Phase Diagrams in Material Science Engineering
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Lecture – 16
Phase diagrams of binary peritectic System-II

So, we are going to continue today on peritectic phase diagrams. And, as I told you in the last lecture, I am going to show you some images on microstructures. Let me first start with iron-germanium phase diagram, which has several peritectic reactions.

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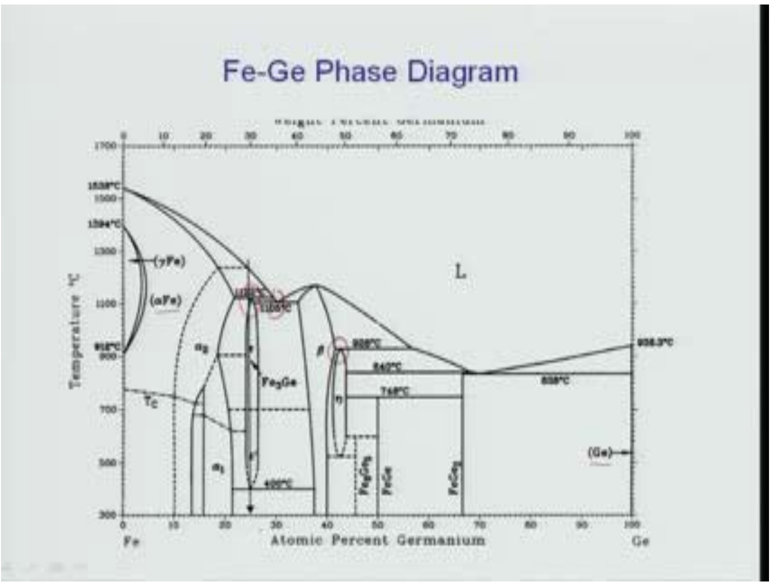

But, I just wanted to show you this diagram mainly because finally at the end of the course, you will be able to read this complex diagrams. As you see here, this diagram contains many phases starting with alpha. Then, you know epsilon, eta, beta and many other inter compounds like Fe 5 G, Fe 6 G 5, Fe G, Fe G2. Correct. But, as usual on the both ends there are (Refer Time: 01:10) solutions.

On the iron end, alpha iron (Refer time: 01:13) solution, you can see here. Alpha iron solution, you can see here clearly that written. This is the one alpha iron solid solution. Similarly, on the germanium end there is germanium solid solution. And, in between this is populated with many reactions. And, we are going to consider only peritectic reaction. So, you can see there is a peritectic reaction here; there is a peritectic reaction there. Clearly, you can see. In addition, there is a eutectic reaction followed by the first peritectic reaction. Correct. So, I am going to show you the results or microstructure from these first and describe it.

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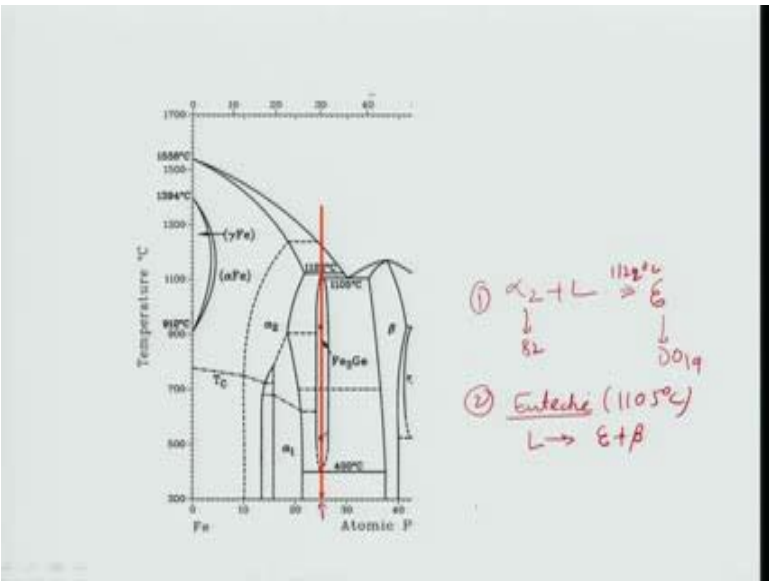

