Phase Equilibria in Material and metallurgical (Nature and Properties of Materials - II)
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Lecture – 24
Phase evolution at Eutectic point

So, welcome again to this lecture number 24. We will first recap the last lecture.

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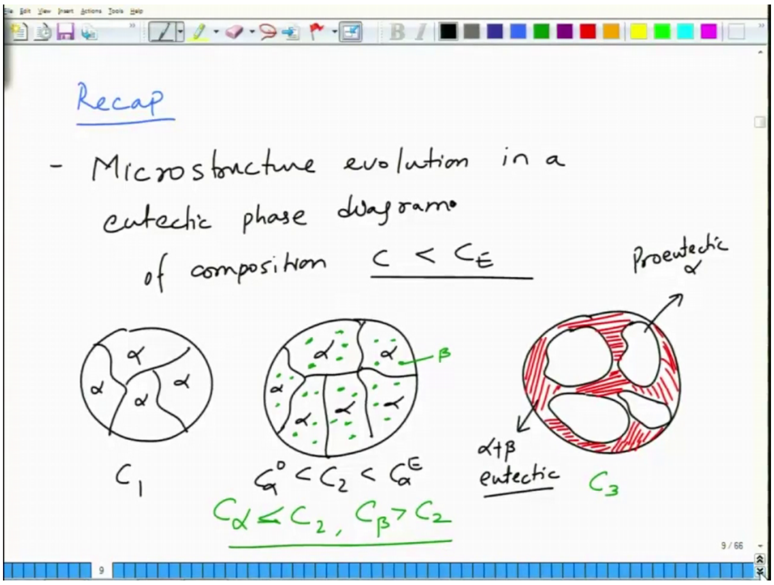

And in the last lecture, we looked at the micro structure evolution in a eutectic phase diagram of composition C less than C E, ok. So, we first looked at the composition in which we formed a single phase alpha, like this. So, this was C 1 composition, and then we looked at composition C 2; which was between C alpha E, and C alpha lecture 0 at lower temperatures.

So, what we has there had there was we had these grains of alpha. So, this is alpha and in between we had these precipitates of beta phase. So, this is beta phase and which were present in a matrix of alpha. So, the composition of alpha was C alpha was lower than C 2, and C beta was higher than way higher than C 2. And phase fractions can be found using lever rule, and then we looked at composition C 3; which we were looking at is which in which you have you have alpha phase. So, you have alpha phase, within this you had these, sorry, let me draw it differently.

So, we had these alpha grains. These were alpha grains, and between these alpha we had this eutectic so, this is eutectic. So, let us say this white in this I think, it is easier to draw the white one. But this is pro eutectic alpha, and what you have here is, alpha plus beta eutectic. So, this is where we were. So, we will continue our discussion on this.

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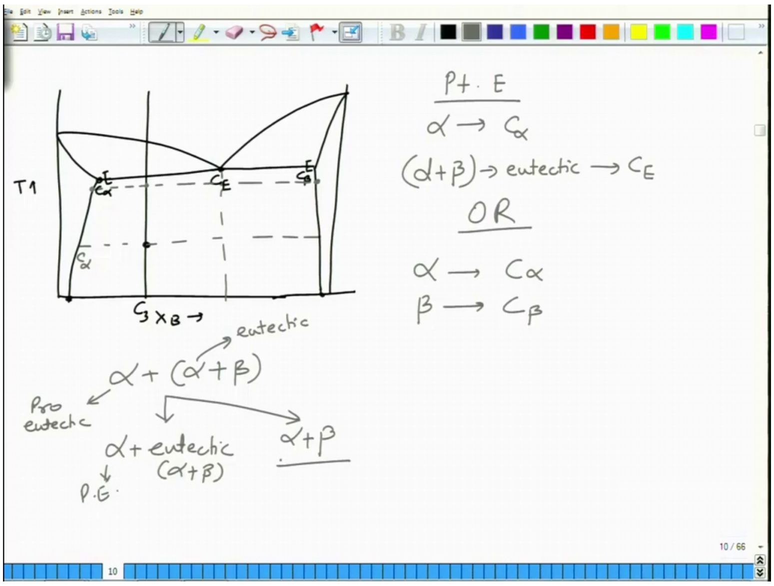

