Phase Diagrams in Material Science Engineering
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Lecture – 49
Ternary Three Phase Equilibria

In this lecture, I am going to primarily focus on three phase equilibrium for the ternary system. Before that let me just tell you about these variation of the isomorphous ternary phase diagram. You know there are many ternary phase diagrams where liquid phase undergoes phase operation just like a monotectic reaction. In a monotectic phase diagrams, you know liquid phase undergoes separation from 1 liquid to 2 liquids, same thing is also possible here correct and two such variations I am going to discuss, one is that in which on the binaries suppose A B for it liquid undergoes a phase operation and because of that there is a maximum in the you see here.

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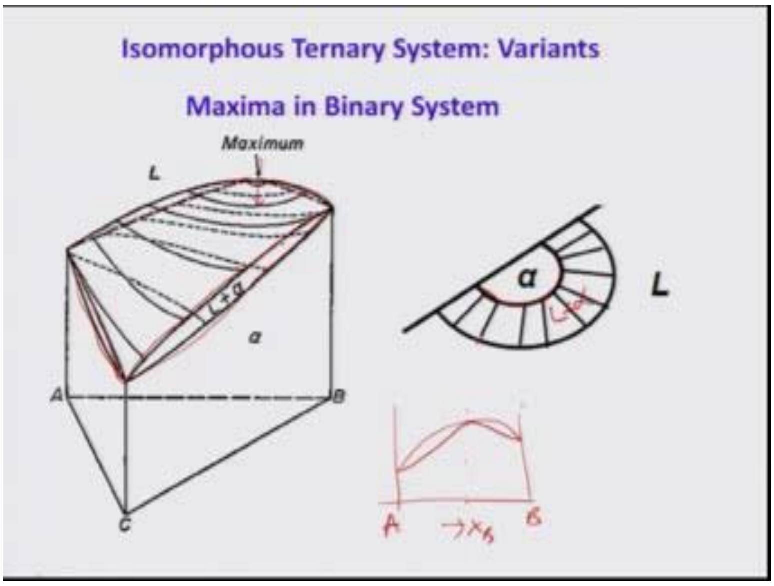

These are the two, let me just tell you both the ends for the A C and B C, here A C is having the second length separate phase diagram; one is like these and other one is like that and B C is also like this, but only A C shows a maximum what is that? It is this is like this and it margins here and then in moves correct.

So, basically this is congruent melting liquid not a separation in liquid state, whatever I told you that is not correct. So, what is the way is basically if I say if I draw A B phase diagram binary this will be like this correct. So, this is what I am talking about if I have maximum you know point in the A B binary like this then how it will look like this phase diagram will look like this a ternary space model and if I project it, this will be like this alpha and then liquid and this is alpha plus liquid. So, these are the tie lines possible at a temperature, if I project it from the top actually if I project this liquidus surfaces; liquidus and solidus surfaces will look like this. Now, this is one variation which is same.

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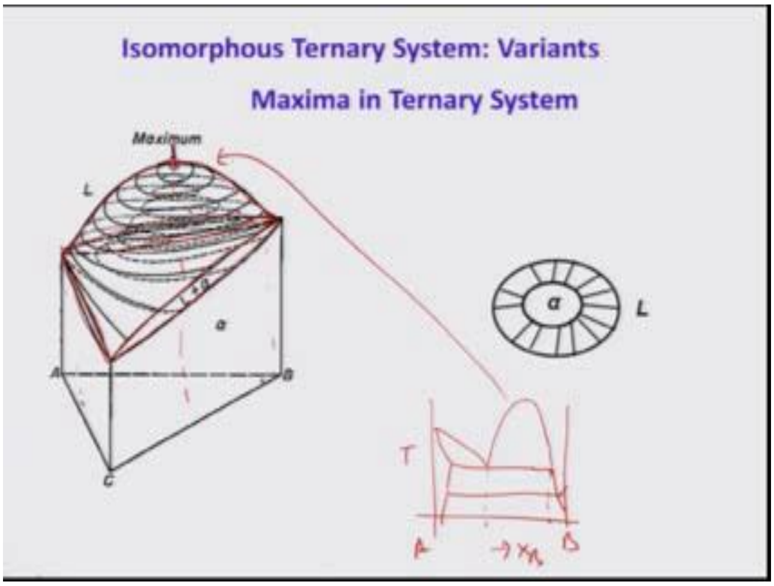

Second variation is that I can also have, you know situation like this which I was telling to you all the 3 binaries will be isomorphous type like this. This is one isomorphous, this is another isomorphous and third one is also shown as isomorphous, but inside the ternary, means inside the ternary triangle the liquid actually has develops is invisibility gap and this was of that as a dome in a monotective system. You have seen right, there is a dome like this correct. This is the dome in monotective system we have seen. So, inside of that this particular thing is present in the ternary system. Therefore, this surface has a maximum point like this and it slopes down. This is seen basically nature of invisibility.