In a nut shell, if I take only the first portion of the Fe G phase diagram, these are what exactly shown here; you have alpha phase and these alpha one, alpha two are different (Refer Time: 02:06) of this alpha phase what are actually structurally. We will not discuss about that. But, on the other hand you have a peritectic reaction here, in which alpha two reacts with the liquid giving rise to epsilon. And, alpha two has a B 2 order of structure. Basically, it is a BCC crystal structure, but order. Epsilon has a hexagonal crystal structure with the order of DO 19. And, the peritectic reaction happens like this way. And, this reaction is followed by. So, this is my peritectic reaction. This reaction is followed by a eutectic and eutectic reaction. What is that? As these reaction happens at 1122 degree Celsius as for the phase diagram.

On the other hand, the eutectic reactions happen at 1105 degree celsius. And, this reaction is basically like this, liquid going to epsilon plus beta, where betas is another hexagonal phase, but not order. It is a different type of hexagonal phase. So, you can see here that if you want to discuss the microstructure evolutions by looking at any alloy composition, here mark like 20 atom percent. This alloy; you need to understand both the peritectic and eutectic reactions. And that is the purpose of this course, so that you understand it and understand the phase formation and the microstructure.

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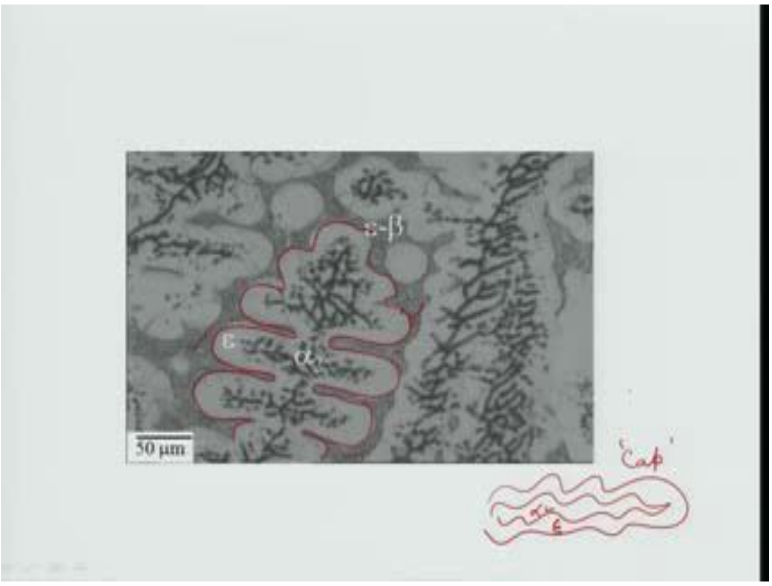

Now, let us look at the microstructure. If I solidify alloy with 20 atom percent, germanium, the one I marked it, right in the last slide. And, you will find this kind of microstructure. And, this is what is a typical dendrite. You can see here; I can follow its shape. This is a typical dendrite. It is just like a tree branch. I am showing you so many different pictures of these drawing it in the (Refer Time: 03:57). But, just to show you that this is a dendrite like this, I have drawn here. But within the dendrite, there is another dendrite, which I have marked alpha two. And, this grey color one dendrite I have marked it as epsilon. So, initially alpha two formed; initially alpha two formed like these dendrites.

So, see here black color. This is alpha two. And then around it, you have epsilon dendrite formation. And, so this morphology is used to show here is like a cap of epsilon and alpha two. This kind of a morphology, which is known as cap morphology is a signature of peritectic reaction. So, by looking at this microstructure in optical metallograph, you can say that there is a peritectic reaction. Now, if you look at this part carefully, these portions in between the dendrites, these are the dendrite; there is a eutectic between; eutectic actually. And, which will be clear here; very clearly you can see here. This is the eutectic. Eutectic is between epsilon and beta. Correct.

