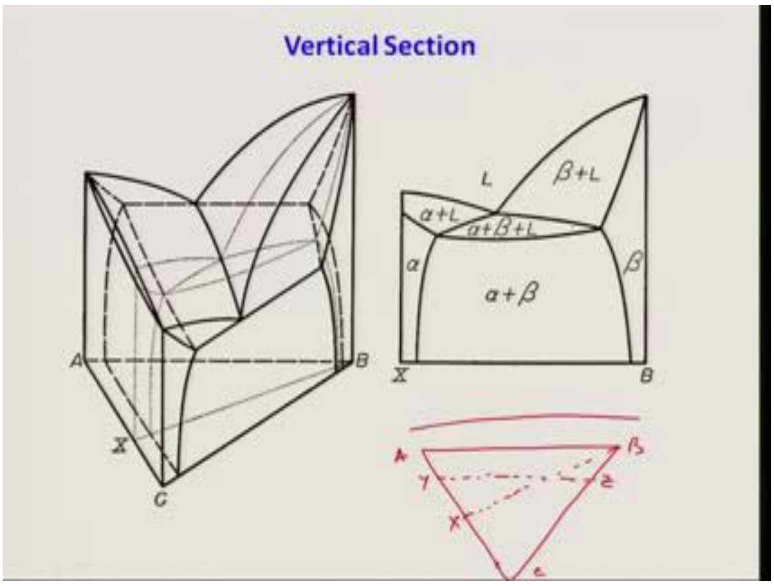
Phase Diagrams in Material Science Engineering
Prof. Krishanu Biswas
Department of Material science and Engineering
Indian Institute of Technology, Kanpur

Lecture – 51
Three Phase Equilibria in Ternary Systems-II

So, we are now going to discuss about the vertical sections of those that type of phase diagram which I have just discussed you in the last class. So, to rewind you again I am actually discussing generic phase diagram in which two binaries forms eutectic and one of the binaries form isomorphous types of phase diagrams the space model I have discussed with you already. Now, I am going to talk about vertical sections then followed by isothermal sections and then finally, solidification if time permits. As you know vertical sections are basically sections taken along the vertical direction that is on the z-directions.

(Refer Slide Time: 01:01)

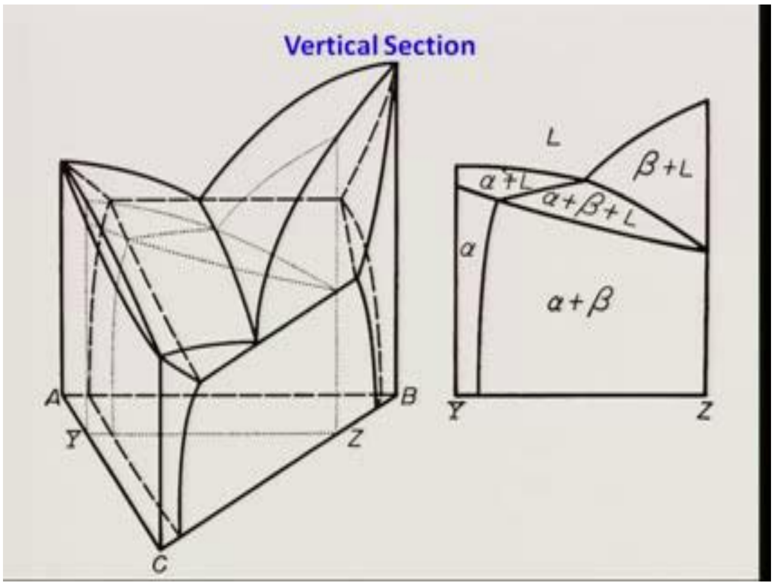


The way we take vertical sections are basically normally two one is from one of the ends of the Gibbs triangle to the opposite side just like B X or X B; other one is line parallel to one of the sides here I have drawn line parallel to A B side which is Y Z correct. So, now, let us look at it here and try to concentrate on this diagram. This is your ternary space model, the solid lines; solid lines on the solid even dotted lines which are very, very thick they are actually part of this ternary things. In fact, you can very clearly see here how the alpha, beta phase field looks like very nicely you can see here. You have to imagine little bit. Now, I am taking as vertical sections along B X. So, I do I take a basically a rectangle along b x and cut the whole phase diagram.

So, what I will do I will cut it along this along that along that this. So, you have a alpha this is the alpha then you have alpha plus liquid because liquid as a top then these part alpha plus beta plus liquid and these vertical section is beta plus liquid and beta right side is very easy to understand because you are supposed to you know the binaries very well, it is very easy to understand.

