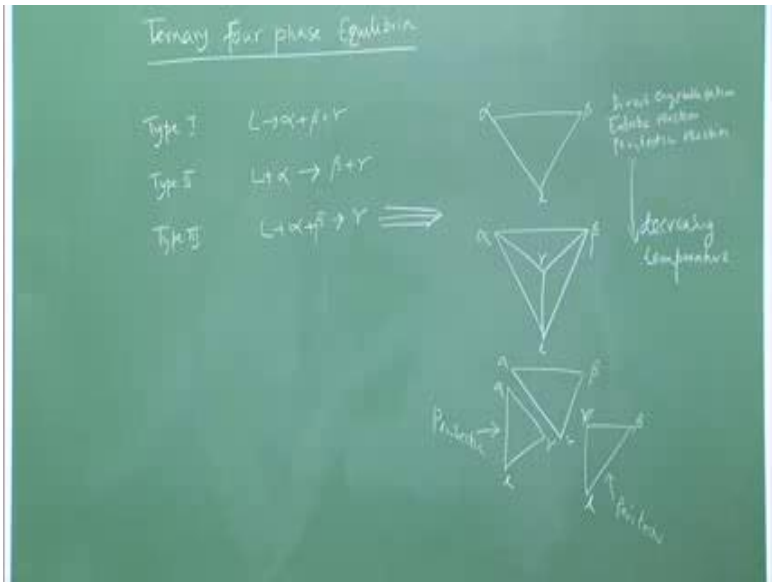
Phase Diagrams in Material Science Engineering
Prof. Krishanu Biswas
Department of Material Science Engineering
Indian Institute of Technology, Kanpur

Lecture - 58
Ternary Peritectic Reaction

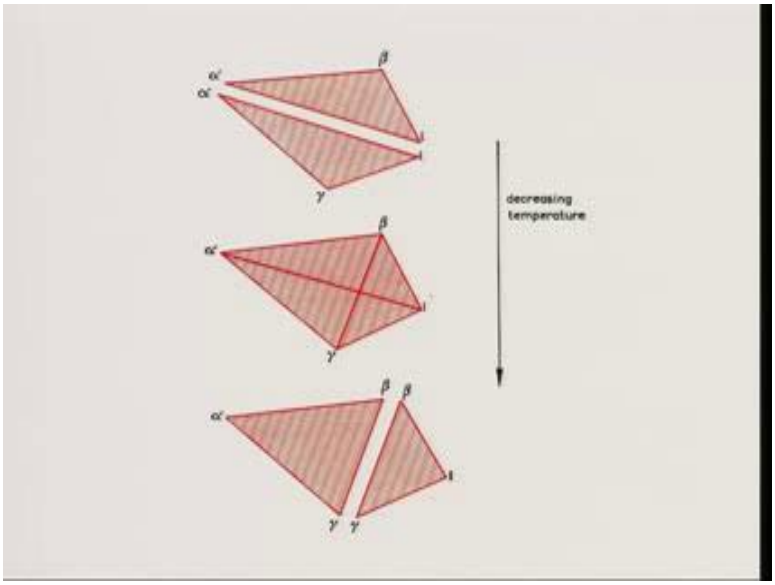
In this lecture we are going to discuss other Ternary Four Phase Equilibria. So, as I told you in the beginning, there are three ternary four phase equilibria possible. The first one was the ternary eutectic, what is that? The first one we discussed essentially is a ternary eutectic is known as Type I.

(Refer Slide Time: 00:35)



That is nothing, but liquid going to alpha plus beta plus gamma, this is the ternary eutectic. Type II is liquid plus alpha going to beta plus gamma, this is known as ternary quasi peritectic reaction and Type III is ternary peritectic reaction like liquid plus alpha plus beta going to gamma. So, this is known as quasi peritectic because it can be either peritectic or eutectic diagram, liquid plus alpha going to beta or liquid going to beta plus gamma both are possible depending on which ever is getting activated. But this is a truly peritectic reaction. So, as you know unlike this Type I these other two types actually a little bit different, let me just explain one by one. The second one the Type II is shown in this picture here.