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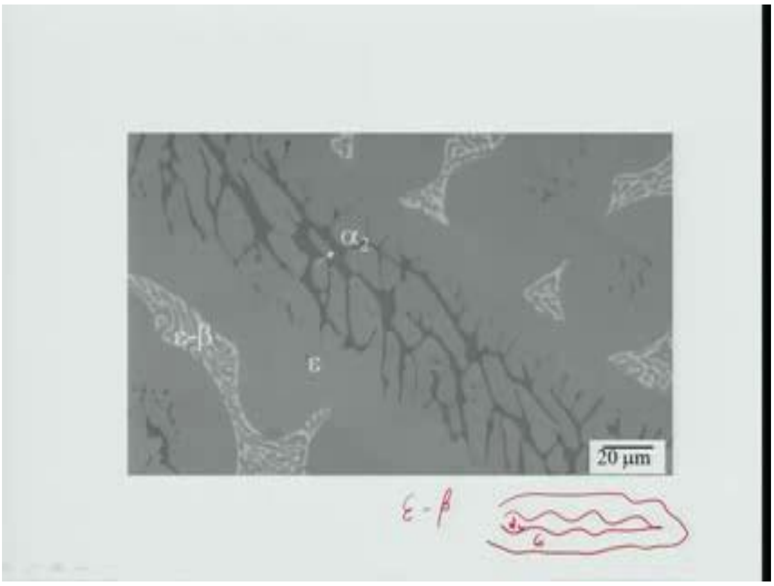

So, let us now discuss more about this peritectic reaction. So, this is the scanning electron micrograph of the same alloy. You see here that alpha two phase is like a black colored things or black contrast. And, it is surrounded by this grey contrast phase epsilon. So as you see here, this alpha two phase remains. It does not transform fully by the reaction. And, this one is epsilon phase. Correct. So, that is actually way to the things to correlate with the way I described in the last class, and, with the real time, a real microstructure. You will be able to correlate this way that any peritectic reaction present in the phase diagram can be seen in the microstructure like cap morphology. That is because peritectic reaction never goes to completion in the real certification conditions. You cannot complete it. If it would have been completed, there would have not been any alpha two phase in the microstructure.

But, we will see that. That is the signature at peritectic reaction has not gone completed. In fact, before it is got completed, it has, under the liquid remaining around this is undergoing eutectic reaction. And, this is the lamellar eutectic, which I have shown you earlier also. So, therefore it is clear that this reaction did happen. Now, let me move on and show you some other phase diagrams. This is the classical copper-zinc phase diagram.

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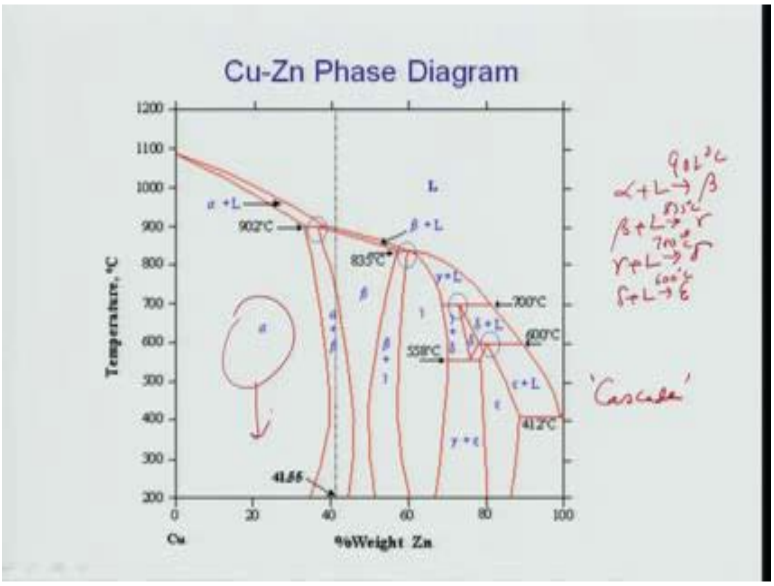

And, we know that copper-zinc alloys are called brass. And, they are widely used in the different applications, not only cooking utensil. Earlier, but also in different kinds of difference applications like, you know, even cartridge is also made up of brass.