So, beta and beta plus liquid is there on the right side, but on the left side what do we have is the alpha that is also easy to understand, but alpha plus liquid and beta plus alpha plus liquid is what is difficult to you can see three dimensionally three-dimensional from the three dimensional picture see basically it curves because you have a three phase equilibrium at the centre or inside the ternary triangle and that will be triangular shape and that is what is a triangular shape you can see here. So, that is what you should remember the triangular shapes of the three phase equilibrium will remain in a over the vertical sections are isothermal sections I have drawn correct this is the first important conclusion difference between the vertical sections you have drawn for the isomorphous systems for the isomorphous system we have basically a lengths or a cut lengths on the both ends that is what, but here it is not that is completely different.

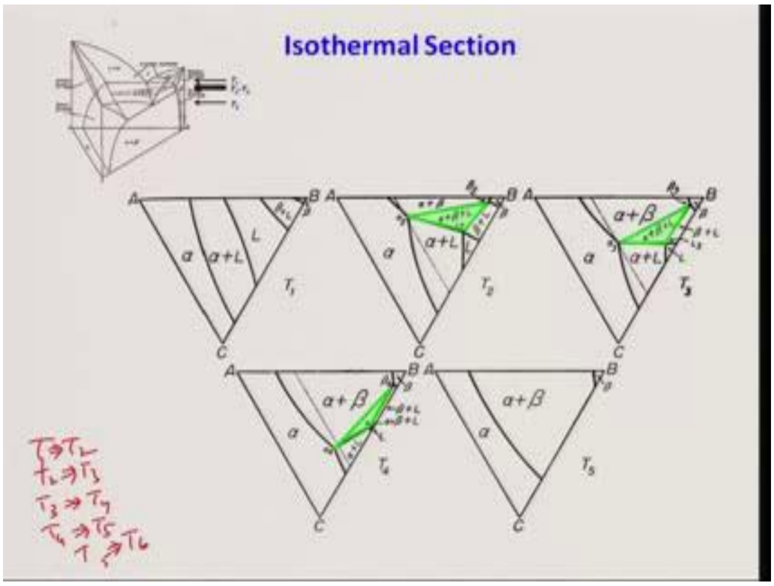
(Refer Slide Time: 03:19)



The next one let us see instead of that if I take a vertical sections along y z which is a line parallel to another sides of the Gibbs triangle that is A B, what I do I take a particle rectangle and cut the phase diagram. If I do that you can clearly see if I cut it will look like this is like that to generate alpha, the alpha plus liquid and here you generate beta plus liquid, no because it does not cut the beta. So, why there will be beta phase. And in the centre, we have a triangle called alpha plus beta plus liquid.

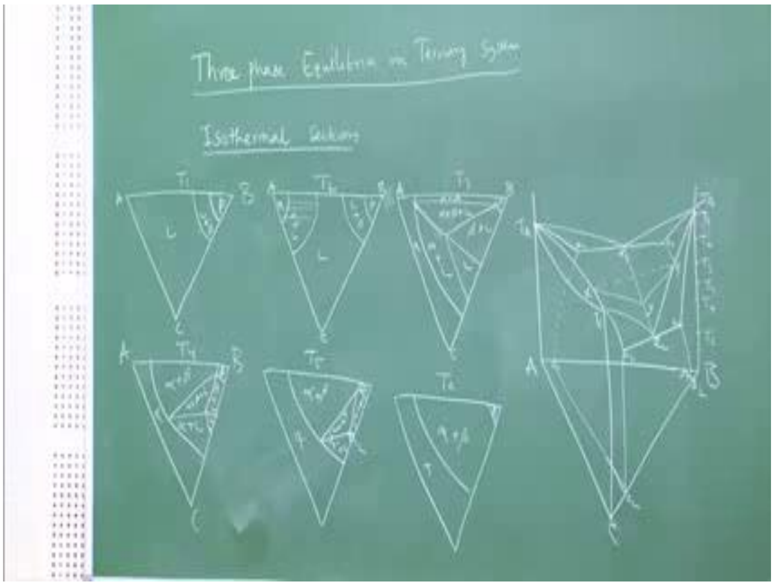
Remember here you cannot draw a tie lines, I told you right you cannot draw tie lines in the vertical sections because they are not connecting the two phase, you know boundaries of the two phases or three phase boundary is a two phases basically we are not connecting very simple. But one thing you have to remember very clearly even though it is a vertical sections you see from two phase we go to three phase single phase to two phase or three phase, this is what the transformation happens, single phase to two phase or three phase at the bottom we have a two phase regions. In fact, this one is more interesting we have single two single, single three double, single double single, single double and single phase distance that is how it looks like. So, this is not difficult right this is not really difficult to understand.