(Refer Slide Time: 01:48)



What actually happens is that there is a four phase equilibrium reaction which is shown in center you see, liquid beta gamma and alpha. But this is preceded by two three phase equilibria one is alpha beta alpha liquid gamma, other one is alpha beta liquid. So, this three phase equilibria can either be eutectic or peritectic type or both of them can be eutectic or both of them can be peritecti. So, that is means what? We form these two three phase equilibrium which among alpha beta liquid and gamma this ends down to the four phase plane, four phase plane means what? This plane which is shown a center, and then the four phase equilibrium reaction happens - liquid plus beta alpha going to beta plus gamma, correct, it happens.

Now finally, when it exit for a four plane three again two four three phase equilibria forms - one is alpha beta gamma, other one is beta gamma liquid. That means that still some liquid is left over which can further away undergo ternary eutectic or whatever any other reaction possible. This is the category number one. In category two which is also known as the Type II, this is very interesting, this is what we will discuss more in detail today in the lecture. Type III actually Type III is the peritectic reaction and now the ternary four phase equilibria will be like this for this Type III, this is like this, this equilibria between liquid and alpha and beta and gamma.

But you know before this happens, this will proceeded by a three phase equilibrium between liquid beta and alpha that is obvious, because the reaction is that liquid plus

alpha plus beta going to gamma. Liquid has to react with alpha plus beta then it leading to formation of gamma and this happens at the four phase equilibrium plane invariant plane. So, before that we must have alpha and beta, if we do not have alpha and beta how I can have reaction on the fourth phase plane, invariant plane that is not possible. So, that is what this is always preceded by formation of alpha and beta in the liquid. So, beta and alpha and beta forms (Refer Time: 04:45) from the liquid then, when the temperature is coming down to the four phase equilibrium temperature of the reaction temperature these three reacts and forms gamma. Now, this is decreasing temperature obviously.

Now, how the exit happens? Exit will be consisting of three phase equilibria - first one is alpha beta gamma, second one is alpha gamma liquid and third one is gamma beta liquid. So, let me tell you that this formation of alpha and beta from the liquid can be directly crystallization of alpha and beta from the liquid or eutective reaction, so direct crystallization of both alpha and beta, direct crystallization of one of those not both, obviously. Then eutectic reaction will lead to formation of liquid plus liquid going from alpha plus beta or peritectic reaction can also lead to formation of. What I mean to say is that first one of these two solids will crystalized like a dendritic form from the liquid then, remaining liquid (Refer Time: 06:35) the liquid will then react peritectically and from lead to formation of alpha or eutectically lead to formation of alpha plus beta.

