Phase Diagrams in Material Science Engineering
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Lecture - 57
Phase Diagram of Ternary Eutectic with Terminal Solid Solution

So students, we have been discussing about ternary eutectic solidification behavior of ternary eutectic alloys. And I just told you that for a simple system in which there is no terminal solid solution solidification easy very easy to follow. So, today we are going to discuss about the phase diagram in which the terminal solid solutions do exist. And I told you that I am going to scan the pictures from the book of Alan prince and so you had discussed you here.

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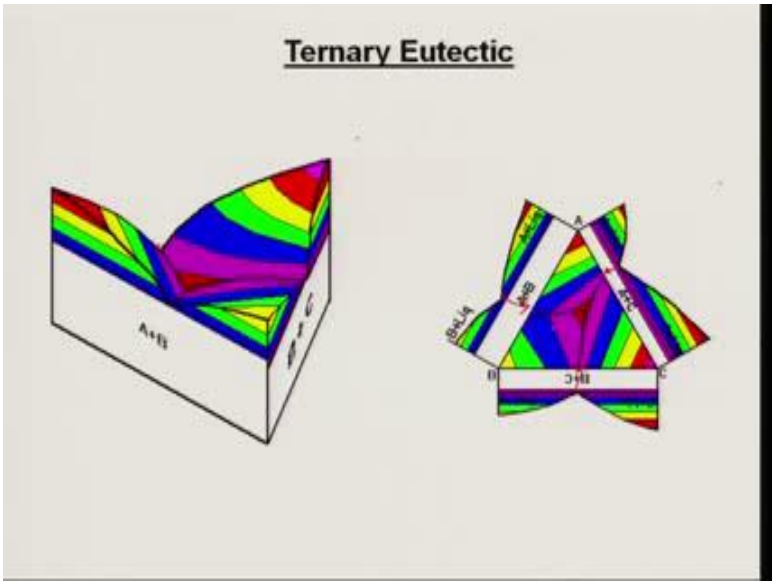

Before that let me just take a recap you know in ternary eutectic with no terminal solid solution, the phase diagram will look like very simple like this. You can clearly see here there are three (Refer Time: 01:04) eutectics; on the three binary sides. And finally, they lead to a ternary eutectic at the central. If I project it onto the Gibbs triangle they will look like this the three eutectics are marked by these red arrows, the central one is ternary eutectic which is sitting inside the triangle.

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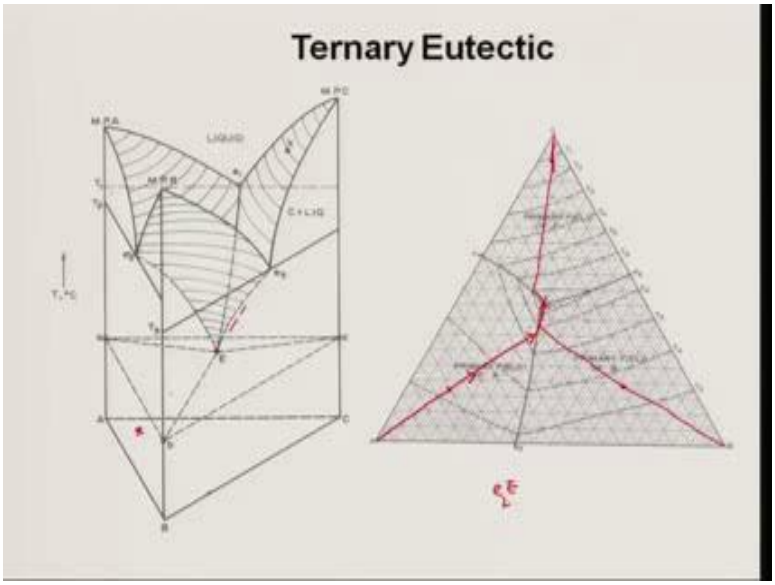

Now, one can easily see how a solidification will happen. Just by knowing the three-dimensional space model as well as also by using the projections on the Gibbs triangle. A three-dimensional space model as you can see here if I have any composition alloy a composition, which is sitting suppose on the primary phase field of A this corresponds to here the composition here, so very easy to form a solidification. How we are going do it I showed you that we can first join these points because this sitting inside the primary phase field of A with a point corner A.