So, we drew a microstructure for phase diagram like this. And we were in this region so, this was C 3. So, at this point so, when you taught at 5 phase diagram completely, this is let us say the phase diagram, am sorry, ok. So, this is the composition C E, this is the composition C alpha, this is a composition C beta at eutectic temperature and then you have C alpha C beta. So, when you are at this point, the compositions of alpha and beta are given as C alpha, let us say I cannot remember what was the point.

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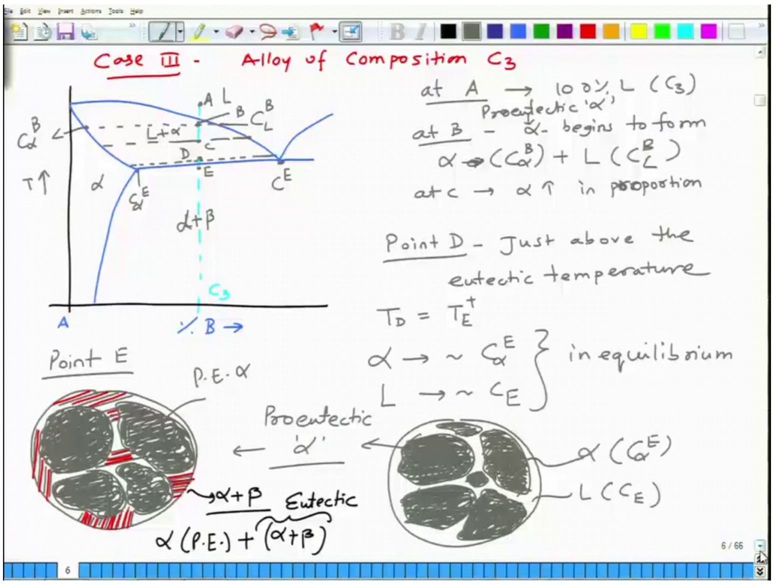

Let us see what point it was, it was point it was point E ok, at point E. So, when you are at point E, this is the point E, let us say below the eutectic temperature.

So, at this point E you have alpha of composition C alpha, let us say which is almost similar to eutectic composition and then liquid and then alpha plus beta mixture which is eutectic mixture of composition. So, you can have 2 ways of describing it. You can say the alpha of composition C alpha, and eutectic of composition C E, or if you just want to describe in alpha and beta, then you can say alpha of composition C alpha and beta of composition C beta, which is this one ok. So, it is necessary to understand this difference, because otherwise it will create confusion in understanding what you get here. So, I will come back to this later, but at point E the microstructure that you get in the previous picture.

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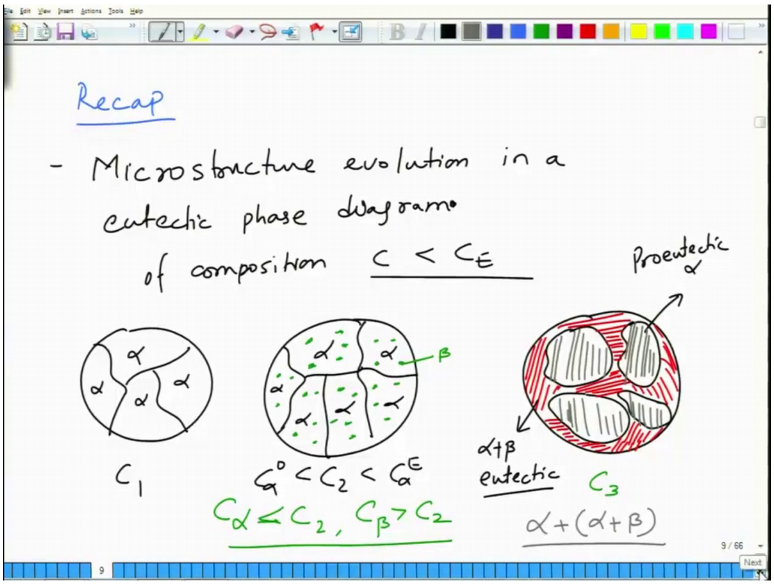

