Phase Diagrams in Material Science Engineering
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Lecture – 41
Phase Diagram for different Solid-state Reaction

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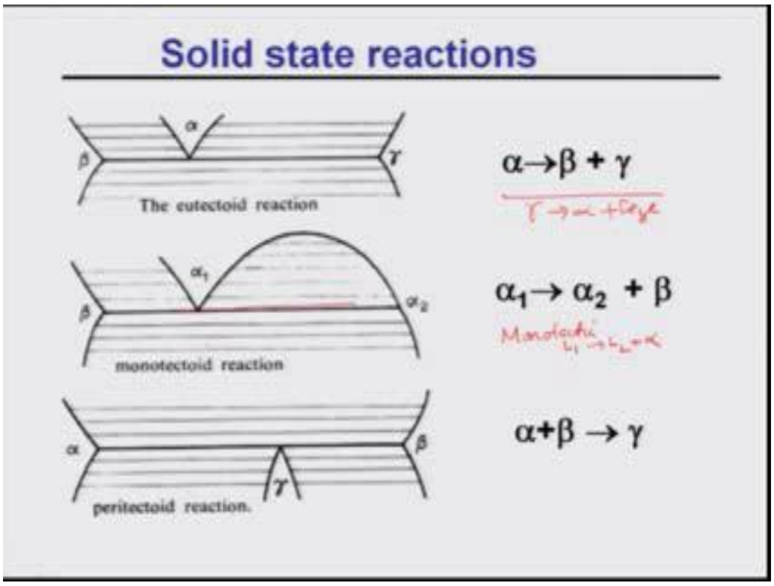

So, in this class, we are going to discuss about the other solid-state reactions, but let me remind you that for the solid-state reactions, we have discussed that we are going to take up three different types of reactions. First one is the eutectoid reaction this is what is this gamma going to beta plus alpha beta plus gamma sorry alpha going to beta plus gamma and that is what we discussed for the steels. Basically, for the steel most important reaction is this pearlite formation reaction and that is a eutectoid reaction. So, you know that reaction is given by gamma going to alpha plus F e 3 C. And the left side, I am just showing you the phase diagrams appearance of the phase diagrams if such a reaction is present this is second taken forms of Alan's Prince book, you can look at it carefully. So, we have a lot of discussion for the last may be I do not know I mean eight ten lectures we discussed about that and that is you that what brought about steels in the cast iron.

Next important reaction is basically the peritectoid reaction which is shown at the last here you see peritectoid reaction is exactly opposite of eutectoid reaction alpha plus beta going to gamma. Sometime confusing, if you look at this beta plus gamma going to alpha, so if you take the other side beta plus gamma going to alpha is what is peritectoid reaction by the way so that is basically predominantly seen in some of the phase diagrams which will discuss. And the second one which is also seen is the monotectoid reaction. If you see monotectoid reaction is what alpha 1 going to alpha 2 plus liquid.

If you go back to the monotectoid reaction, monotectoid reaction is what, monotectic liquid one going to liquid two plus alpha this is exactly same as solid-state L 1 and L 2 is replaced by alpha 1 and alpha 2. So, alpha 1 and alpha 2 have same crystal structure and their compositions will change; beta will have different crystal structure. Structure in the phase diagram or I will give you serious looking like this alpha 1, alpha 2, beta and this the monotectoid transformation temperature correct that is what is we are going to study this reactions in more detail manner. So, you know, first I will take on the peritectoid reaction and discuss about it then I will take up the monotectoid reactions; about ten minute each of this reaction I am going to spend, because this reactions are not so predominately observed in the phase diagrams that is why. So, let us first draw a peritectoid reaction phase diagrams where peritectoid reaction is seen.