So, invisibility exists over a composition domain like this invisibility exists. Similarly, you have invisibility exist from this part to this part composition. We can see here exist we are not discussing in details about that because these are out of see domain of this of this course, but these things are already there in the books, if any interested reader wants to know they can discuss, they can read it and understand it carefully. Now, I am going to move in to the section which is important what is known as the ternary 3 phase equilibrium.

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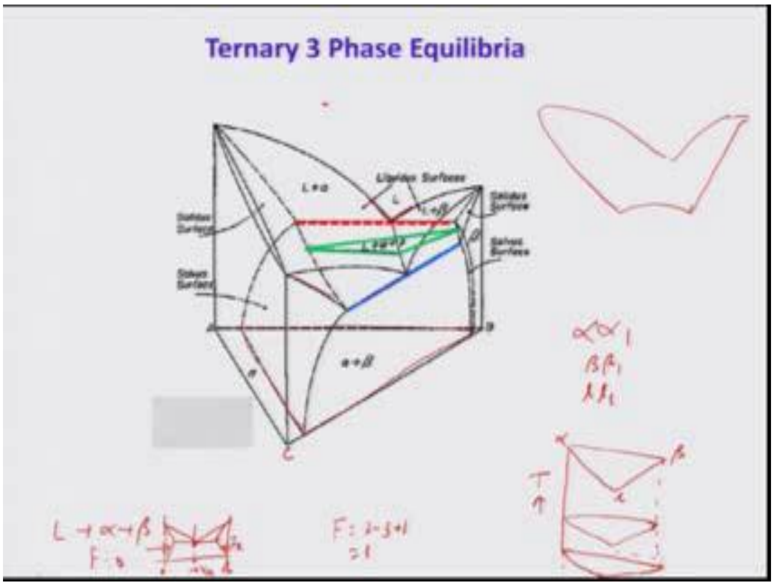

Now, in a binary system what is a meaning of 3 phase, you know 3 phases can a binary system when the degrees of freedom is 0 like in a eutectic. In a binary system we have eutectic liquid going to alpha plus beta 3 phases can I go exist in a eutectic diagram or a peritectic or a syntactic or a montectic and this is represented by the horizontal line the parallel to the composition axis. We represented or I say horizontal line this is a eutectic temperature here.

Now, this thing using feature in ternary phase equilibrium is that because it is in a ternary system this is F equal to 0 in a ternary system, P is equal to 3 minus 3 plus 1 that is equal to 1. So, F is mono variant system, if system is mono variants when it occurs over a temperature range it cannot be at a point, or cannot be at a fixed temperature in a binary system degrees of freedom is 0 because of that your temperature is fixed temperature, this is a composition, this is a temperature you cannot change you know this when ternary system you have one degrees freedom.

Let us suppose and that is why we say that this 2-3 phase equilibrium in a ternary system can occur in a temperature range understood that it occurs in a temperature range. Now, for any of these 3 phases any as a composition of the 3 phases vary with temperature; obviously, alpha liquid and beta will vary as a composition temperature. So, we can represent equilibrium by 3 curves is what one is alpha, alpha 1; remember one is alpha alpha 1, other one is beta beta 1 and I will explain you why at temperature T 3 phases alpha beta and liquid are L equilibrium. So, therefore, lines alpha beta alpha L and beta L will form a triangle correct it will form a triangle. How? Let us look at it this can be done like this, this is beta alpha liquid.

Now, as a temperature goes down we can represent the whole system like triangle, set of triangles I have drawn only 2. So, one can draw many, many of them. So, set of triangle, this is liquid, this is at the top and I thing let me just draw little bit better way. So, that is the idea so that means, what L B L is a tie triangle we can represent this whole thing by tie triangle now let me explain on from this space model. As you see here the space model has the everything here A, B, C and you have 2 binaries B C and A C has eutectic reactions, there is a binary eutectic there is a binary eutectic there you can clearly see know that is the eutectic point this is the another eutectic point here, but on the other hand A C has isomorphous binaries.