So, there are different types of brass; alpha brass, alpha plus beta brass, epsilon brass. And, all of them are marked here. But, the important thing is that in this phase diagram there is at least five peritectic reactions. All of them are marked by this circle, like this circle, you can see one, two, three, four are marked. There is at least, sorry, there is at least four peritectic reactions, which you can see here. Not five, four. The first peritectic reaction is it can be written as alpha plus liquid going to beta. So, this is the first one at 902 degree Celsius. Correct. Second one is at 835 beta plus liquid giving rise to eta or gamma, sorry. This is at 835 degree celsius. Then, you have another one; gamma plus liquid giving rise to delta. This is at 700 degree celsius. Correct. You can see here. And then, last one is delta plus liquid giving rise to epsilon at 600 degree celsius.

So, this kind of peritectic reactions coming one after another is called cascade peritectic reaction. In the literature, cascade is like a waterfall. You can see that when it happens in a brass. So, if you really want to understand brass microstructure, you have to understand peritectic reactions. There is no other way. That is what I told you that this is the classic systems in which peritectic reaction appears a lot. And, so therefore if you want to control the microstructure alpha beta brass or beta plus delta gamma brass or n, delta brass or epsilon brass, you must know that the, you must know, have a idea of peritectic reaction morphologies.

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Now, let us look at microstructure alpha brass, which is single phase. You can see here this is a alpha phase field, single phase and beta brass or alpha plus beta brass two phase. So, alpha brass will have a single phase alpha grains. And, you can see when the twins around here, these are the twins. You can see here, I am marking. Or, let me mark it with a green color or the blue color thing. So that, you can see it this is a twin; this is a twin. There are many twins are present. This is a twin because copper zinc alloy is twined very easily. And, none other than alpha plus beta brass will have both alpha and beta. And, you can clearly see there is grey or black color stuff.

Let me just select a black color chalk, a black colored thing here. Grey or black color things. Inside, this is what is known as alpha phase. And, outside one is a, your, something different color, let me just put it. I will put this colour. This is the one. So, this is what is beta and the other one is alpha. This one is alpha. So, that is actually a (Refer Time: 09:59) peritectic reaction again and it retains there. So, 70 percent copper or 40 percent zinc will have alpha plus beta brass.

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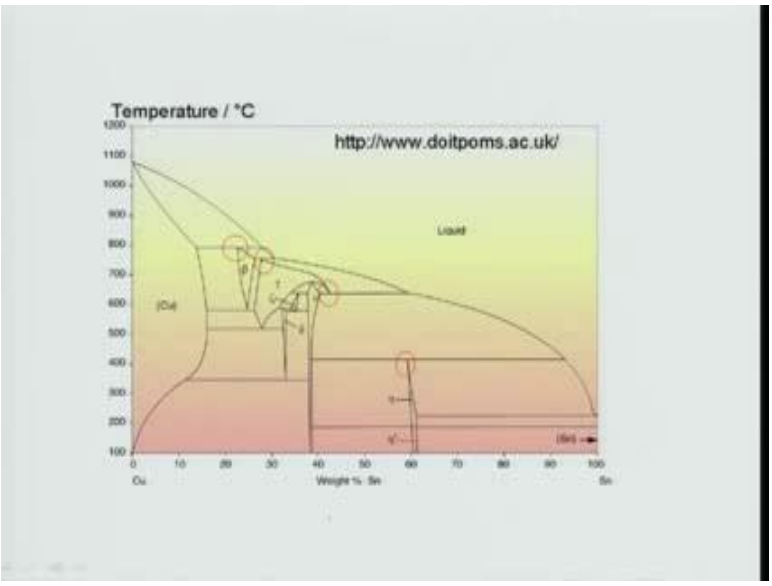

Similarly, for copper tin system which is a basically a bronze, you can have a peritectic reaction; several one; one, two, three, four are shown here at different temperatures. So, beta bronze or epsilon bronze or eta bronze, they are all produced by peritectic reactions, different peritectic reactions. And, just to show you a picture on microstructure of that this is your alpha beta bronze.