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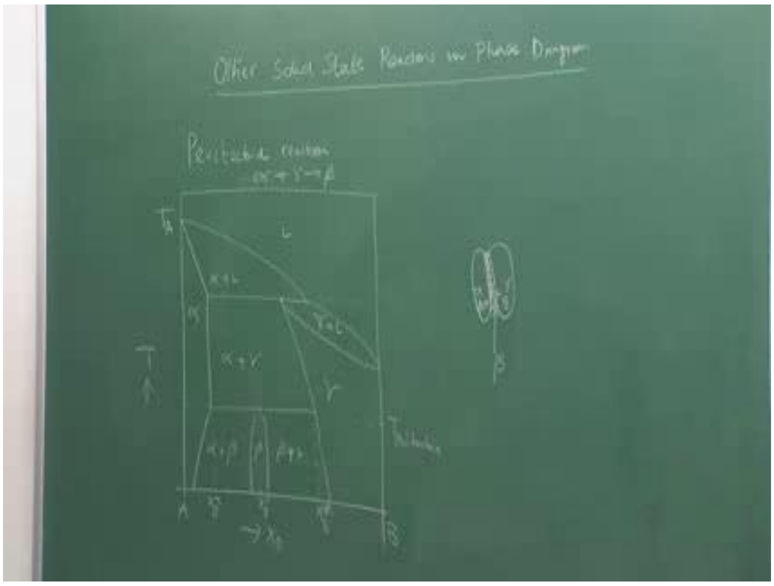

Peritectoid, so this is what is the phase diagram this is temperature axis, this will be the composition axis between two components A B; liquid, alpha, alpha plus liquid, and then this is gamma plus liquid this is gamma alpha plus gamma, beta alpha plus beta, beta plus gamma that is what is a peritectoid reaction thing. But here actually I am showing you both the peritectic reaction as well as the peritectoid reaction. So, let me first tell you the peritectoid reaction; this is the peritectoid isotherm; this is the peritectoid isotherms. And in this case, for the peritectoid reaction is alpha plus gamma, close this, alpha plus gamma going to beta that is what is the peritectoid reaction. It is opposite of eutectoid reaction; and this happens at a low solid-state lower temperatures.

We know because you need to have peritectoid reaction you need two solid phases. So, therefore, any peritectoid reaction is you know is presided by either a peritectic reaction or eutectic reaction or eutectoid reaction, all the things are possible that meaning is that because this reaction requires two solid-state solid phases for the reaction to happen. So, you can get only two solid phases when you have a peritectic reaction like this or eutectic reaction or a eutectoid reaction.

So, here actually peritectic reaction happens at peritectic temperature and what is the peritectic reaction. Peritectic reaction is what is very simple alpha plus liquid going to gamma we know that one solid phase reacts with the liquid into gamma, so that is what the gamma phase field is present. And because of these two phases presence you have reaction and having a peritectic reaction peritectoid reaction. So, we are not going to spend time on the peritectic reaction as we have discussed a lot. So, what will happen in the peritectoid reaction, let us discuss about that.

So, let me just take out these things because otherwise you are going to getting influenced by that. So, you know that if I have alpha and if I have a beta alpha and gamma present like this. So, peritectoid reaction will happen at the interface like this; peritectoid reaction will happen like that at the interface. And as soon as the peritectoid reaction product if beta will form the interface will be you know it will form at the interface and therefore, the contact between these two solid phases will be vanished there will be no further contact possible. So, any further reaction is possible only when the diffusion of the atoms from alpha to gamma vice versa from gamma to alpha is possible.

Now, if you look at this diagram at the peritectoid transformation temperature X B alpha of this composition, reacts with beta of X B beta composition these two compositions, and forms sorry not beta, gamma this is gamma end right and forms a beta of this composition. So, that means, beta composition lies between alpha and gamma correct. So, if you want to form more beta and where only by diffusion of atom from alpha to gamma or gamma to alpha as I did. So, which atom will diffuse from alpha A, because alpha reaching because this is the amount of B. So, A will be the rest amount quite a lot. So, A will diffuse this way and again gamma is reaching B. So, B will diffuse this way. And when they will come in contact, the atoms will come in contact and it has a definite compositions of X B beta then this will solid layer will form that is how it happens.

So, therefore, initially they will come in contact and form a thick layer of beta any further reaction requires diffusion of a through this layer b through this layer and come in contact each other and forming more amount of beta. And you know this reaction normally happens at lower temperature. So, because it happens at lower temperature, this is highly unlikely that the beta will be formed completely by consuming all alpha and gamma this is highly unlikely, in fact, does not happen. What actually happens is that you have all the three phases remained in the microstructure, all the three phases remain; you cannot actually have a complete reaction possible. Even if you keep the sample at this temperature diffusion is not substantially enough. So, this is what actually the problem of all peritectoid reactions present in the phase diagrams. So, now as I told you that the peritectic reactions are not widely seen. So, I am just going to tell you some of this phase diagrams.

