Phase Equilibria in Material and Metalluurgical (Nature and Properties of Materials - II)
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Lecture – 23
Phase evolution in Hypoeutectic region

So welcome again and we discussed a new lecture again today lecture number 23. So, before we get into this lecture, let us recap the last lecture.

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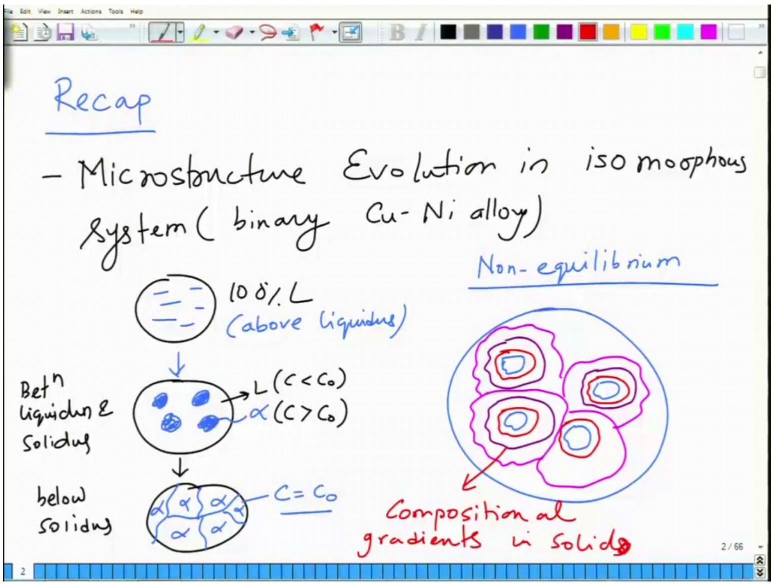

So, in the last lecture, we discussed the Microstructure Evolution in isomorphous system and basically binary copper nickel alloy. So, we looked at the microstructure on both equilibrium and non equilibrium condition. So, under equilibrium condition, your microstructure goes from 100 percent liquid to this is above liquidus to from a intermediate state between liquidus and solidus where you have this chunks of alpha phase.

So, this is alpha phase and this is liquid phase. So, alpha of composition some intermediate alpha of composition typically higher than the it will be x C greater than C naught and this will be typically C less than C naught ok. And finally so, this is between liquidus and solidus and finally, below solidus. You will have completely alpha phase.

So, this is alpha alpha alpha alpha alpha alpha; these are grains of alpha separated by the grain boundaries and this alpha will be of composition C is equal to C naught.

So, this is how the equilibrium structure will develop. On the other hand, mic in the non equilibrium structures, now non equilibrium happens because the cooling is not slow enough because of that the solute partitioning in the solid state is not complete as a result the solid which forms earlier is richer in solute as compared to the solid which forms later.

So, as a result the microstructure that we form is am not going to draw all the microstructures, but the microstructure that is formed the material initial chunks which are followed by chunks which are formed at a later stage. And then you have another and then the next one; this is just schematic ok. So, what it depicts is that you have compositional gradients. So, you have compositional gradients in solid in solid phase which have to be removed by a solutionizing or homogenizing treatment after the solid has formed.

Now this is something which happens most alloys because of because the cooling rates are fast as a result solid state diffusion being slower cannot lead to complete homogenization of the solid within the during the solidification itself. As a result extra (Refer Time: 04:13) extra homogenization step is needed to homogenize the solid.

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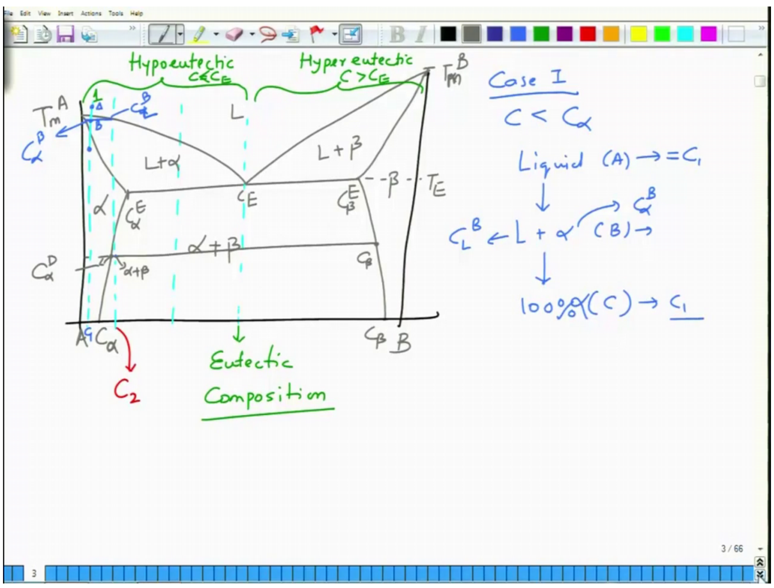