It is a mixture of alpha plus alpha plus beta, ok. So, this alpha plus alpha plus beta can be described in 2 ways. So, first way could be it is alpha plus eutectic ok, this eutectic it is alpha plus beta. Or you can simply say it is alpha plus beta which is also fine. But then the distinction is here alpha is present in 2 different forms. Although, the alpha of composition of alpha is same, composition of alpha in both eutectic as well as in pro eutectic phase is same, same as C alpha. The form in is in which alpha in this image the alpha pro eutectic alpha is present in this form of these grains; where is in the form of eutectic it is fair it is present in the form of these plates. Both of them have similar composition is just that their morphology is different; whereas, beta is present only in the form of plates. So, this alpha is pro eutectic alpha, and this is eutectic alpha.

So, the choices generally of the reader, whether he would like to he or she would like to present it as pro eutectic alpha, plus eutectic alpha and beta or total alpha and total beta. So, how do you find the proportion of proportions of these alpha and beta pro eutectic alpha and alpha plus beta or alpha plus beta? We will come to that later on.

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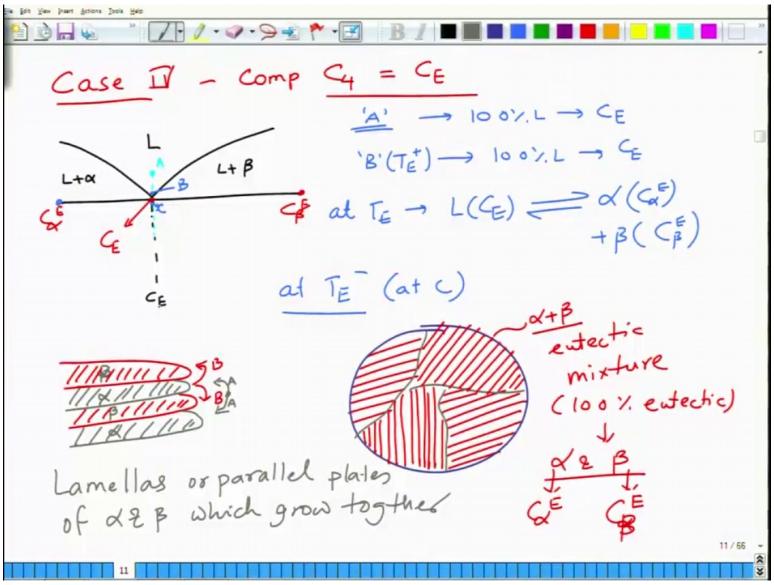

Now, finally, let us discuss the microstructure evolution of case 4, which is of composition C 4; which is same as C E. So now, we are looking at eutectic composition. In this case the phase diagram, so, let us just draw the phase diagram corresponding to a eutectic region

So, we have liquid, we have liquid plus alpha, liquid plus beta and this is of composition C E. And this transforms at various points. Now let us look at the transformation at various points. At this point, it is 100 percent liquid of composition CE, ok. Just before the eutectic temperature, let us say point B, which is let us say T E plus just before the eutectic temperature it is in 100 percent liquid form of composition. Just below the eutectic temperature, at the eutectic temperature, it undergoes a eutectic reaction at T E, liquid of composition C. Liquid of composition C E dissociates into 2 phases, alpha of composition C alpha E eutectic plus beta of composition C beta E.

So, at T E minus what you will see which is at point C, at C what we will see is that, a mixture of only alpha and beta. So, the microstructure would like this, would look like this. So, you will have these grains of eutectic. So, these are so, let me like this. So, this will be alpha plus beta eutectic mixture. It is 100 percent eutectic consisting of alpha and beta; alpha of composition C alpha E and beta of composition C alpha C beta E. Now alpha and beta proportions can be found out by applying lever rule. So, we will do the exercise of so, this is C alpha E, this is C beta E and this is C E, the proportions can be found by applying lever rule.