And if I join this like this, then I extend this line further. So, if I extend this line that means, what from these points as the alloy is getting cool down, you are going to have more and more precipitation or crystallization of A. Finally, the crystallization A will continue till this red line here, it is meeting the curve on e, e 2 this curve. So, as it meets here you are going to have crystallization of both A as well as B carrying from the liquid. And finally, the solidification path is follow along with this path. So, therefore, this is going to be like this. Similarly, any other cases you can discuss, but you in ternary eutectic system, there are different set of alloys, which can undergo eutectic reactions.

Obviously, the most important alloy is having composition corresponding to point e and these alloy with correspond to composition e will undergo ternary eutectic reaction which is nothing, but liquid going to alpha plus beta plus gamma. There are other alloys also which can undergo these reactions, I want to give you some examples one is this one

which I have given. So, alloys which is sitting compositions which are falling on the primary phase fields of A I, A B or C will start crystallizing the component in which phase field it is sitting and then finally, it will lead to formation of the binary A plus B or B plus C or C plus eutectic. And at the end, we will have ternary eutectic A plus B plus C this is the category number 2.

So, category number 1 was composition corresponding to point T; and category number 2 is composition which is falling in the primary phase field. Category number 3 is the composition which is falling on these three eutectic points, binary eutectic sorry these three falling on these three curves actually e 2 e, e 3 e or e 2 e. As you can see if the composition falls on these three curves each of one of these three curve what will happen first it will crystallize both two components A or A and B in case of e 2; B and C in case e 3, and C and A in case e 1. And it will keep on crystallizing in these two components or these two phases ever A and B in case of binary A B e 2 and B and C in case of e 3 and C and a in case e 2, and finally, to release the point e where ternary eutectic will form.

So, there are three sets of alloy compositions which we have you seen. These all this alloy compositions will lead to formation of ternary eutectic, but obviously, there are other things will happen prior to the ternary eutectic reactions. In the first case, there will be nothing else with a composition falling on the point e and all it is ternary eutectic will form. The second case first A or C or C, any of these three component if you slice followed by the distillation of the two components together like A and B or B and C or C and A depending on which binary which points it is meeting, whether e 2 e, e 3 e or e 1 e. And finally, it will be it will be liquid will be final liquid solidify as a ternary eutectic. In third case from the beginning onwards if the liquid pulling up the liquid will lead to a distillation of both two phases A or B in case B 2; and B or C B and C in case e 3, C and A in case of e 1. So, these are the three important crystallization events I told you pathways.

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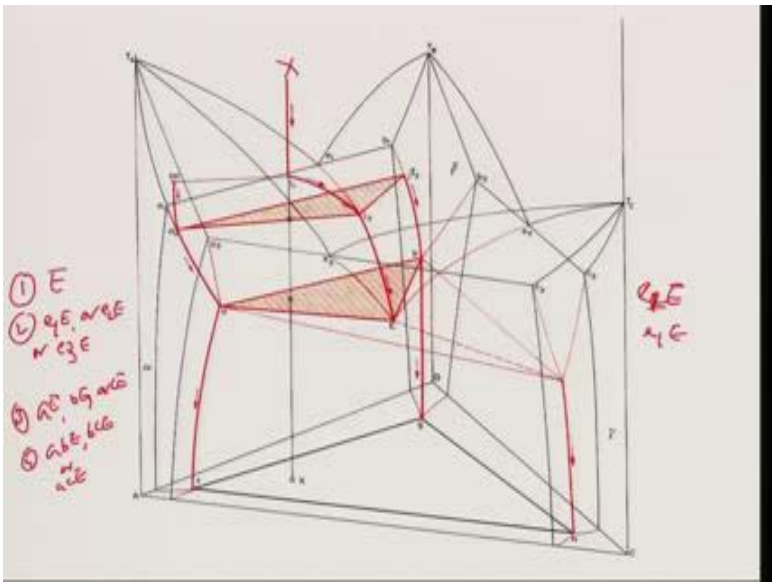

Now, let us look at the crystallization of the solidification of the alloys for eutectic system for a ternary eutectic system in which octagonal solid solution like alpha, beta, and beta is this side and gamma is present, beta is here, gamma is here present. In this case, there are actually four set of alloys which can undergo ternary eutectic reaction. Obviously, the first one is the alloy composition corresponding to point capital E. And this will lead formation only ternary eutectic between alpha plus beta plus gamma that is easy to understand.