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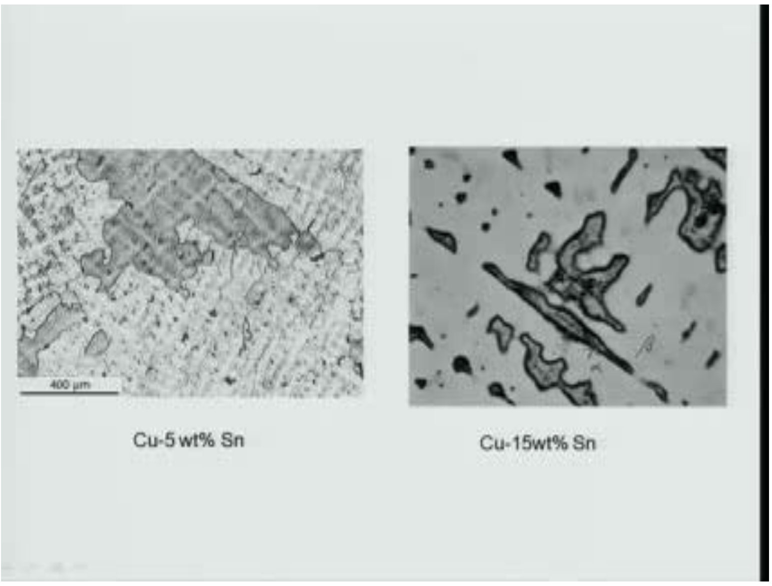

You can see here copper 15 percent or tin alloy, this is your alpha and this is your beta present. Alpha is present like a skeleton and beta is presents like a bulk grey color phase, alpha is like a black color, same thing here also. This is what is your alpha, this is what is your beta. So, you can see the signatures of peritectic reactions in phases.

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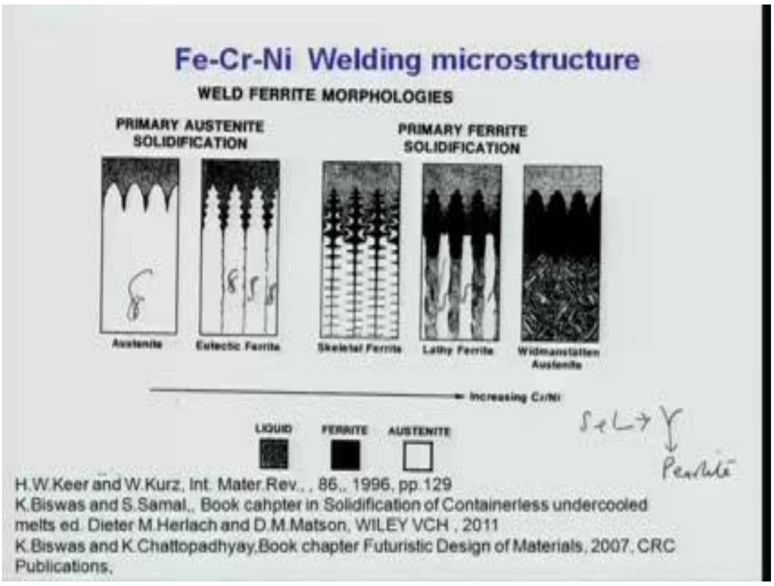

Now, I, last one I want to show you are that in this case of welding of stainless steel and chromium nickel, which is a classical problem. So, as you know this is a ternary alloy. So, we have not discussed with ternary phase diagrams. But, just to excite you or just to let you know that these things can be extended from binary to ternary systems, I want to show you.

So, initially you have austenite or gamma grains. Gamma is FCC iron. And, these dendrites, gamma dendrites grow. And then, there is a reaction between the gamma and your liquid. And, so therefore what will happen? This is the eutectic ferrite. You can see here eutectic presence. So, therefore this reaction will lead to formation of this dendrites, so that this is what is your; I am sorry, this is not gamma, this is delta. So this is, sorry, this is delta. I should not make any mistakes. So, these are actually delta iron. All of them are delta. And then, delta plus liquid reacts and form gamma. So, you can see here. And this gamma, then later on surrounds here in the delta, but delta remains retained. You cannot remove delta iron. Correct.

On the other hand, this delta, this is called lat type of ferrites or which your delta. And, the gamma, which is already transformed to; gamma will transform to pearlite because gamma is not stable; pearlite. That is what you see here. These are pearlite. So, but question is that as delta retained in the microstructure, the delta actually creates problem later on because delta transforms to alpha iron. And, alpha iron is a soft phase. And not only that, it is volumized function. So, therefore the welds crack during microstructure, during solidification. So, this is a typical problem of peritectic reaction in a stainless steel welding.