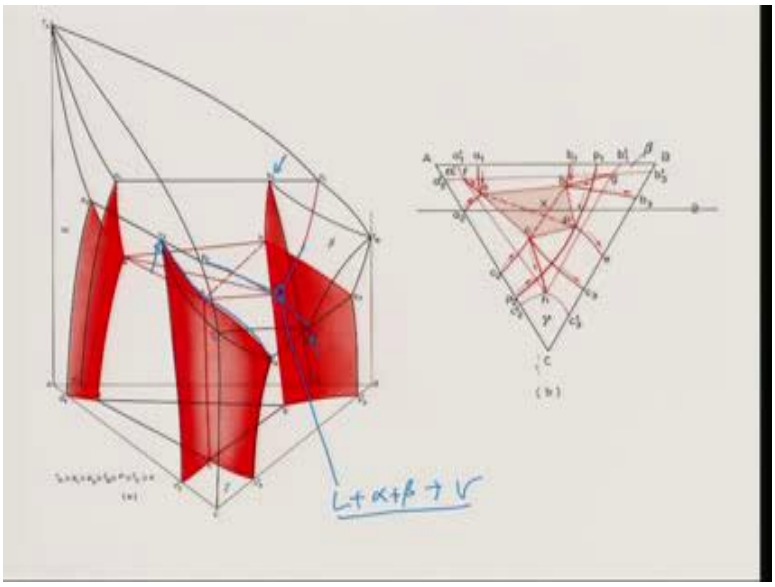
So, basically your task is to form the alpha and beta above the ternary four phase equilibrium plane, right this invariant plane. So, this can be done by eutectic or peritectic reactions. And what then this reaction will happen the Type III phase equilibria (Refer Time: 07:05) will happen lead to formation of gamma and in the exit plane you have two three phase equilibria (Refer Time: 07:13) liquid alpha gamma, liquid gamma beta liquid. This can be either peritectic, mostly peritectic type, what does it mean actually? That means, is that below this four phase equilibrium invariant plane you will can have two peritectic reactions or one peritectic (Refer Time: 07:14) reaction possible; that what is this thing.

So, that is means if I cool down this liquid directly from the high temperature first thing will happen as a crystallization of alpha or beta from the liquid then, an eutectic or peritectic reaction which will lead to formation of three a two phases alpha and beta from the liquid and after that it will descent, this three phase equilibrium thing will descent four phase equilibrium invariant plane which will have this reaction liquid plus alpha

plus gamma lead to formation liquid alpha plus beta sorry liquid alpha beta lead to formation of gamma and once it exit from the four phase (Refer Time: 08:23) plane you can have three phase equilibria - one is alpha beta gamma which is understandable, other two are in form a liquid they can be either peritectic or peritectic plus eutectic diagram. So, this is what will happen this is a scheme of reaction which is possible.

Now once you know that, once you this kind of stuff then you know what you think about the reactions, right or what do you think about the diagrams. Let us now see the simplest one which is shown here, suppose I have a ternary space model which will show the Type III reaction.

(Refer Slide Time: 09:13)



In which two binaries form peritectic one binary form eutectic. You can see A B binary forms a peritectic A C binary form a peritectic, but B C binary form a eutectic, correct. And this will lead to the formation of three type or Type III actually ternary four phase equilibria and it is shown here like that. These are the zones of primary alpha beta and gamma and this is the eutectic reaction, let me change the color this is the eutectic reaction and these two are the peritectic reactions one here, and one there.

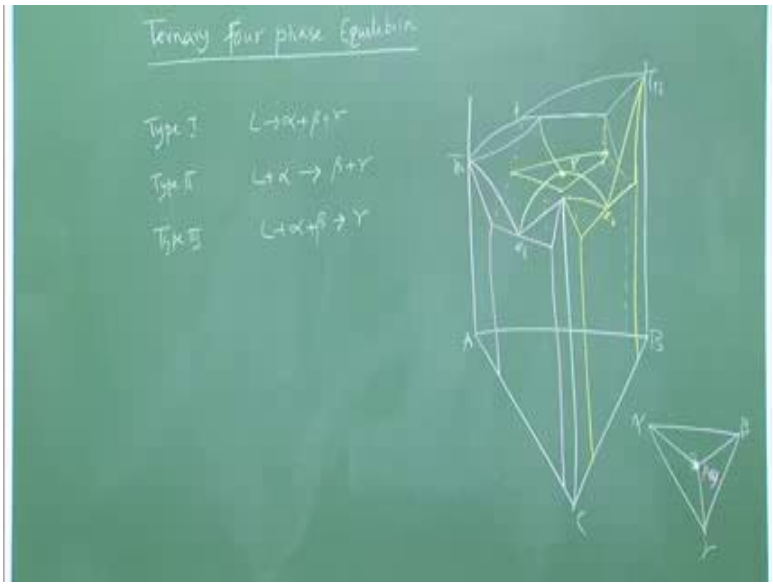
And then at the center what will happen? If I extend these points you get this is a peritectic point p 2 this is the peritectic, this is the peritectic point p 1, if you connect it you get a peritectic point here correct, you see here P, capital P. These capital P is corresponding to liquid plus alpha plus beta going to gamma. So, therefore, if I project