Second one is alloy composition lying on the invariant mono variant rather liquid curves like u 1, u 1 e, u 1 e is this curves we can see red mark given or e 2, e 3 e or e 2 e. In all these things, what will happen first thing it will form is it will crystallize both alpha plus beta. Suppose, if I can take alloy composition corresponding to these curve e 1 e. So, as the alloy composition hit as it cooling down it will hit this surface. So, this will crystallize both alpha and beta finally, it will reach L 2; from L 2, it will move to E - capital E where it will crystallize both alpha plus beta all the things a alpha plus beta plus gamma. So, I let me write down the first composition which corresponds to e, second composition is corresponding to alloy composition lying on the mono variant curve e 1 e or e 2 e or e 3 e, any of this mono variant curves on which the composition lie.

Third one is that top. If the composition lies on the top of A E, A E is what A corresponding to this E corresponding to this. So, this is the top, you create a top here.

So, the one which is shown is basically the one which is lying on that. So, A E top or B E or C E, and fourth one is basically composition lying on a B E or B C E or a C E, the three any of these. So, there are four compositions which are which are important. The top two I have already discussed let us now discuss the three. So, one such composition is shown as a x x.

So, as you see here follow everything, which is shown as like a red arrows then it will easy to for you to understand. If you see here carefully as I cool it down the alloy things will start happening at point L 1 y. At L 1 this alloy composition will touch the liquidus surface which is going down this liquidus surface which is going down right liquidus surface which is going down will touch there. And therefore, it will start crystallizing alpha or composition alpha 1 you can see here correct. So, as it crystallizes alpha of alpha 1 composition and further cooling will lead to change of liquid composition along L 1 to L 2. And similarly solid composition will vary along alpha 1 to alpha 2. What will happen from cooling down from L 2 to L 2 or other temperature T 1 corresponds to L 1, temperature T 2 corresponds to L 2 is nothing but crystallize from more and more alpha and alpha will have different compositions along this curves, so like alpha 1 to alpha two.

But as soon as I reach L 2 this is hitting the curve or hitting the trace of e 1 e, you can see here this L 1, L 2 line or curve is meeting the turf or the or the value error e 1 small e 1 to capital E. Because it hit that valley this means that it has to crystallize both alpha and beta, so that is why I have shown I have drawn an triangle with compositions of alpha given by alpha 2, composition beta by 2 beta 2 and the liquid L 2 correct. So, this is three phase equilibrium between alpha 2 beta 2 and L 2. So, because you are cooling continuously cooling down, so therefore, from L 2 to above e, this will keep on crystallizing alpha and beta of different concentration; and the constant composition of alpha 2, alpha will vary from alpha 2 to small a beta will vary from beta two to small b correct these two things are shown here.

I hope you are following it and finally, once the composition is meeting at the four-phase equilibrium point e then the remaining liquid is solidify as a ternary eutectic. So, therefore, it is not a very difficult for you follow it up. Let me first reiterate it again. So, as I cool down the alloy from the high temperature nothing will happen above the point corresponding to L 1. And as it comes down to point L 1, this is going to meet the

liquidus surface; and because of that any drop in temperature further below L 1 will lead to crystallization of alpha composition of alpha 1 correct. And this one will continue this crystallization of alpha will continue till as a temperature goes down from T 1 to T 2 corresponding to point L 2 and liquid composition will change from L 1 to L 2 where the solid composition will change from alpha 1 to alpha 2.

Now, something new happens at point L 2, why because L 2 is a point corresponding which is sitting on the valley small e 1 and capital E these valley small e 1 capital E which this is the thing, let me write down again is sitting on that. So, because it is sitting on this this has to crystallize both alpha and beta because this is eutectic e 1 is a eutectic corresponding to binary of a B producing alpha plus beta. So, therefore, the valley connecting e 1 to e will produce both lead to crystallize from both alpha and beta. And here something will happen alpha 2 of alpha composition corresponding to alpha 2 beta corresponding to beta two will crystallize from liquid so that means, that you are going to have a three phase equilibrium between alpha 2 beta two and the liquid L 2 it form a triangle. And any three phase equilibrium is present by triangle we have seen.

So, further cooling from L 2 above E capital E lead to nothing but crystallize from more alpha and beta. Once it reaches the point E this is going to crystallize or produce ternary eutectic, this is what will happen. Now if you are having a compositions like sitting on A B E right A B E on this or B C E you can say B C E or A C E does not matter. Here it is showing a B e what will happen this will lead to formation of you know again alpha and beta simultaneously followed by formation of ternary eutectic. So, there is no need of discussing that now you know further to this we can also have different variation of ternary eutectic right.