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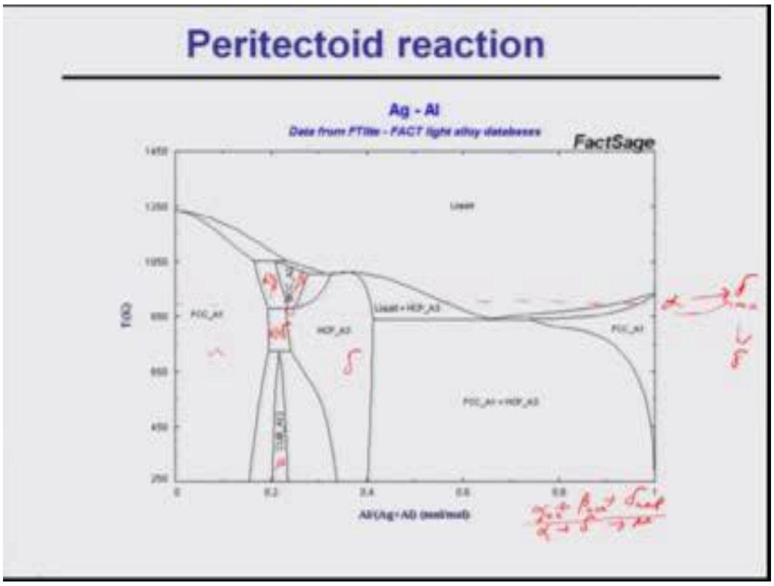

The first one is the silver aluminum phase diagram. This is obtained from the FactSage free website. See, there are two peritectoid reactions here; first let me discuss about this one. You see here this is the single phase; it forms by this is alpha, this is gamma. So, alpha plus gamma going to beta correct you see this is what happens; not only that here there is a peritectoid reaction, which you cannot see here. In fact, that is because there is a phase here alpha plus alpha plus something else I think it is delta also can lead to formation of gamma this is the way reaction happens.

So, there are two reactions here one is the alpha plus beta sorry I think I am doing some mistake, let me clarify. This is not this, this is delta. So, alpha plus and this is beta by the way. So, because I could not get a phase diagram where all these things are written carefully. So, as you see here alpha plus beta going to delta this one reaction and another one is I am making lot of mistakes. So, this is not delta, this is epsilon, and this is delta actually. So, this is alpha plus delta and this is what is beta sorry this is what is beta and this is alpha plus beta correct. So, you can have this reaction that is what I mentioned here at this temperature.

This is the first reaction alpha plus beta going to delta. The second reaction is alpha plus delta going to mu correct. So, and you know this first reaction alpha is fcc beta is bcc and this is acp delta is acp, this is more important reaction and more interesting than this one. So, there are two reactions which you can see, this one the first. The second one you can easily see the way I have drawn in the board exactly same. The first one is not easily observed, but you have to carefully zoom this diagram to see that. So, this is the first diagram which shows you two peritectoid reactions very rarely is seen in the phase diagrams.

Now, the few things I would like to tell you here I know and although people not this is not industrially important alloy silver aluminum and silver is very expensive also. But in this sometime people theoretically study this and this peritectoid reaction can be modified as you see in that peritectoid reaction is very slow. So, therefore, the first differs peritectoid reaction I am talking about it this one where alpha plus beta going to delta and the it is very (Refer Time: 13:14) reaction one fcc phase reacts to the bcc phase form a acp phase very, very classic reaction. If you want to study theoretically phase transformation, this is a very good system in solid-state system. Now even you have been observed that you can bypass this reaction as just like a peritectic reaction peritectoid reaction can also be bypassed. So, alpha plus beta and react and form delta massively this is called massive delta, delta m, m a, you can form that by massive transformation or rather alpha can duly transform to delta by massive transformation that is also possible.

And when this forms these delta then delta will have a similar crystal structure as the or the equilibrium delta which is present this is not equilibrium delta this is massive transform delta. Massive transformation delta means compositions of delta will be same as the composition of alpha from where it is forming. So, let us not write like this this is what will can happen. Alpha can massively transform to delta and then this kind transform to later delta. So, this is one of the way of transform of making faster way of delta formation. So, that is the about the first peritectic reaction peritectoid reaction first thing about peritectoid reactions. So, now, I am going to move into the second one that is the monotectoid reactions. As you know monotectoid reaction is basically liquid state very solid-state variation of the monotectic reaction and let us do that here first in the board.