So, these are the two microstructures that we looked at in alloys. What we were finally, looking at was phase evolution in a hypoeutectic phase diagram. So, you have a eutectic phase diagram like this ok. So, you have liquid plus alpha alpha alpha plus beta liquid plus beta and beta phase. So, what we want you to understand here is so, this is the composition CE, this is the composition C alpha E, this is the composition C beta at the eutectic temperature.

So, this is T E. So, this is TM B took this as B, this is TM A and B sort of solid solubilities in alpha and beta at eutectic temperature and these are the solid solubilities of alpha and beta at room temperature C alpha and C beta at room temperature; all are at room temperature. Now we want to understand that evolution of microstructure in such a solid at various composition.

So, for example, this could be the first composition, this could be the second composition, this could be the third composition and this could be the fourth composition. The evolution of microstructure on the other side will be similar to what happens in the left side if such that the phase is a different. So, as you know in the eutectic phase, diagram this region is called as hypoeutectic hypo eutectic in the lower than the eutectic composition. So, basically C less than CE and this region is called as hyper eutectic here C is greater than CE and one which is at the center is called as eutectic composition.

So, we first looked at the scenario 1. So, in case of case 1 when C composition of the alloy is lower than the C alpha, which is this point. So, at this point what happens is that the alloy goes from liquid state to liquid plus alpha. So, at this point liquid, then it converts into liquid plus alpha. So, this is A this is B and finally, at C it is 100 percent alpha at C. So, liquid composition at this point is same as let us say C 1 C 1.

At this point your you can draw the tie line, so, you will have composition of liquid as CLB and composition of alpha will be C alpha B which is so, this is C alpha B and this point will be sorry this will be CLB, this will be C alpha, D this is the tie line that you draw and finally, when you come to 100 percent C point 100 percent alpha then what you have this composition is same as C 1.

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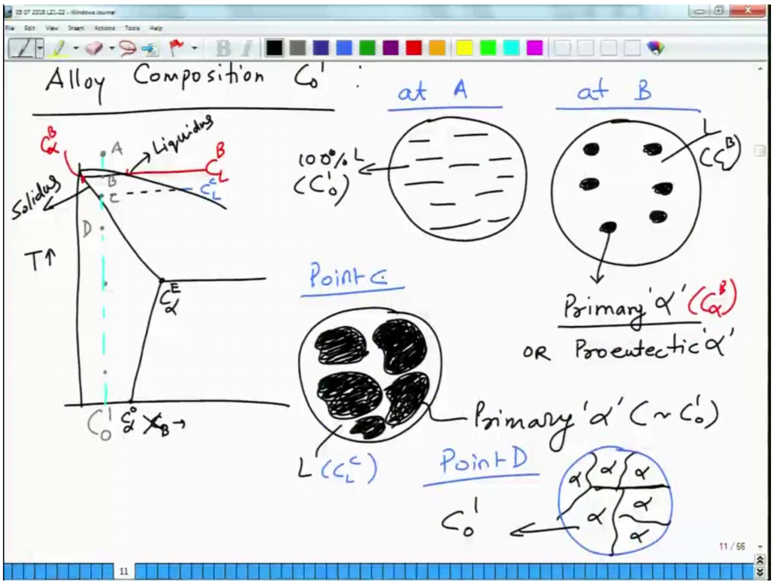

So, this is how the microstructure evolved. So, the microstructure when if I go to this lecture, I will just open the mi the microstructure from 100 percent liquid to some B at point B and these compositions different and this alpha is called as time real for eutectic alpha. And before this alpha is nearly from if you buy little amount of liquid and when you are passed the solid solidus line, then 100 percent alpha of compositions C naught 1 C 1 ok.

This is how we did the microstructure evolution and we finished, we were at this point looking at microstructure of an alloy whose composition is higher than the solid solubility B will be in A at room temperature. We will close this and we will go to; so, this is what we will do now.

