Phase Transformation in Materials

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Lecture - 10
G vs X for Eutectic System

So, students we have been discussing about this phase diagram and phase stability. In the last lecture I explained you how we can draw phase free energy composition diagram for isomorphous system that is; which is phase diagram in which we have complete solid solubility in both in liquid and the solid states. So, we are going to move ahead. First thing we will do is take because we are going to show now immiscibility little bit. First thing we will take again isomorphous systems with a little bit of immiscibility.

Immiscibility in the sense not that immiscibility of the phase diagrams. I am following the book of porter easterling. This is in the first chapter itself page number 1333. If you have the book you can kindly follow up. So, if there will be system with a immiscibility gap. So, therefore, with a first case we are going to discuss is that there is a meeting point of this (Refer Time: 01:16) of the solidus and liquidus curve. So, let me just draw that phase diagram then it will be clear to you.

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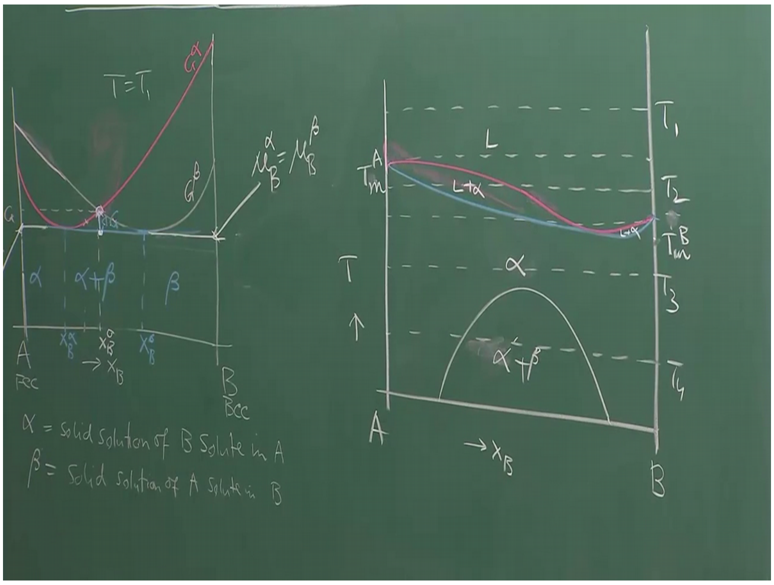

Suppose this is a T m A and this is T m B, sorry I will draw it in color. So, otherwise is very difficult to follow in a video color looks nice. So, oops and that is what happens suppose there is a meeting point of both the solidus and liquidus somewhere, somehow it will look like again we will draw the free energy composition diagram at the different Temperatures.

So, first is this is a liquid plus alpha liquid plus alpha sorry, we have to put liquid plus beta also. And I am going to draw immiscibility gap. You will also find such a kind of phase diagrams the alpha phase forms and then it is basically transform into 2 solid solution phases alpha prime and beta. It is better to write alpha prime and beta because alpha, alpha prime may be same phases, but different compositions possible stability phase.

So, how we are draw the phase at the in composition diagrams. This is at T 1, this is at T m A and this is to the suppose T 2. Then I draw it at T m B. And I draw it T 3, I will draw it at T 4. So, I have only increased one more Temperatures from T 1 to T 4. So, to in order to explain you; obviously, all of these diagrams we cannot we cannot draw it. So, what I will do is I will draw a Temperature T 1, then I will T m A I have already drawn in the last lectures. So, it will be similar then I will draw T 1 T 2 T m B T 3 and T 4. So, this is at T is equal to T 1.

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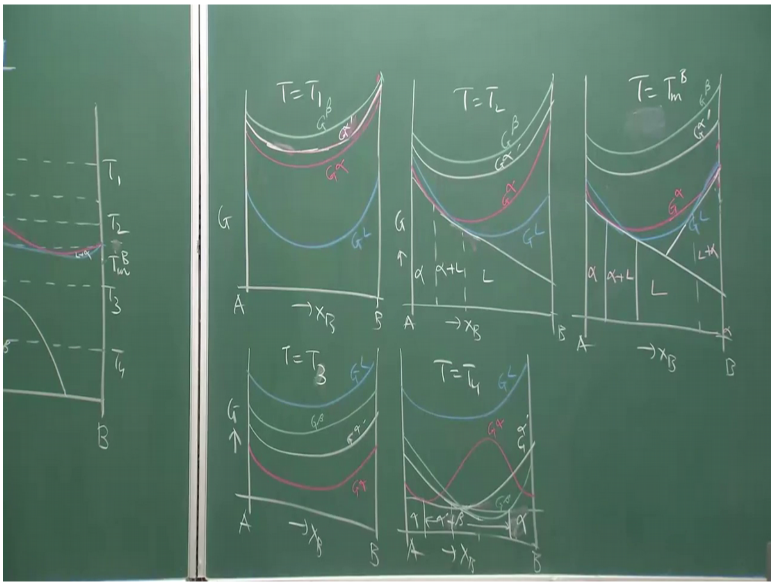

