α + β)	$C_\alpha(\alpha+\beta)$ and $C_\beta(\alpha+\beta)$	One(2C, 2P)

Now in the in this particular slide you can see that there are different points are marked here and at each point we are giving you a list that how what different phases will be present, what will be the composition of each phase and what will be the degree of freedom at that point.

So, if you see at point P you have only 1 phase a liquid phase composition of that phase CL will be weight percent of B in A which is the overall composition. So, you can say CL will be equal to C naught at this point and the degree of freedom will be 2 because, you have 2 component you have 1 phase ok, so degree of freedom will be 2. So, I can change the temperature as well as the composition at in the liquid phase without, so I have 2 degree of freedom both can be changed.

At point Q you have 2 phases present alpha and liquid, composition of each phase alpha phase is a composition C alpha in alpha plus liquid and composition of liquid is CL in alpha plus liquid. Again as we did earlier that I can have a tie line, suppose this is my point Q this is the overall composition C naught and if I draw a tie line like this, this will give me composition of C alpha in alpha plus liquid this will give me composition of C liquid in alpha plus liquid and total C here composition is CL is equal to C naught the overall composition.

The degree of freedom here is 1 ok, either I can change temperature or I can change the composition at a at a particular location ok, point R that that is in alpha phase you have one single phase alpha the composition of that phase will be equal to C alpha. In alpha phase and degree of freedom will be 2 at point E, there are 3 phases in equilibrium liquid alpha and beta the liquid has the composition of CL alpha as the composition given by point M ok.

So, just below the eutectic point we can find out. So, this is the composition CL being divided into alpha and beta. So, alpha will be having the this composition and beta will have this composition. So, maximum solubility of B in A maximum solubility of A and B which is in this particular slide is given by A point M and point N, at point S you have again 2 phase alpha plus beta and the composition C alpha alpha plus beta between alpha plus beta and C beta in alpha plus beta and degree of freedom is again 1 ok.

So, this is the complete information of this particular phase diagram at different points, what are the different phases present what are the composition of these different phases, which are present and what is the degree of freedom at that particular point.

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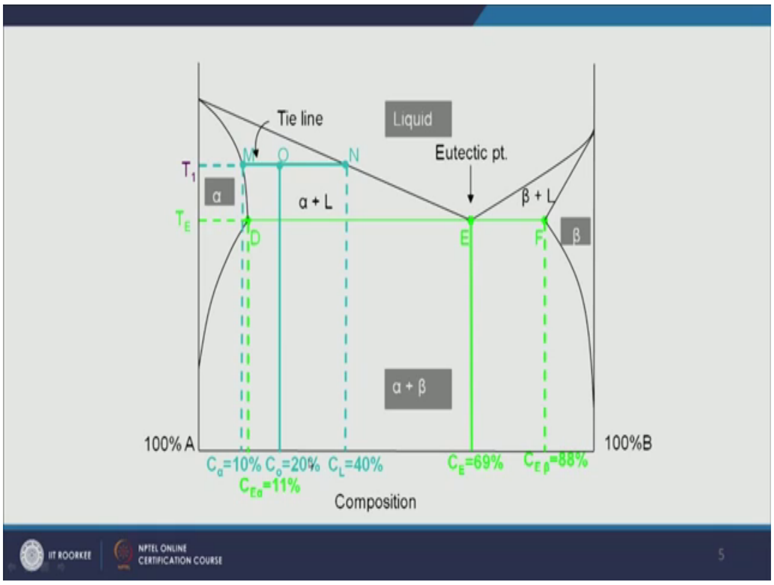

Again in more ways the same information is shown in terms of percentage here now ok. So, for example, you have a overall composition C naught of 20 percent given by the point O. If A2 phase region I want to find out what is the composition of alpha that will be given by C alpha.

For example, here is 10 percent at N point N it will be composition of liquid, which is given by 40 percent B and now I can also find out that what will be the fraction of each of this phase. For example, at point for overall composition of 20 percent at point O I want to know at a temperature which relates to the point O which is given by T1 here. I want to know what will be the fraction of alpha phase and what will be the fraction of liquid phase.

So, let us do one calculation here. So, according to that diagram we are saying that.

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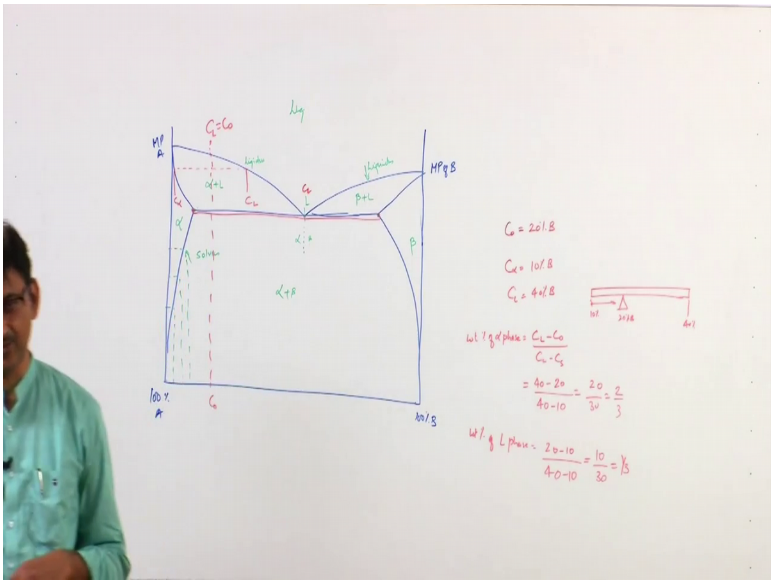

Overall C naught is equal to 20 percent B and from here we are saying that the C alpha has the composition 10 percent B and C liquid has composition 40 percent B. Now I want to find out the suppose these are in weight friction what will be the weight fraction of alpha phase, for example weight percentage of alpha phase.

So, again we will use the lever rule here ok, so this is my lever arm fulcrum is at 20 percent B and this is at this at 10 percent, this is at 40 percent, so I have the compositions ok. So, I will use this composition, so weight percent of alpha phase will be given by this arm length.

So, this will be CL minus C naught divided by CL minus CS ok, if I put all this values CL will be 40 minus C naught is 20 divided by forty minus 10. So, this will be equal to 20 by 30 that is 2 by 3, if I want to know weight percent of liquid phase then it will be this arm length ok. So, 20 minus 10 divided by 40 minus 10, that will be equal to 10 upon 30 that is equal to 1 by 3.

Now, you if you remember I told you that I can get weight percent of liquid phase, just by subtracting what if I have get got 2 by 3 in as weight percent of alpha phase; if I subtract this out of 1 I will get the weight percent of liquid phase ok. So, if it is in percentage I say percentage if it is in fraction I say weight fraction of liquid phase. So, right now it is in fraction I can say weight fraction of liquid phase or weight fraction of alpha phase.

So, this is how you can calculate the different compositions and different weight fractions ok, some other also are shown here for example, if eutectic has a 69 percent overall composition, you can find out that what will be the fraction of alpha phase in this and what will be the fraction of beta phase.

So, the overall eutectic composition is given by 69 percent I want to know what will be the composition of alpha phase. So, that is coming as CE alpha as 11 percent at F, it is coming CE beta is 88 percent and so you can find out that what will be the fraction of alpha phase and what will be the fraction of beta phase in a eutectic. So, when you eutectic reaction is going to take place and with that we I say thank you.

We will stop this lecture here itself and then we will go to the cooling and how the micro structures evolved during the solidification in different systems.

Thank you.