(Refer Slide Time: 04:48)



Now, let us look at isothermal sections. So, the way we draw isothermal sections are like that you know actually let me just draw it on the board and then I will come back to these things. I will draw it at six different temperatures and it is important that you will also practise a little bit things. So, I remove these part I draw the isothermal sections.

(Refer Slide Time: 05:17)



In fact I draw it on the board because this is much easier then drawing the vertical sections. So, we will take a isothermal sections at very high temperature suppose T 1, I am just drawing the temperatures T 1 and this is again T 2 T 3 T 4 T 5 and T 6 what we do normally we take a triangle which is same as horizontal triangle and put at these temperature wherever the triangle will cut this space model we draw. So, obviously, at T 1, it is very easy T 1 is very easy. T 1 will have only beta and beta plus liquid, because beta b has highest melting temperature you can see here B has the highest melting temperature T B.

So, therefore, this will be beta and then we have a very small zone liquid plus beta largest beta. This is the section at T 1. I told you this is very easy I do not need to discuss in detail. This is at T 2, temperature T 2 this is distinctly defined why because you are not only cutting these surfaces of liquidus circle, but also this side of liquidus surface. So, this will be leading to alpha also; C has a lowest melting temperature out of the three components. And as you know once you have single phase, you will have liquid plus beta, similarly you will have alpha plus beta liquid. The portion which is the series we have lot of liquid that is what it tells you correct.

So, let me just draw the next one here at T 3 at T 3 you are not only you are going to cut even the ternary section because you can see here T 3 is almost below the eutectic point of U 1 below the U 1 actually. So, because of that it will cut the ternary sections that is why the complex that is why the things will come, but what will happen it will have because it is lowered than this. So, it will have a large alpha zone alpha extended you will have beta and obviously, we will have alpha plus beta also, this is alpha plus beta.

And finally, we are going to have a triangular alpha plus beta plus liquid and liquid will remain still liquid will remain because we are above e 2. So, liquid will be there right because if the liquid will be there till e 2, below e 2 there will be no liquid because e 2 is the lowest melting eutectic out of these two so that is how this section will look. So, what we have we have a large alpha as you see here if you cut it T 3, you will have a large alpha zone this is what you see here this thing is almost similar to that, but little bit smaller. And you have also have alpha plus beta because you have this alpha beta thing will be represent and you have a beta at the end corner this corner and then three phase region followed by the liquid alpha plus l beta plus l this is a T 3.

Now, what happens at T 4? At T 4, you will have similar things all thing change will be change will be only that this region alpha plus beta plus liquid will be less prominent; alpha will be more extended more amount of alpha will be formed. And you have large zone of alpha plus beta alpha plus beta-beta solid is more. On the other hand, liquid is slowly vanishing, but if you clearly see liquid is remaining on the binary B and C and penetrating into the ternary correct that is what another important aspect because this is the lowest melting eutectic sitting on the BC side. So, that is the triangular (Refer Time: 11:14) three phase zone.

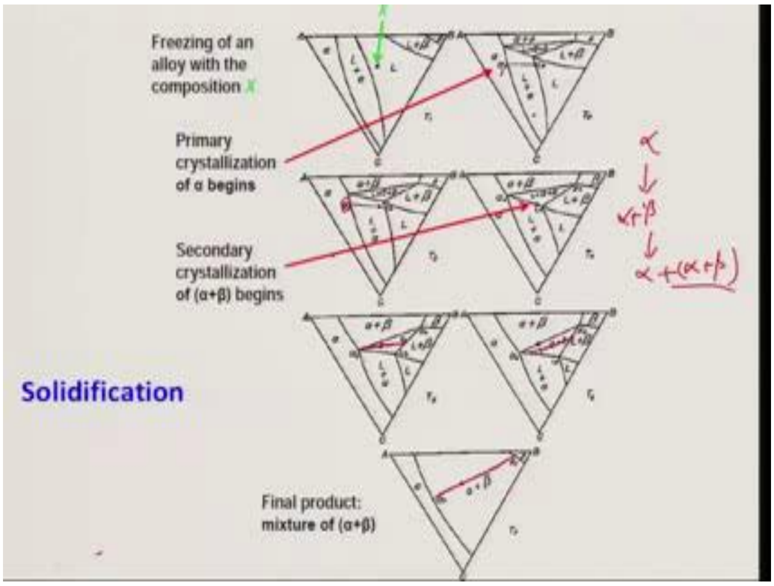
You could see this triangle actually getting slowly slowly smaller. So, that is you go down the temperature this will be becoming smaller as smaller next one is T 5, T 5 will have large chunk of alpha almost and beta will be small beta is small because beta zone is small here you can see here beta is basically small solid solubility of beta I know A and C solubility in B when the beta phase is very small that is what and then you have basically a small, small zone of liquid ternary phase a three phase zone is also small T 5 is also sitting above the e 2.