So, this is G versus composition diagram this is T is equal to T m B T is equal to T 2 sorry T m A I am not going to draw. And again this on this side is T sorry T equal to T 3 T 2, I have drawn T m B sorry. And then this 2 will be at T 3 T 3 is not required to drawn

T 3 is I already drawn let us draw it. And last one will be at T is equal to T 4. So, as you see there actually were 3 phases here liquid alpha prime and beta.

So, I have to draw all of them otherwise it will not be clear. So, as you see here liquid has a lower free energy it will be at left position all through. Because this is liquid and sorry liquid I am drawing in the different color. So, this is what it is then what about the alpha and alpha, alpha prime and beta. This is alpha prime. So, there 4 phases and all will be (Refer Time: 05:31). So, I will draw it alpha beta oops beta will be different color. So, this is G alpha, this G beta alpha prime. And alpha will be similar type because all the 3 stability is different. So, whether you draw it at higher or lower Temperature does not matter. So, let us draw it higher position.

So, it is very clear that alpha in liquid is stable in all the composition range at T 2. You can clearly see that at some range alpha is stable at some range liquid plus alpha is stable and some range liquid is stable; that means there is a crossover between liquid and alpha. So, let us do it quickly. So, that is the liquid. So, let us first draw the alpha because alpha is stable .on a right side alpha and liquid there is a cross over and for beta and rs there is no point oops sorry I have drawn it same color it is a problem.

So, this is beta G alpha gl and alpha prime be somewhere there. So, as there is a crossover let us do a common tangent and this common tangent will remarked at 3 regions alpha liquid plus alpha liquid that is what you see here liquid plus alpha is stable at small composition range. Alpha is also liquid is stable at large composition at the B region at T equal to T m B. There is alpha is stable at large range then liquid plus alpha then liquid and at the end again alpha obviously. So, therefore, it will be little bit different. So, how it will be it will be looking quite interesting. Let us see how you can draw it. So, liquid is stable only for a small composition range. So, alpha is stable.

So, let us draw for the alpha, because alpha is having instability. So, therefore, oops sorry it is should not be like this alpha is stable then liquid plus alpha liquid. So, it should go down little bit or this will look bad and liquid crossover. Then it is stable then it is another crossover here and it will meet both there that is what it will happen.

So, let me write down and beta and alpha prime is not of significance. So, alpha liquid. So, there will be 2 you can see there will be 2 tangent, because there are 2 crossovers again one tangent here remark at these 2 it is another tangent there remark at basically this will meet here only at this B end. So; that means, I have this is alpha plus liquid then there is a small range in which liquid is stable and then this is liquid plus alpha and only at B end alpha is stable. So, that is what it looks like there 2 common tangents between these 2 curves because 2 crossovers are there.

Now T 3 is very simple alpha is most stable. Therefore, I draw the alpha curves at the bottom liquid curve at the top alpha prime beta will be somewhere in between and beta. So, at T 4 that is what both alpha prime and beta are stable; that means, there has to be crossover between alpha prime and beta, but remember there will be 2 cross over because in this range alpha and alpha is stable. Then alpha prime beta is stable then again alpha is stable. So, that is why actually alpha will go through a very interesting things.

So, first let us finish that liquid. Liquid is here at the top no point of discussing on liquid because this is at the top. So, now, alpha will be very funny it will pass through such a kind of things. Because it is unstable it is undergoing a transformation from alpha to beta plus alpha prime. So, in the left side is it is a equilibrium with alpha prime and beta. So, therefore, alpha prime and beta will be coming like this.

Let us draw for the alpha prime yes alpha is stable alpha prime. And this is alpha and beta will also be stable somewhere. So, there will be crossover beta. So, I can draw several common tangents. So; obviously, most important common tangent between alpha and beta and there is a common tangent between alpha sorry alpha prime and beta. So, this is beta and there is a common tangent between alpha and alpha prime. So, this will be something like this.