Now, with these introductions of the peritectic microstructures and peritectic phase diagram, let me just show you that a peritectic reactions, peritectic phase diagrams can be actually extended for compound formations. And, in the next class I will discuss about that in detail. But before I go into that compound formation, compound forming phase diagrams, I take the simple peritectic phase diagram and show you the composition process; free energy versus composition diagrams in the board.

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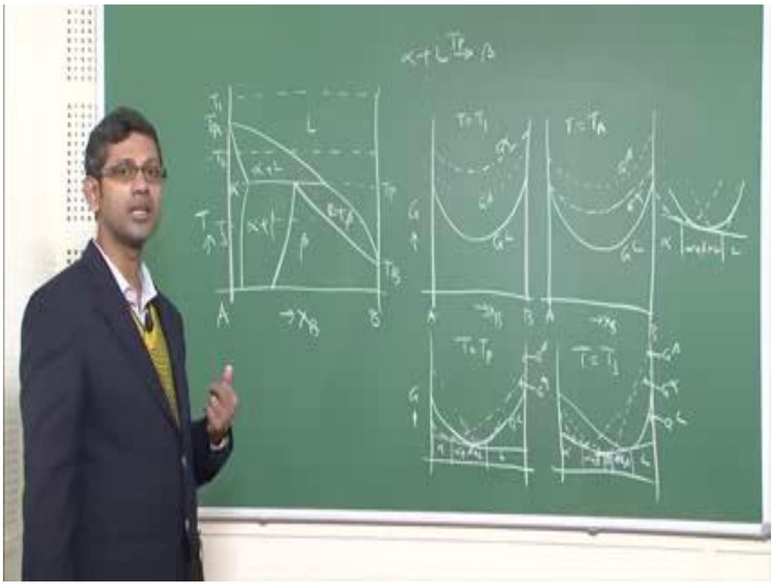

So, first thing I will do; I will just, you know, draw a classical peritectic phase diagram, the one I have drawn in the last class. I hope by this time you have learnt my tricks how I am drawing the phase diagram. This is temperature versus composition diagram. And, this is the simple possible peritectic reaction. So, this is T A melting temperature of A, this point, this is T B melting temperature of point L at B, element B and this is alpha, this is beta. Rest of the stuff is very easy. So, this is beta plus or liquid plus beta, this is alpha plus beta and this is alpha plus liquid; this is the simple possible phase diagrams of peritectic reactions. So, and in this diagrams I showed you how the beta forms in different ways, in the last lecture. And, also this lectures also I have shown you how the beta forms.

So, peritectic reaction is basically alpha plus liquid going to beta. And, this happens at T P at peritectic temperature T P. Obviously, this is the peritectic isothermal at T P. And, you can see this as these two ends of that. And, please study this phase diagram nicely because you will get in assignment, some problems on how to calculate the amount of beta phase formed from these horizontal lines or from these tie lines at T P. I will solve also in some of the classes. But, I am just telling you that you should look into these diagrams very nicely.

Now, I would like to show you the phase diagram, the free energy composition diagrams, G versus X B are at different temperatures. So, let me take temperatures like this one is T 1 and T A. And this is T 2, varying temperature T P. And here, I take temperature here, which is the most difficult one T 3. So, I will draw at these four temperatures; T1, T A, T 2 and T 3. T B is not interesting temperature at all. So at T 1, you see if we want to do a free energy composition diagrams, you have to first look at the phase diagrams. So, how many phases are present here? There are three phases present; alpha, liquid and beta. So, in each of these diagrams I need to draw the free energies of three phases. That is the idea. So, how I will do draw it? It depends on which are the phases stable and which are the phases are not stable in the phase diagram.

So at T 1, at temperature equal to T 1, I could say all the liquid phase is stable. Here, you can see here at T 1 liquid phase is stable. So, for alpha and beta the free energy curves will be above the liquid free energy curves. So, this is what it is. So, this is for liquid. And, again I have to use dotted lines for alpha and beta. This is for beta, suppose. And, this is what is your alpha. Why alpha will be above? Because alpha is; it does not matter actually the alpha above or beta above. But, this is what in a relative disposition of this curve for the liquid alpha and beta.