So, therefore, that will be liquid, but liquid is very small this is what is the liquid very small very small, you can see the liquid is slowly, slowly reducing. So, T 6 is one again very easy; at T 6, it is below the e 2, so that everything is solidified. So, it will have basically a large portion of alpha small beta and alpha plus beta; this has more similarity with this T 6 and T 1 has similarities. So, that is why actually this what do I say this isothermal sections look like. You have to you know although I am doing it very fast quite fast, you can actually imagine you can see it in front of this 3 d space model and imagine, but one thing is common in all this pictures the ternary phase zone sorry three phase zone alpha plus beta plus liquid it means a triangle this triangle has three corners; you can see here one sitting as alpha, one sitting as liquid, one sitting as beta.

Similarly, here also one sitting on alpha, one sitting on beta, one sitting on liquid, one sitting on alpha beta and liquid that is obvious because. So, therefore, I can actually draw here again tie lines between the binaries; in the binaries, you can draw tie lines very easily to all the binaries sorry all the two phase you can draw this tie lines correct. So, that is what is shown in this picture here very nicely drawn picture from the book very nicely picture has been drawn from the book. So, you can see here that this is the three phase zone, three phase zone, three phase zone. Now a liquid is quite higher, but here temperatures are less there are five temperatures instead of six I have shown you.

In fact, T 1 is lower; in T 1 you can see alpha plus liquid T 1 is same as a T 2 actually the T 2 is here the T 1 whatever I have shown in the board then T 2, T 3 is exactly same as what I have shown you see you have to basically replace T 1 with T 2, T 1 will become T 2, T 2 will become T 3, T 3 will become T 4, T 4 will become T 5, T 5 will become T 6 correct and you get turned to all this things very easily fine. So, that is basically about the isothermal sections and the vertical sections. Now, later me let me go into the let me start will carry over in next class also, how to think, how to you know follow the solidification parts of these alloys, little bit requires thinking process and also thinking in three d space model.

(Refer Slide Time: 15:36)



Let us suppose I have an alloy composition is given by x. And I have to see a solidification hard I will do well the initially alloy sitting on the initially alloy sitting on the liquid fully liquid. So, as you solidifies here as go to the next temperature you know this is T 2, T 1 and T 2 you see here liquid is it is in between liquid plus alpha. So, alpha will be forming because it is close to alpha. So, what is the way we do is that whatever is the closest phase field of solid field we connect the triangle. So, again this is the tie line. So, at 3, three more amount of alpha will form fine then finally, what happen finally, from there it will enter into the three phase field alpha plus liquid plus beta this is the point then you draw a tie line between alpha and like this, this is the tie line formed. So, finally, it is basically become a like this and finally, this is what is this.

So, what does it happen first it forms alpha then form beta, because it will form alpha plus beta actually eutectic and it will solidify it alpha plus alpha plus beta eutectic that is as usual because this is an alloy which is not falling on to the eutectic exile on the eutectic this is little bit of the eutectic composition that is why. Now, we will follow is that this is the point and it goes on this liquidus and the temperature goes down precipitating alpha with the composition of alpha 2 given; and then at T 3 more amount of alpha forms composition will be alpha 3; at T 4 it is moves into the from these liquidus line it moves into the three phase between the line between the two phase liquid plus alpha and liquid plus alpha plus beta.

So, point is that as it hits that point, it forms more amount of beta by eutectic reaction. So, eutectic precipitates responds more and more eutectic form more and more eutectic form finally, you have liquid alpha plus alpha is an dentride and the another one is the eutectic between alpha plus beta.

In the next class, I will just discuss the 3D space model and tell you how it will form. In fact, I need to draw you the 3D space model in the board that will take some time. So, before I begin the next class, I will draw that space model and show you how this solidification will take place.