So, this is how the microstructure evolves; microstructure so when you have composition either on the hyper eutectic side less than the solid solubility of being A or A and B, you form a single phase alpha, you can have beta if you are on the B side. When the composition is higher than the solid solubility of being A at room temperature, but lower than the solid solubility of being A at eutectic temperature which is typically higher then you have grains of alpha with small precipitates of beta present in the grains of alpha; where alpha composition is typically lower than the alloy composition, and beta composition is significantly higher than the alloy composition. But the proportion of beta is significantly lower.

In the third case what you have is you are in the so, let us let us before we go to third case. We go to case 4; in this case we are at the eutectic composition, where liquid of composition C E transforms directly into a mixture of alpha and beta. And alpha and beta, since they form all of a sudden like word has to convert into alpha and beta together; it tends to form in a red ordered fashion. So, the way it forms is that, you have these colonies of alpha and beta growing parallely like this. This is alpha; so, this is beta, let us say this is alpha this is beta this is alpha. So, let us for the sake of color coding, let us say this is of this color. Whereas, beta is of this color, ok. What happens is that, we know that alpha is rich in A and beta is rich in B. So, as a result, since alpha has formed from liquid and it is rich in A the B atoms have to migrate to this side.

So, B atoms migrate to this side; whereas, beta B beta face being rich and B the A atoms migrate from beta to alpha, these are A atoms. So, a atoms migrate from beta from to form beta. So, that they form they go towards alpha whereas, B atoms are shifted towards beta. So, that they form alpha beta. So, that is and since it happens together, both of them grow together, and they grow together in the form of panel plates typically which are called as lamellas. These are lamellas or parallel plates of alpha and beta which grow together through solute partitioning ok.

So, this is how the microstructure of a eutectic would typically look like, parallel plates of alpha and beta, the composition of alpha would be C alpha composition of beta would be C beta E, but the overall composition of alpha and beta would be C E we will come to the lower fractions phase fractions a little while later. And for the composition which is between the solid solubility of being and a eutectic composition you have a microstructure like this, in which you form a pro eutectic alpha which is this phase. So, this is the gray phase, pro eutectic alpha. And whatever liquid is remaining just about the eutectic converts into the eutectic alpha and beta mixture; where alpha beta phase is the red phase and alpha phase is the light colored phase. And they so, the microstructure looks like this.

So, I will show you the real microstructures in a little while, before we finish but let us finish the composition analysis, and phase fraction analysis of eutectic phase diagram. So, I hope you understand what we have done at this point in terms of microstructure evolution.

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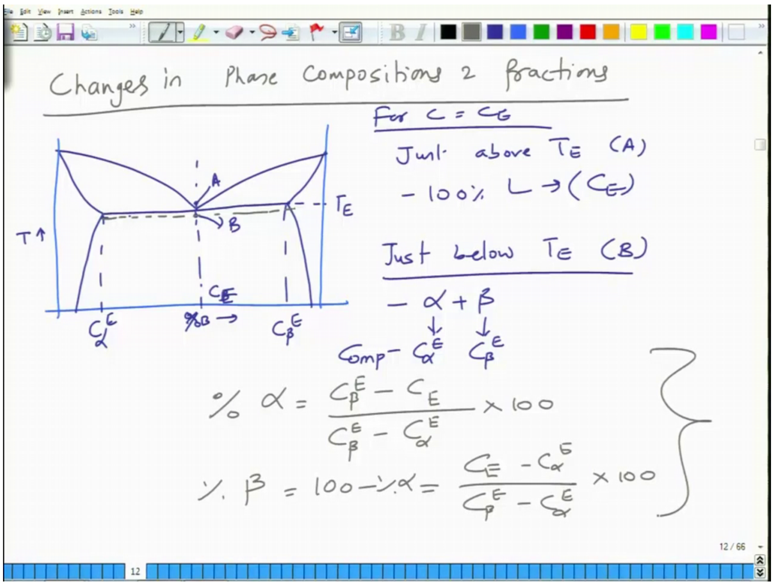

So now let us look at changes in the phase compositions and fractions. So, let us begin with, let us first begin with eutectic composition itself, ok. So, this is percentage B this is C, CE, ok.