So, in this case we have shown all the binaries A B, B C and C A they form eutectic among themselves. But that need not be the case I do not know whether I have told you that it is a unique, but ternary system, but that is not 100 percent correct. So, there are situations where even ternary eutectic is possible or four-phase equilibrium of ternary eutectic type is possible even when some of the binaries are not forming eutectics. Let us see what will happen I will just give you two examples of that on the board. And let us see whether we can draw it properly.

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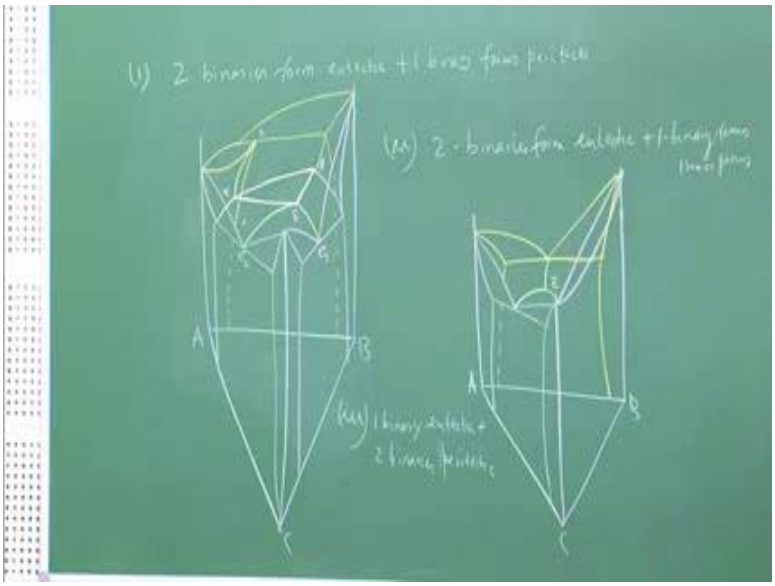

One is that when two binaries are eutectic; two binaries form eutectic and one plus one binary forms peritectic. So, how it will look like let us draw it. Although it will be little complex, but still follow me you will be understand it very clearly. So, suppose I have a C binary as an eutectic I have drawn using white color A C binary eutectic and then also B C binary forms an eutectic. On the other hand, A B forms a peritectic reaction A B couple forms peritectic type of phase diagram. So, how it will look like not very difficult to do it, we know the peritectic reaction will be like this ((Refer Time: 17:11)) little bit, so that you can understand. So, you see here there are two eutectic reactions e 3 and e 2 and there is a peritectic reaction p 1 here.

So, and if I try to connect them connect them using these color chalks. If I try to connect them, it will have form ternary eutectic alloy. So, let me see whether I can do it this is a green color chalk, this is point one and this one. Another point, connect these two and these two eutectics, these two eutectics or rather let me draw a triangle this way this is eutectic this is alpha beta. So, this also forms a ternary eutectic. So, this is one variation of the things. Second variation is that you can have two eutectics. So, this is one variation number one, variation number two is two binaries form eutectic and one binary forms isomorphous. This can also lead to ternary eutectic and it is little bit I will draw very simple way let us not complicate things.

So, first is that the binary between A and C forming the first eutectic first eutectic, you can see here. And the second eutectic is between A and B this also done very clearly seen and the third one will form a isomorphous. So, let me just draw this isomorphous between B and C, this will also lead to ternary eutectic inside it; it is very not very difficult to understand that. So, you can actually connect these two eutectics and one of these ends will lead to eutectic that is all.

So, there are different variations there is a another variation also. You can have I am not drawing the third variation is very subtle also. I am not going to draw it. It is for you to remember this you can one binary eutectic plus two binaries forms from peritectic this will also lead to formation of a ternary eutectic. So, you have seen that two ternary eutectic where all the three binaries forms eutectic and that we have discussed extensively in details. And there are other two in other variation of that is that in the first case two binaries form eutectic and one binary form peritectic or one binary form eutectic and two binaries form peritectic. Third case or rather second case here two binaries form eutectic and one binary form isomorphous all of these will lead to formation of isomorphous sorry ternary eutectic inside the triangle. So, with this, I conclude the session on this ternary eutectic system. Now, in the next lecture briefly I am going to tell you other two-phase equilibrium.