So, at temperature T 1, liquid phase is stable in all composition range from pure A to pure B. Now at temperature T 2, at temperature T A rather, not T 2; let us now do it for temperature T A. T equal to T A. Correct. So, at T equal to T A, you can see here that at pure A end, at the end pure A, the free energy, the solidus and liquidus of alpha phases meeting. So, therefore only at pure A end, the free energy curves of alpha and liquid will touch each other at the pure A end.

So, otherwise liquid is stable in all. So, I will draw a liquid G L. And then, I draw the, I draw the alpha phase. This is G alpha. So, G alpha and G L curves are only intersecting at pure A end. This is pure A. Right. Well, all compositions G alpha is sitting or above the G L. So, therefore G L is more stable. And for G beta, it is already above. Correct. because G beta phase is not stable at all any composition range. So, I have to do it for now T P. So, I hope you understood this that at T A, only these two curves will meet G alpha and G L at the pure A end, not anywhere else. So, similarly for pure for T A, temperature T equal to T P, at this peritectic temperature, you can see here alpha is stable till this composition. Then, you have three phases stable; alpha, liquid and beta. And, then from this to this composition, liquid is stable.

So, when you have two phased field alpha and alpha plus liquid and then liquid. So, therefore alpha and alpha curve and alpha liquid curves will crossover. So, let us first draw that liquid one. Correct. So, the liquid one and alpha one will crossover. So, how will it cross over alpha one? So, let me just do that. It has crossed over. And, at the same time beta is stable here. So, there will be a tangent between, common tangent between alpha liquid and beta. So, I am drawing that. So, this is G L and this one is G alpha and this one is G beta. So, between these two curves L and liquid and the alpha, if I draw a common tangent or rather, it is better to draw a common tangent between three of them.

So, to do that you have to extend the alpha curve little bit more. Let us do that. So, you can draw a common tangent between these three and this is where it touches. So, this is alpha. This is where it touches. This is where it touches between alpha and liquid. So, this is liquid, this is alpha plus beta plus liquid. So if I zoom it up, this particular portion, it will be like this; liquid curve, then alpha and beta. So, three curves will have a tangent. So, this is what is alpha, this is liquid - this part, alpha plus beta plus liquid; that is what I have done here.

So, this part is shown as zoomed (Refer Time: 21:34). Now, I will do it for a temperature T equal to T 3. So, at temperature T equal to T 3 you have; not very simple situation. You have alpha phase present until this composition alpha plus beta, until this composition, beta liquid plus beta and liquid. So, I have a crossover of alpha and beta, and again, here beta and liquid.

So, first let us draw alpha. Alpha will be like stable for certain composition range. Then, it will go up. This is for G alpha, then G beta will crossover. G beta will be above. It will crossover and remain like this. So, these two will have a tangent between themselves. This is alpha, this is alpha plus beta and then you will have a liquid curve coming like this. We will have another tangent between liquid and alpha. And, in between there is a range beta is stable.

So, liquid plus beta and this is liquid. So, that is not easy to do. So, you have to draw this curve in such a way that you can make common tangent. I have drawn two common tangents between alpha and beta here. This is the common tangent to alpha, beta. And, this is the common tangent between liquid and beta. So this, for this is beta and this is G L. This, you need to practice more then only you can get it. But, in the books it is there. So, that is actually, that is how actually all these free energy composition diagrams are drawn and explained.

Now beta is, here is a solid solution phase between two composition end B, but it can be also a intermetallic phase or it can be also a line compound. Just like a line. I have shown you in the iron-germanium phase diagram. There are many compounds like Fe G 3Fe 5 G 6, like that. So, these phases are also formed by peritectic reactions.

Now as a (Refer Time:24:02) of these peritectic reactions, we are going to discuss in the next class, the nature of this peritectic reactions or nature of formation of these line compounds and what are the rules for the line compounds; because these compounds are very important for the simulation because these compounds have changed the concepts. And, it has been applied. These compounds are applied for various applications.

So, therefore we need to know these compounds very nicely or quite aware, if you want to understand phase diagrams or material science nicely. So with these, in the next class I will start discussing about the compound formations and move on.