So, at C E just so, this is eutectic temperature just above. So, for C is equal to C E alloy composition is C E. So, just above T E we have 100 percent liquid of composition C E, just below T E, we have mixture of alpha and beta. Alpha of composition C alpha E, and beta of composition C beta E, C alpha E and beta of composition C beta E. So, this is at this point so, first we are looking at this point A and now we are looking at B, ok. So, we draw we draw the tie line, and percentage of alpha is nothing but C beta E minus C E divided by C beta E minus C alpha E, in 200. Similarly, percentage beta will be equal to 100 minus percentage alpha or C E minus C alpha E divided by C beta E minus C alpha E into 100.

So, this is how you determine the proportion of alpha and beta phase in the eutectic; when you have 100 percent eutectic mixture.

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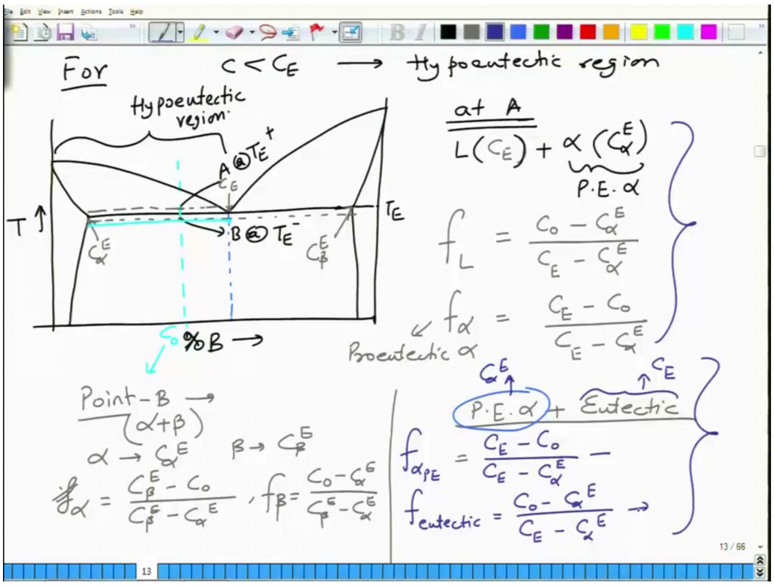

Now what happens when situation is different when you have what happens for composition which is less than C E in the hypo eutectic region? Of analysis which we are doing for high eutectic region is valid for hyper eutectic region as well. So, we will not do that in here. So, we have again below the phase diagram. Now we are at a composition which is this composition, which is C naught, ok. So, this is the composition C naught which is a so, this region is called as hypo eutectic region, ok. So, just above this temperature so, we first look at the temperatures.

So, this is T E so, we look at point a which is equal to T E plus, and we look at point B which is at T E minus just below T E and just above T E. So, at A just what we have is we have liquid of composition. So, if we draw a tie line so, we have liquid of composition C E. So, this is the point C E, this is the point C alpha E, and this is the point C beta E. Liquid of composition C alpha C E in equilibrium with alpha of composition C alpha E. So, this is pro eutectic alpha, so, what is percentage liquid at this point? Percentage liquid is or fraction let us say fraction of liquid ok, f L.

So, f L is nothing but C naught minus C alpha E divided by C E minus C alpha E, this is the f L and f alpha is nothing but C E minus C naught divided by C E minus C alpha E. These are the fractions of 2 phases. Now this liquid will transform into so, this is fraction of pro eutectic alpha pro, eutectic. Now the moment you come to point B you have 2 options. One either you describe the microstructure as alpha or beta, or you describe the microstructure as pro eutectic alpha plus eutectic.