Therefore, in a binary eutectic system 3 phase, we draw a horizontal line to show 3 phase equilibrium correct here also between A C also a horizontal line red color. Now, in a ternary system, we show this equilibrium by tie triangle that is what is shown between liquid alpha and beta. Here, you can see here there is a tie triangle correct at these tie triangle actually moves goes over here this is what is a tie triangle and this is therefore, the whole equilibrium is discussed as a stack of tie triangle as you decrease the temperature, as you going down temperature the tie triangle is what I showed you. So, therefore, if I, what is my temperature and this is how, the tie triangles will keep on changing.

Basically what will happen the composition changes, composition with 3 phase will keep on changing as the temperature tie triangle positions of the each tie triangle will also change. This much is very important for you to understand, I think that is needs to be very, very clearly understandable, otherwise whatever I am going to discuss complex steps will not be clear to you. So, that is why I am going to do in a board.

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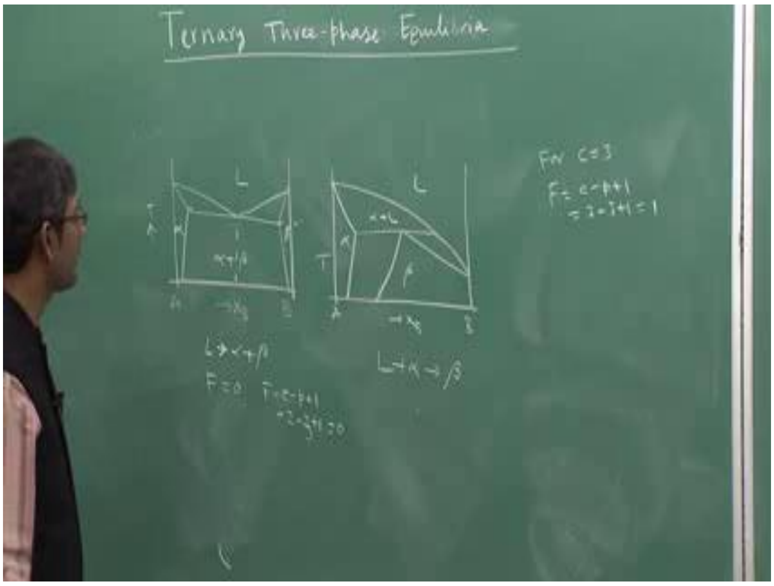

So, what I am going to say is that in a binary very carefully try to understand in a binary 3 phase equilibrium temperature is represented by a tie line by a horizontal line. This is for eutectic, sorry peritectic one can actually draw that. So, both the cases the 3 phase equilibrium liquid going to alpha plus plus beta, here liquid plus alpha going to beta here and represented by a horizontal line parallel to the x-axis that is what it done, but in a ternary system you cannot do that why because in ternary system the reason we can do this in a binary system is because F is equal to 0, why because F is equal to C minus P plus 1, C is 2, P is 2 1 sorry C is 3 that is equal to 0 correct 3 phases, but in a ternary system for a ternary system for C is equal 3, F is equal to C minus P plus 1.

So, 3 minus 3 plus 1 that is equal to 1 is a bio mono variant system that is why you cannot do it because this F equal to 0 this point and this temperature are fixed here that is why, but there it is not fixed. Therefore, the whole thing will have to take over a temperature the temperature this 3 phase equilibrium will be taking place over a temperature range not at a fixed temperature like a binary. So, how do you represent that that is what is the most important thing I need to discuss with you that can be represent simply by a tie triangle.

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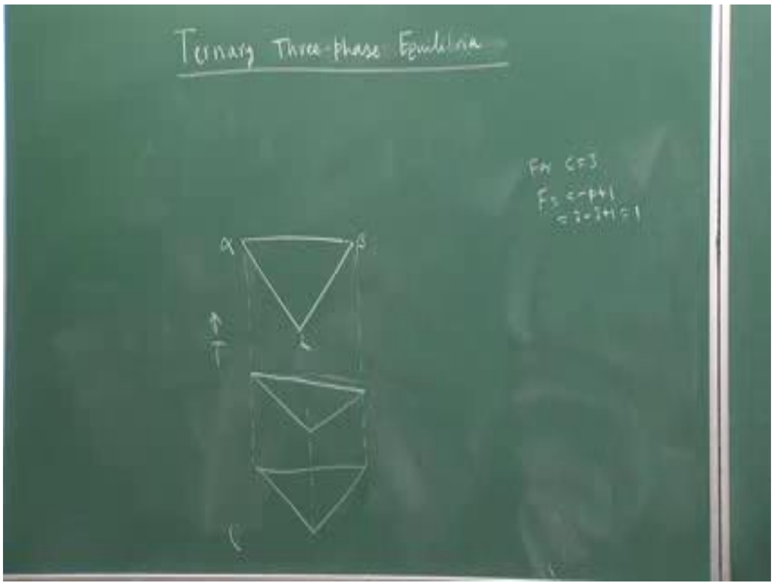

