Phase Diagrams in Material Science Engineering
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Lecture - 53
Three Phase Equilibria

So, in the last lecture, I have discussed you with you about the solidification behaviour of an alloy, ternary alloy in which you have two eutectics, binary eutectics and one isomorphous system exists. And actually I use this as a model and I have been discussing with you for three phase equilibrium in ternary system using this model.

Now, you know there are many ternaries in three phase equilibrium possible, like you can have a peritectic reaction between or at least one of the binaries can have a peritectic reaction, other binary can have a eutectic, and third one can have an isomorphous or in fact, one of the binaries can have monotectic possible. But these reactions and also the equilibria are little bit more complex, so that is why I am not discussing. But one of the things which is a corollary of the things which I have discussed in the last three lectures is that you can have a binary ternary systems in which two of the binaries will be isomorphous and the third binary will form eutectic systems. So, the thing which I am trying to say you is like this.

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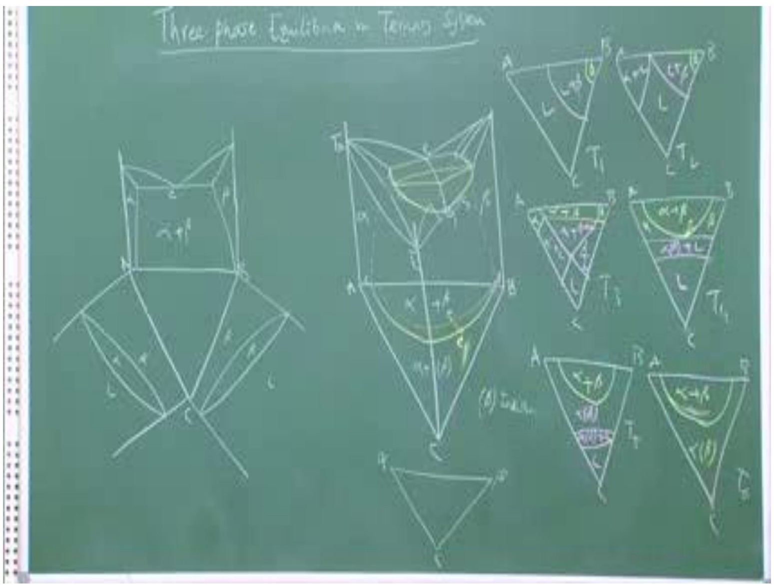

Suppose you have a ternary system like this in which you have three binaries and two of them form isomorphous system, one of them forms eutectic. I am talking about that. So, in this case, how the space model will look like and also how the isothermal sections will look like. So, as you see here this is alpha this is alpha-alpha, this is beta this is beta. So, and this is alpha plus beta. So, by looking at this diagram or this picture, you can understand that these two isomorphous, so they are miscible, they are miscible a and C are miscible in all compositions all concentration B and C are miscible in all concentrations both in liquid and solid state. So, there is no problem when I put them put A C and B C binaries together that is not an issue at all.

The problem is that what will happen to this eutectic whether the eutectic will expand in all concentrations ternary compositions or it will have a limited existence inside the ternary triangle that is what is the important aspects you have to realize. The point I am trying to make is that what is the extent to reach the eutectic will solubility gap between alpha and beta will extend inside this ternary triangle in the ternary composition that is what is the important thing.

Well, let me just draw this phase diagrams, first the space model. Space model is very important I am going to draw it then I will discuss further. So, space model is what you have been landing for me for the last five six lecture before drawing I like to tell you that it is always easy if you can draw the space model and thing in three dimension, but it is not the case always. So, A and C will form a isomorphous system right t a and t C B and C also form isomorphous system, but I will not draw the whole thing fully, why because it will look nice. You can see many things. These are the two cuts pieces; it indicates that you have a isomorphous systems. Let us not draw it.

And between A and B you have a eutectic how to draw that obviously, like this correct so that is how it will look like. So, this is the eutectic point E and this is C, this is D, these are sitting on the binary remember that. Because each one is a binary we have just put these things up, we are taken these pieces up and made the diagram. The question is whenever this such a thing available to you the question you always ask is that how much inside this ternary triangle this gap or solubility between alpha and beta will exist. This is alpha and this is beta. Well, it is it has been observed that because of the addition of these t third element C remember this eutectic is between A and B, so because of addition of the third element C eutectic temperature will go down quite a bit, it will not go up.

One point I will have to tell you in ternaries or in quaternaries whatever, whenever you add a third or fourth element normally the binary eutectic temperature will go down. It is just like a Gauss law or whatever. So, here also eutectic temperature will go down and this will be like this. This is e 1 it will go down till e 1. Why it will go down remember e is sitting on the binary, this is a binary composition e 1 is sitting inside the ternary somewhat there or similarly to this composition.