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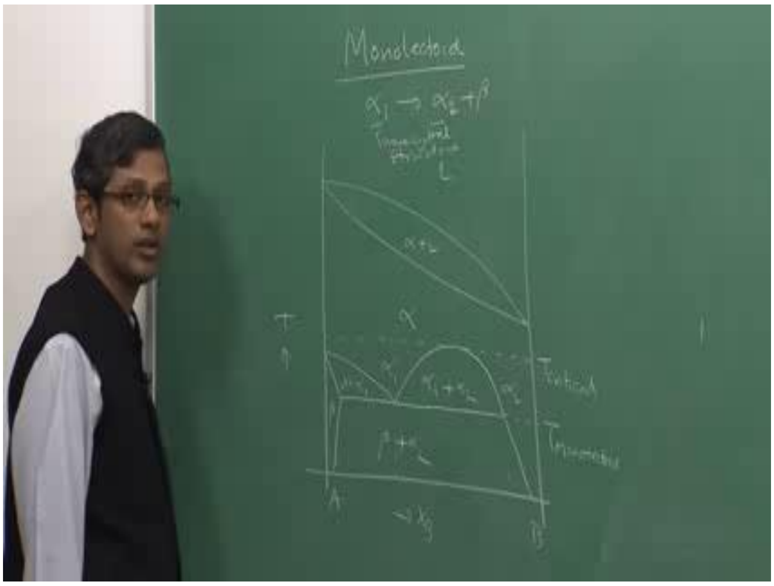

The one reaction which is exemplary is this alpha 1 going to alpha 2 plus beta. So, phase diagram where this can be observed look like this. Normally, this is basically a schematic phase diagrams. So, this is a liquid, liquid plus alpha. So, we have alpha and this alpha will transform to solid-state transformation again we will have a loop; these are the phase boundaries. So, as you see here this is the critical temperature same as like monotectic reactions, critical temperature forms monotectic reaction, this is the monotectoid temperature. So, at the monotectic temperature, alpha 1 transform to beta plus alpha 2 that is what I showed you correct in the phase diagram.

So, basically you need a prerequisite alpha that is why this alpha normally forms by you know such a kind of phase diagrams, but it can also form by other reactions like peritectic reactions possible, and then it can undergo such a kind transformations this is widely observed. So, basically these two things will have same crystal structure alpha 1 and alpha 2 same crystal structures, but beta will have different crystal structure. The composition will vary see alpha 1 has a compositions given by this point alpha 2 has a composition given by this point at this monotectic temperature monotectoid temperature so that is the difference. So, this is there in the book. Now, few two systems I am going to discuss where these things are observed one is known as nickel zirconium.

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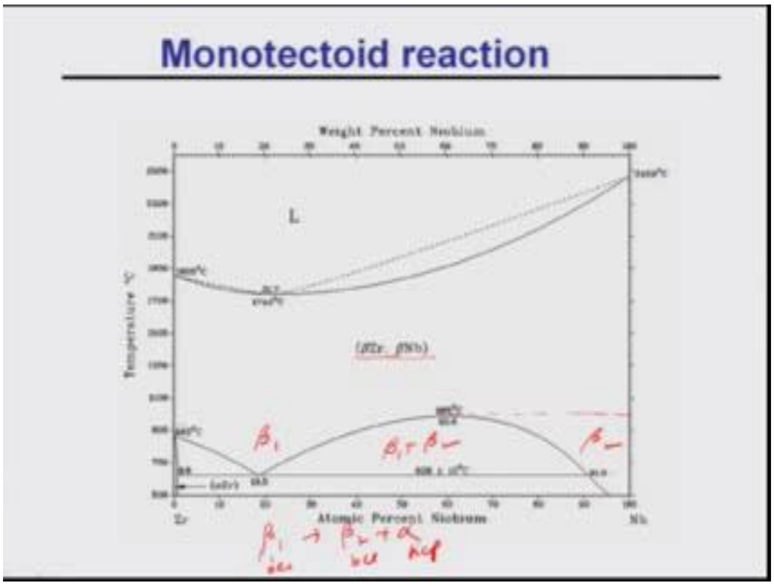