This is the tie triangle at a temperature T, T equal to T 1. Now, I can represent the whole thing correct in a series of tie triangle, series of tie triangle like that; obviously, I am the way I have drawn. So, this is the function of temperature the way I have drawn is that all the tie triangles looks like similar, they may not be they may have different steps different steps in not in different steps different sizes; obviously, the one which will by sitting at the bottom can have larger size.

Now, let us get back to this phase diagram hopefully you have understood this part in this phase diagram I am saying that I am going to represent these whole thing feature as this alpha beta liquid plus alpha plus beta tie triangles correct. So, you see here the liquidus surface is much complex here by compared to the isomorphous system liqudus surface is shown here, written here. This is the liquidus surface is very, very complex is on the left side it is same, but on the right side it is like this on this side. It is very, very different I have to draw it little bit more is like that in a isomorphous system it was like this surface.

So, completely different liquidus surface correct similarly solidus surface will have like quite to be difference. As you see simply going for 2 phase equilibria 3 phase equilibria the whole three dimensional construction gets quite a bit changed and one is to really look at this. Secondly, we need to also look at the solver surfaces what are the solvers in a binary you have solvers. These are the solvers, what does the solvers, what do the solvers tell about you they tell you how the composition of alpha and beta phases changes at a function of temperature.

Similarly, here also they are going down as you see here that means, as a temperature decreases beta is becoming more rich and rich B alpha is becoming more and more rich in A or C. So, if that is what is a avid evident. So, that is why the triangle will expand as I showed you one triangle at top, one triangle at bottom I am showing you triangle has expanded it is becoming bigger and bigger. Therefore, these are the construction can be represented by this.

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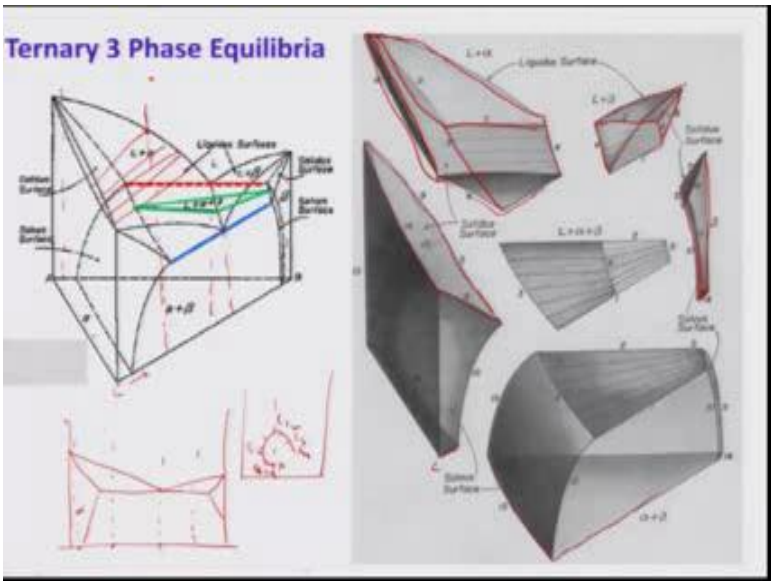

There are many such things, let me just show you this three dimensional features today. So, three dimensional features are like this I am just going to show you this zone first alpha if you see here alpha alpha has this much of C this much of B rather this much of B this is C and and then it goes like that correct. Similarly, this is goes like that then it is iso it is coming isomorphous.

And finally, it is meeting there this is one geometry; this is the alpha phase field binary alpha field, what is the primary beta phase field? This is also like this part I have drawn this part and it will like this again going down here triangle correct that is how it will look like, they have two primary phase field very easily detectable. Now, alpha plus beta phase field is basically like extended triangle you see here this is triangle little bit not a triangle, it is a trapezoidal little bit. This is what at the room temperature as you go alone this and these are the tie lines draw in a one surface correct this is all 2 phase regions.