Now, one can actually draw these things these triangles to show or let us draw it by yellow chalk. What I meant to say is that it can have this triangle. What is this triangle mean let me draw it extends little larger way. I have drawn the triangle in such way that one of the corner of the triangle is sitting on the e, e 1 line remember this is the binary sector, this is the extension of the binary eutectic inside the ternary. So, this is what is the liquidus surface is changing the slope it is going down it is just like a heal it was just like a heal it is going down.

So, this is the liquid composition L, this is the alpha composition, this is beta composition. So, you can clearly see that three phase equilibrium can be represented by this triangle again so that is the critical feature of the ternary phase diagrams that means, three phase equilibrium this will be given by triangle. Now this is the third triangle. So, one can draw many such right triangles. In fact, one can actually take this things little bit this of way I think I have made a small mistake things are ok and I have just made a small mistake to connect these points. This will be green chalk is better otherwise you would not see it. Then what will happen this one will meet here.

So, what is that mean the solubility difference between alpha and beta are extending just like this that is how it can be drawn if I project this thing? So, what is happening that if I adding C element into the binary A B, this is how the liquidus surface is going down and it is reaching a minimum point e 1 at which the eutectic is done or rather alpha and beta phases can be differentiated. Beyond e 1 look it is alpha and beta phases are indistinguishable. Why because they are composition and things are not differing much that is why. So, beyond e 1, you cannot have basically it is goes little bit up also. So, one can actually draw it comes down and goes up this C 1 here. So, C 1 is the critical point I will explain what is the meaning of C 1 is the critical point at which this is e 1.

So, this will be so if I draw it this way many such things. So, it is such like that e 1 c 1 pretty this clear. So, basically what does it mean it means that liquidus temperature going in going down and at a temperature corresponds to e 1; e 1 is same at c 1 actually let me tell you. There is a (Refer Time: 10:32) of compositions beyond e 1, some zone is exist where alpha and beta are distinguishable, but beyond C one the composition more than C one or above this side alpha beta is indistinguishable. So, one can actually write down this is like this, this is alpha plus beta, and this is alpha plus beta, but this beta is indistinguishable that is what. So, what does mean this beta is indistinguishable between from alpha that is the point you must try to remember.

Now, let me just try to draw the isothermal sections it think it is possible to draw it here one by one. This is at temperature T 1; at T 1 we have only obviously, you will have beta, beta is the highest melting or B is the highest melting elements beta and then you have liquid plus alpha liquid plus beta sorry a liquid. And at lower temperature this is t 1, at T 2, it will be like this. Liquid, liquid plus beta, alpha plus liquid, it will extend till further lot temperature a BC. This will be little bit here you are going to see this triangle whatever I have drawn here at the position this is the triangle which will exist and then you can actually connect these two points. So, this is alpha plus beta plus l and this is alpha plus L, liquid beta plus L and further half is alpha plus beta. So, this is at T 3.

T 4 will have similar things no it will be different that is what we are going to see this interesting thing that what I have drawn at the bottom and this will be like this then you have a zone like this. Now, this is the point C 1. So, therefore, this is alpha plus beta eutectic which is extended from the binary this is the ternary and this is alpha this is beta and this is the point C this is the point C not C one C right. And then we have a liquid alpha plus liquid sorry I should use the same colour alpha plus liquid. Actually one can write even better way because you cannot distinguish between alpha and beta because why you can write this whatever beta and alpha will form inside the liquid in between equilibrium with liquid will not be distinguishable from the alpha.

Same thing will propagate, so T 5 at temperature T 5 same thing will propagate. This is alpha plus beta, and here this is liquid in indistinguishable alpha beta, and alpha, just like this. So, now, we have gone to low temperature. So, that C point it is below the C point. So, it is much lower this point C wherever it is sitting. And at still low temperature T 6 solidification will be over. And what will happen you will have a zone in which alpha beta eutectic will form beyond which only alpha will form. So, by looking at this isothermal section you can clearly understand what will happen to three-dimensional thing. So, only thing critically important is that because you are extending this eutectic point inside this ternary this triangle. So, therefore, this extension will lead to a point in which beyond which alpha and beta are indistinguishable you cannot distinguish them between because composition will be similar (Refer Time: 16:54) also will be similar nothing will be distinguishable, and that extends that moves on from these two, these two these points correct, so that is what will happen.

And as I told you this is the this feature triangular feature keeps on moving keeps on saying only at it is moving all these seen at this temperature beyond that you not more three phase equilibria exist. Basically this three phase equilibria is telling you that eutectic reaction is taking place here beyond which there is not much eutectic reaction only alpha or whatever alpha or beta which are both are the indistinguishable from each other precipitating out from the liquid.