So, when you want to do as pro eutectic all when you want to do just as alpha and beta, in that case when you draw the tie line, you look at the intersection of tie line with the alpha and beta solvers. So, this point which is same as C L phi N C beta. So, at point B which is just below eutectic temperature. Alpha is of composition C alpha E and beta is of composition C beta E. So, fraction of alpha is same is C beta E minus seen C naught divided by C beta E minus C alpha E. And fraction of beta is equal to C naught minus C alpha E divided by C beta E minus C alpha E. However, if you want to now represent the microstructure in this case, then C then fraction of pro eutectic alpha is now in this case instead of considering the now you are considering through eutectic phase alpha and eutectic phase.

So, if you want to consider the eutectic phase, you need to consider this as a boundary of tie line. So, when you thought a tie line now, the tie line is from here to here, not from alpha to beta it is from alpha to eutectic. So, then fraction of in this case your alpha is of composition C alpha E, and eutectic is of composition C E, ok. So, f P E the pro eutectic f alpha P E is equal to C E minus C naught divided by C E minus C alpha E ok. And f eutectic is nothing at nothing but C naught minus C alpha E divided by C E minus C alpha E. And if you notice what we have done for point A is same as for point B, if you consider pro eutectic alpha basically, whatever the liquid was present earlier that is converted into eutectic.

So, these 2 are same, the percentage liquid that is calculated here at point A is same as percentage eutectic that is calculated at point B, if you just consider liquid; however, if you consider alpha and beta phases separately, then their compositions as well as fractions are different. So now, you can you can also calculate from this, this is the amount of pro eutectic alpha. This is the amount of eutectic; you can calculate what is the amount of alpha in the eutectic. So, amount of alpha and the eutectic would be amount of total alpha minus.

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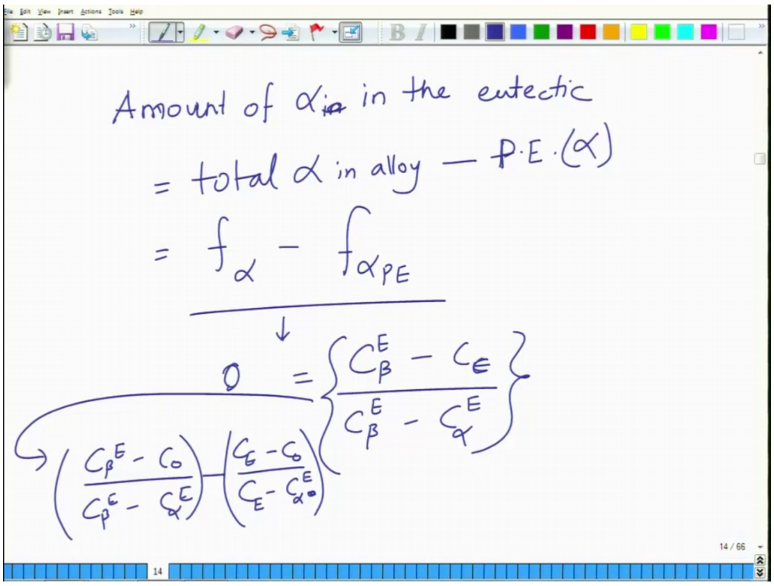

So, amount of total alpha in alloy minus pro eutectic alpha. So, total alpha in the alloy is given as let us say which is basically this f alpha, which is f alpha minus f alpha P E. This is how you determine and this you can also determine from just by doing that and this should work out to be same as. So, this alpha and the eutectic will be same as C beta eutectic minus C E divided by C beta eutectic minus C alpha eutectic. So, this should be same as this. So, if you if you subtract f alpha P E if you subtract f alpha P E from f alpha.

So, which is basically you can do the maths C B. So, basically C beta E minus C naught divided by C beta E minus C alpha E C beta E minus C alpha E minus of C E minus C naught C E minus C naught divided by C minus C alpha C alpha E. So, this is what basically this will be. So, this is how you determine the proportion of different phases and pro in below and our eutectic temperature in the in the mix eutectic mixture as well as in the liquid phase. So, we will do further analysis of phase diagrams in the next lecture.

Thank you very much.