What are the other 2 phase regions liquid plus alpha, liquid plus alpha, liquid plus beta, liquid plus alpha, liquid plus alpha is like this. This is a again a trapezoid, you can see here this is what is the triangle trapezoid and the easiest one is liquid plus beta, this is again I do not know what is the shape can be called, it meets at the center this look like a pyramid correct so, but liquid plus alpha plus beta that is what is a more important it is like a lot of triangles, correct. All the triangles are shown here exactly the way I have drawn in this picture. So, these are the three different the these are the different phase you know, one is single phase alpha and beta second one is 2 phase liquid plus alpha and liquid plus beta alpha plus beta and liquid plus alpha plus beta is consisting of these triangles correct and again I am showing you.

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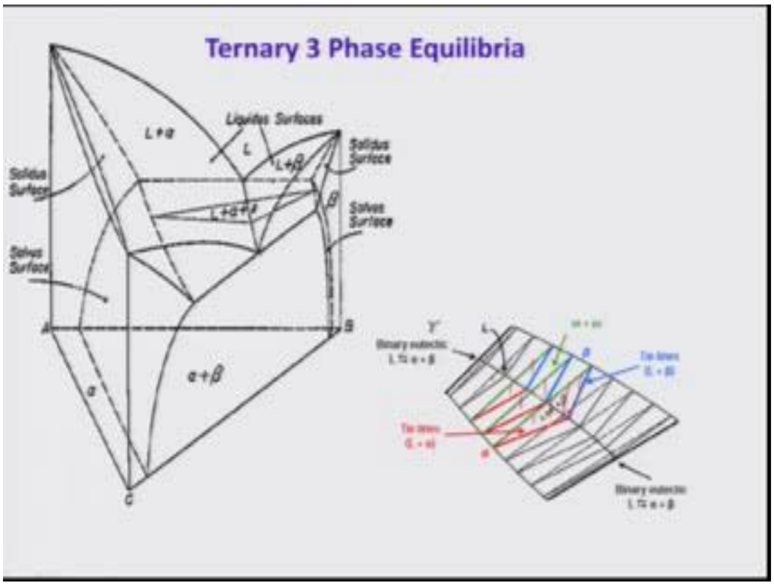

You can see here that these are for the binary eutectic on the alpha plus beta alpha plus beta here and this is for the tie lines correspond to that. So, this is the whole triangle shown here from top to bottom. So, one can actually draw tie lines inside I will show that am I clear I hope this construction is understandability.

Now, one can actually show one can actually discuss even, sorry one can actually discuss even the solidification of these, but I am not going to doing it today, I am just going to discuss with you how the thing things can be can be come soon. So, solidification of these alloys there will be 1, 2, 3 three different types of alloys for which you have discuss solidification; one which composition will lie well inside the alpha or beta thing that will be same as what I discuss with isomorphous system. Well, let me just tell you the binary then it will be clear to you in a binary.

Normally, you can discus three different types of alloys. So, one is this other one is this and third one is this or this. So, what are these called? This is eutectic, these are hypora hyper eutectic and this is well inside this alpha this phase same thing here, can be done. So, we can discus alloy composition with same as eutectic one of the eutectics. We can discusses with the alloy composition little alloy from the eutectic, but well in within the two phase region and third one is; obviously, same as I told you just now for this within the alpha. So, your alloy composition given by this or another one is given by this and third one is a given by this or this.

But, well inside the tie triangle not on the binaries, there are different ways one can discuss. The first one which is what the same as isomorphous is basically for the alpha or beta phase will which I am going to will not discuss for the alloy composition with eutectic. Well, the solidification actually depends on you know well which eutectic are considering; obviously, with is the 3 phase liquid 3 phase solidification zone, but we are going to talk about only the two phase things, this one which is little bit higher from the solidification here again.

Obviously, the liquid will hit then the comp alloy composition will hit this liquidus surface and one can actually draw this is a liquidus and this is solidus. So, one can actually draw the solid. So, we can see here this is try tie line as slowly as the temperature goes down this is what will happen. Finally, as the temperature will reach this is solidification will be over correct. So, if I draw it on this position I am not shown you. So, this is my liquid. So, liquidus will be following like this and solidus will follow like that and it will solidify. So, again this is L, this is X. So, this is L 4, L 3, L 2, sorry S 4, S 3, S 2. This is S 3.

So, one can actually follow exactly this sequence and understand the solidification, but for the eutectic, it is not going to be the same which we are going to discuss in the next class in the detailed manner, but for the time being I request you to look at the different steps which I have shown you in the class today. This steps are basically vital for us to you know out the solidification path ways, understand these phase transformation behavior. So, there with that will take care of this rest of the part in the next class.