So, this is one of the variations of the phase diagrams compared to the one I have been I have taken as a model and discussed. This is also important in the sense that this is more frequently observed as I told you the important systems like what bismuth, antimony and lead, no this is not bismuth, antimony, lead will be having the system which I discussed. Bismuth antimony forms isomorphous systems bismuth lead form eutectic, lead antimony form eutectic, but such a kind of system do exist I am not able to remember right now. I can tell you later on such a kind of systems actually are existing many metals systems will show this kind of behaviour. So, now let us so that is about the three phase equilibria.

So, in the subsequent lecture, I am going to discuss with you about the four phase equilibria. And I think I let me tell you the whole plan for the lectures which I am going to take. From next week onwards, we are going to see, but not next week there are about ten more lectures which are going to see in this course; obviously, because I have finished the single phase equilibria for ternary, three phase equilibria two phase equilibria for ternary three phase equilibria for ternary. Now, I am going to also discuss about four phase equilibria for ternary. And then I am going to say you tell you about some important ternary system like stainless steels and some of the ceramic systems also and that is how we wind up in the whole course. And we will have end semester exams or the final exams are on 24th of this April or so second of May, no not second May, 24th and 31st of April. So, you will you will get a one week time to study we will we will not have any lectures on these assignments that is how I have planned.

So, in the four phase equilibria as you know four phase means what in a ternary system four phase equilibrium means is a invariant point because; obviously, because in a ternary system we have three components. So, maximum number of phases we can coexist in a three compounds system is four (Refer Time: 20:10) to the Gibbs phase rule correct. So, what are these four phase equilibria.

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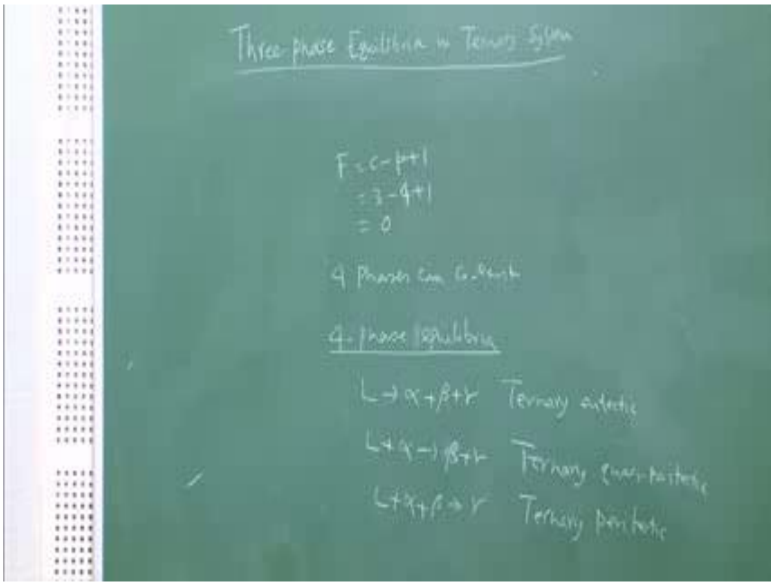

So, maximum number of systems maximum number of phases is basically 3 minus 3 plus 1 sorry 4 plus 1 is equal to 0. So maximum four phases can coexist in a ternary system. As suppose to three phase in a binary systems. So, four phase equilibria means what that situations where this four phases are in under equilibrium. So, there are actually if I concentrate only liquid solid system there are actually three important reactions, one is this one what is known as ternary eutectic, other one is ternary quasi peritectic alpha plus liquid going to beta plus gamma and last one is the peritectic. So, there are three different four phase equilibrium systems can exist. This is the straight forward this is the ternary eutectic. To give you example aluminium copper silicon forms a ternary eutectic alpha aluminium silicon and Al 2 Cu. This is a very, very complex type of things neither a peritectic reaction nor a any other thing this is looks like quasi peritectic reaction. And most over cases is this is case by passed there are situations this is a ternary peritectic reaction it occurs in some other systems.

In the subsequent lecture, I am going to concentrate mostly on this ternary eutectic system not only because it is observed frequently, but also it is easy who are the students to understand. I will give you some light on these or these, they are also important, but we will not go in detail of these four reactions. This is this will be the most important reaction which I am going to discuss.

As you know it is obviously, if you want to have a ternary eutectic systems, either you need to have all the three binaries to have eutectics then you have a ternary eutectic inside it or two binary ternary eutectic and third one will have some other reaction like peritectic or types. But we are going to take simplest one that is we are going to construct three binaries in which all of them has binary eutectic between themselves like AB, BC and C has binary eutectics. And we will discuss so that is what is the plan for the next 4 or 5 lectures.