I do not assume as zirconium actually zirconium happens to (Refer Time: 17:56) two crystal structures room temperature it is a C p high temperature it is a bcc. So, one can actually transform this high temperature phase which is bcc beta monotectoidically to alpha plus niobium solid solution that is what is shown here. So, you see here this is the exactly same as I have drawn. So, at high temperature, you have a isomorphous phase diagrams leading to formation of beta niobium-zirconium solid solution which is bcc and then you this transform into alpha zirconium plus this is basically beta 1 plus beta 2. So, this is beta 1 and this is beta 2, and here this critical temperature 988 monotectoid transformation temperature 620.

So, therefore, this two beta will have bcc structure alpha and zirconium has a acp structure as you see here. So, basically reaction is like this beta 1 going to beta 2 plus alpha. So, beta 1 has a bcc structure beta 2 has a bcc structure alpha has a acp structure this is only because of this structural differences of the zirconium low temperature and high temperature phases that is why it (Refer Time: 19:25).

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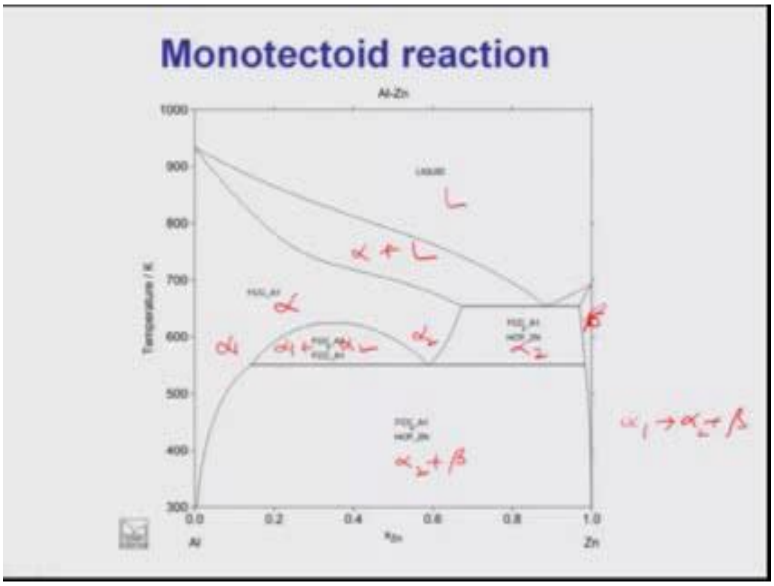

But one can also have a different thing possible when you have aluminum zinc system. In aluminum zinc system also you will have you know this is classically eutectic system. So, you have a large solid solubility then eutectic reactions and this leads to liquid, liquid plus alpha, alpha and this one transform into alpha 1 plus alpha 2, and then this is where this fcc a one alpha plus alpha plus this is suppose gamma or beta. So, this will be alpha 1 plus this is alpha 1, alpha 1 plus beta So, reaction is alpha 1 going to I am sorry this will be alpha 2, alpha 2 plus beta this is the monotectoid reactions that is how things actually happens in monotectoid reaction. But here there is no you know such thing happen like nickel zirconium nickel zirconium, zirconium actually remains is two two difference kind of states that is why nickel zirconium has such a kind of structure, but in this case it is not the case. So, therefore, such a kind of thing is not true.

As you see here the compositions of alpha 1 alpha 2 can vary this is the alpha 1 composition this is the alpha 2 composition I think this is alpha 2 yes cannot be alpha 1, so that is what is correct alpha 2. So, as you one thing you understood this reads this diagrams this phase diagrams are very uncommon that is why we are not used to it even I am not used to it this phase diagrams. So, sometime I am also making mistakes, but you have to read it properly to understand that, but you can correct that that is the way I am doing it you can correct this phase fields. So, with this, actually I complete my short lecture on these solid-state reactions.

Now, in the next class we are going to take up few ceramic phase diagrams and show you how the ceramic phase diagrams actually can be read or can be interpreted. Obviously, we will take simple ones like solid solution eutectic, peritectic or may be some solid-state reactions. So, we will spend few lectures on that and before actually moving to something else like ternary phase diagrams.

Thank you.