So, you can clearly see this is where the alpha is stable. And this is where alpha plus beta prime alpha prime beta is stable alpha is stable. And again this side alpha beyond this alpha is stable. So, that is why it stays large compositional range alpha plus beta prime is stable. Why the alpha curve goes through such a kind of behavior because alpha is have skating undergoing transformation known as phase separation. So; that means, in this region the alpha has a alpha has it is free energy curves such a kind of steps; that means, there delta h values are much higher.

Please go back to the discussion on the quasi chemical theory, where we have discussed that for a set of parameters the free energy curve of a particular phase can show miscibility gap and this what it is showing. So, miscibility gap alpha is clear this part is little bit complicated because of the so many cross overs the free energy curves, but important thing is you must remember that it is this free energy of alpha which is behaving in a different manner is no longer looks like a typical inverted parabola, but it is it is initially starting at a parabola. Then it goes high very peak and again goes back and this is signature of any kind of phase separations, whether it is a phase separations in the free energy compositions or any other phase separations.

Obviously, this will all come back as a part of our exercise in whenever we do that. So, the next 8 minutes, whatever I have in this lecture let me just show you what will happen to eutectic; obviously, this is little complex, but let me show you eutectic which is much more simple the reason I show you the very complex thing is that. So, that you are used to draw that even phase free energy composition diagrams of the systemic complexity.

Now, let us look at the eutectic which all of all of you know eutectic is a reactions therefore, it reactions can has to be represented by horizontal line in the phase diagram.

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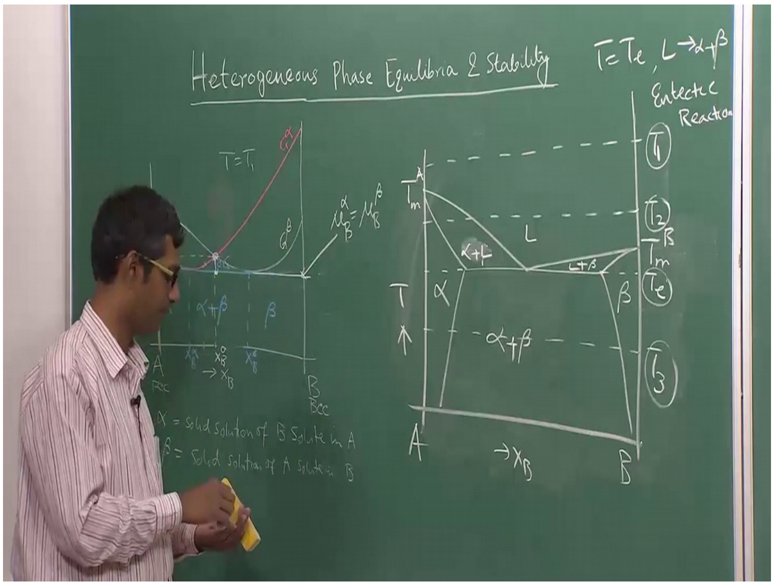

Simple eutectic system with 2 solid solutions alpha and beta and with a eutectic reaction liquid going to alpha plus beta; this is alpha plus beta sorry this is alpha plus liquid not beta liquid plus beta. So, these are all this is the simple possible phase diagram this melting Temperature a melting Temperature of B to make things is very simple

Let us draw the Temperature at which we will draw it. We will draw at all the at free Temperature, this is the eutectic pressure it has the reaction at the eutectic Temperature that T equal to we have liquid going to alpha plus beta. This is what is known as eutectic reaction and then will draw it at T 3. So, we are going to draw at T 1 T 2 Te and T 3 others you can try and do yourself solve your 4 Temperatures.

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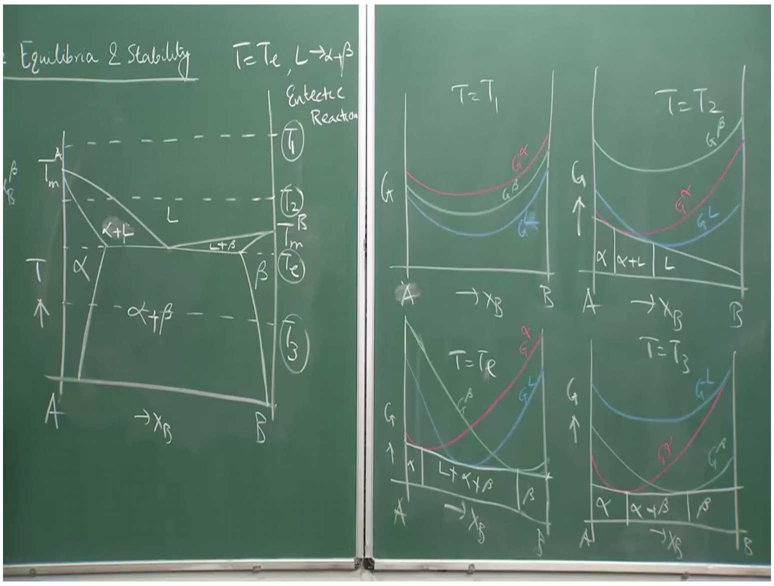

G versus composition at T equal to T 1 T 2 T 3 sorry T e that is a Te and at T 3 fine.