these whole things it looks very complex although to you, but this is how things are actually discussed. So, as you see here because of you have two peritectic reactions - one eutectic if you extend them, this is the extension of the peritectic, this is the extension from another peritectic and this is extension of the eutectic all of them will meet on the fourth phase plane which is nothing but a given at the point p and at that plane is three reaction happen liquid plus beta plus alpha going to gamma.

Now, you can project it on to the triangle, how you can project on triangle? You can see here this is the alpha phase field, beta phase field, gamma phase field; then you have a point p here which is corresponding to ternary peritectic reaction, point c actually corresponds to this point which is nothing but intersection between the peritectic reaction between A B and B C actually, c 3 extended like this and c 2 extended like that then you get the point c. That is what you get, c 3 and c 2 extended at the point c, right. And then you have a point A and B already marked alpha point a is coming from these two ends and point is p is coming from these two ends. And P is sitting inside that ternary, inside this a is a h g f, h f g triangle it is shown here also, correct.

So, below that point P you will have a three phase equilibrium reaction - one is nothing but alpha plus beta plus gamma that is not important other two can be a peritectic type liquid alpha and beta, liquid alpha and gamma and liquid beta and gamma. So, this is one such equilibrium things possible. You can also have you know, the last thing I draw is another kind of equilibrium let us see whether I can do it, is that you can also have this ternary phase four phase equilibria of Type III when you have two eutectics and one peritectic on the binary. So, how it will look like let us see.

(Refer Slide Time: 12:52)



So, let me first draw the binaries. So, eutectics between A and C which I have been doing always A and C and this is the eutectic, and then another eutectic is between C and B, this is also very easy to draw they are sitting on this frontal surface and we are drawing in such way always B has higher melting temperature so that you have a consistency in understand it, right. The third one that is between A B forms an peritectic. I think I have done a mistake here no it is correct. So, I have got two eutectics e 1 and e 2, and this is the peritectic small p.

So, therefore, this is T A, T C and T B, T C I am not drawing it. So, now, we can extend these three things one is the eutectic, other one is this eutectic and this peritectic. This will form this reaction right. So, that is how it will look like. Now, one can actually join these points and get a better idea. So, this is what is this ternary phase model will look like. You have to draw yourself to understand it clearly otherwise you will not be able to get feeling of how things looks like, once you draw it properly things will be clear to you. So, this is another such. So, therefore, this small p is always used and small e is used to have to denote the binaries, binary peritectic or eutectic reactions; capital E or P is used for ternary peritectic or ternary eutectic reaction, right, this is sitting on that.

Therefore, this is actually for sitting on four phase plane, one can actually draw even the triangles like that this point one, this is point two and then this two actually point three.

So, if I draw it properly this will look like this and P is sitting inside that, right that is all. So, P is sitting inside this triangle, this is the four phase plane.

So, therefore, if I draw that properly it will be like this. Now, what are these? This is P alpha beta gamma, right that is what I have drawn. So, P is corresponding to liquid this will be liquid composition. So, that is the way one can draw there are other things also possible, if I find time I will show you in the next class.

But in the next class predominantly I will discuss Type II. Type II type of eutectic systems and Type II is little bit you know, it is not an easy things to see three dimensionally. This Type III is still easy thing to pursue because it is a peritectic. Type I is basically ternary eutectic, Type III is ternary peritetic, but Type II is a mixture of peritectic and eutectic that is why we will do that at the final thing. So, that is for the next class and then I am going to discuss with you and the last is this few examples of the ternary phase diagrams that will be finishing the course.

Thank you.