So, in order to explain you in details in an eutectic reaction, you can have many types of eutectic phase diagram, but this is more general and it is you know more generic in the sense that you have a solid solutions at the a rich end alpha solutions at the B rich end beta because alpha can have some amount of B into a beta has some amount of A in B and this solid solubility drops as function of Temperature is in (Refer Time: 14:43). This is solvus then this goes down and the function of Temperature and in between you have a eutectic reaction, this reaction tells you the liquid is stable till that Temperature Te, but below that Temperature Te liquid undergoes a transformations leading to formation of alpha and beta at together simultaneously. And that is what is basically eutectic reaction.

Therefore, actually I have a 2 sets of no liquid plus alpha, liquid plus beta, 2 regime we can actually think of this curve is nothing, but super impositions of 2 isomorphic system this is one that is another one which I will show you at the end.

So, let us now draw the free energy composition diagrams. There are you can see there are 3 phases here liquid alpha and beta. So, I must have 3 plots in each of these Temperature. So, first at T 1 liquid is stable. So, therefore, it very easy this is liquid. And I draw alpha at higher, basically it should be beta. So, alpha and then beta sorry this is liquid. So, at all compositions liquid, free energy can be settle lower position. Therefore, it is more stable at T 2 you can clearly see alpha is stable for some range. Then alpha plus liquid then liquid; that means, there is a crossover between alpha, alpha and liquid free energy curves while beta will remain at the top.

So, I first draw beta curve correct. And then I draw alpha. And I draw the liquid it will be a crossover; obviously, because alpha and liquid are stable at certain composition range you can see here. So, then whenever crossover I draw a common tangent between them very clear. There is no point of discussing again and again same thing liquid has lower positions between alpha is low and between liquid plus alpha is stable at the eutectic Temperature both liquid and alpha and beta 3 phases are stable at that Temperature. Therefore, they will be having a common tangents. How it is possible? Let us do that.

So, first I draw the alpha, sorry first I draw the, we should write down alpha and liquid otherwise you will not be able to follow clearly. So, first I draw the alpha. As you see alpha is stable here beta is stable there at this positions. So, therefore, there will be a cross over between alpha and liquid here. Crossover between beta and liquid there and beta n at the end this entire all of 3 curves will be having common tangent. So, alpha beta and liquid this is G l.

So, as you see here there is a common tangent between 3 sorry common tangent between 3. So, that Tells me that alpha is stable here, beta is stable there, very clear. This alpha and beta at the lower positions and in between this liquid plus alpha plus beta are stable, because there is a common tangent between of the 3 curves. That is what we has at the eutectic Temperature these 3 phases must be stable. The 3 phases must be stable at the eutectic Temperature. That is very clear that is why all the 3 curves are actually having a common tangent. And that is why this free energy at the chemical potential of alpha in of A in alpha and liquid and beta will be equal here.

Similarly, chemical potential of B in alpha liquid and beta will be equal there at Temperatures T 3 again alpha is stable alpha plus beta and beta. So, therefore, crossover between alpha and beta phase diagrams will happen, liquid will go up alpha and beta and there is a there is a crossover; therefore, I need to draw a common tangent again. So, that is how actually it will look like for a simple eutectic system in 2 solid solution of (Refer Time: 23:38) presents.

And as the common thing you have learned from this is that, if I have to understand the stability of the multiple phases we have to look at the crossover. So, the free energy curves and a then draw a common tangent. That is the basic message a clear basic message you will get from all the discussion from this lecture.

And the last lecture and I have that is why I have not removed this particular diagram because this is where the basis of whole discussions starts. And we could use this one to explain all kinds of phase diagrams and phase transformations. The reason I am drawing all these curves again I will draw some more in the next class also, and you can go on then move on to show you that this aspects actually is a vital in understanding phase diagram and phase transformations.

So, let us stop here, and then we will move ahead in the next lecture.