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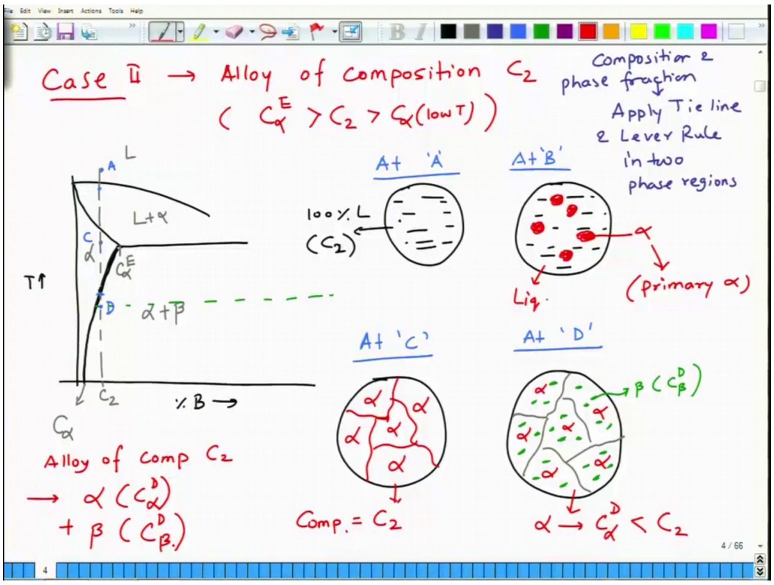

So, case 2 is for alloy of composition C 2. And what is C 2? This is C 2. So, this is C 2. So, C 2 is an alloy whose composition is higher than C alpha, but lower than C alpha E. So, it is C 2 is higher than C alpha which is at low temperature or room temperature in most many cases, but lower than C alpha at eutectic temperature. So, that is the solution. So, phase diagram looks like. So, am just doing that phase diagram, I will not draw completely. So, this is percentage B this is temperature. So, this is the eutectic line and this is your scenario is and following an alloy whose composition is this.

So, this is C 2 C alpha, this is C alpha E ok. So, we are so, this is liquid this is liquid plus alpha this is alpha and here you have alpha plus beta. So, what will happen here is that now let us take the point A. So, at A microstructure consists of 100 percent let me draw a little small circles otherwise will not able to draw all of them here. So at A, it is hundred percent liquid and whose composition is same as C 2.

Let us go to point B it is point B point B is just below the liquidus. So, point B what you will have is you will have liquid mostly with some solid forming. So, solid will be present. So, these chunks of small pieces of solid which could be regular in shape, this is alpha and this is pro eutectic or primary alpha ok. So, this is primary alpha pro eutectic is generally which is above the eutectic line.

So, in most cases we call it is as primary alpha. So, this is primary alpha and composition of this can be determined by tie line and this is liquid when you come to point C. So, I will not discuss the complete. So, solidification through this line. So, when we come to point C, so as a home exercise what you can do is that apply tie line and lever rule in 2 phase regions to determine the phase compositions and the fractions. So, at C, so this is for composition and phase fraction determination. At point C what we have is we will have so, this alpha would have grown into bigger pieces and finally, the liquid is completely solidified.

So, what you will have is you will have these chunks of alpha. So, this is alpha these are grains of alpha which are separated by grain boundaries. So, these are grain boundaries and the overall compositions of alloy is same as C 2 composition same as C 2. Now what happens is that we will come to point D here, what happens is that as you come into the solidify as you come into the solid region and as you keep decreasing the temperature, the solid solubility of D in a decreases gradually. So, this line is solidus line that shows that solid state will be of B in a gradually decreases,which means at this point the moment alpha plus this particular point.

This is the cross over point, it starts moving it starts expelling B out of it and that B precipitates in the form of beta phase because if you look at the phase diagram and the right side you have beta phase. So, if you look at this point. So, we are looking at this point if we draw tie line at this point, what you have is alpha and beta phase equilibrium this is the composition of C alpha at whatever D and this is the composition of C beta at this particular point. So, what happens here is you have this alpha phase the grains of alpha ok.

So, you have these grains of alpha and within these grains of alpha you have formation of some beta phase. So, beta phase gets precipitated in the form of small precipitates. So, small crystals of beta will be forming here and there. So, this will be beta phase and beta phase composition is given by tie line which intersects at some point composition is beta B and the composition of alpha is changed to C beta D C alpha D sorry, which is lower than C 2 ok. So, basically an alloy of composition C 2 is a mixture of alpha of composition C alpha D plus beta of composition C beta D the phase fractions can be formed by similar manner.

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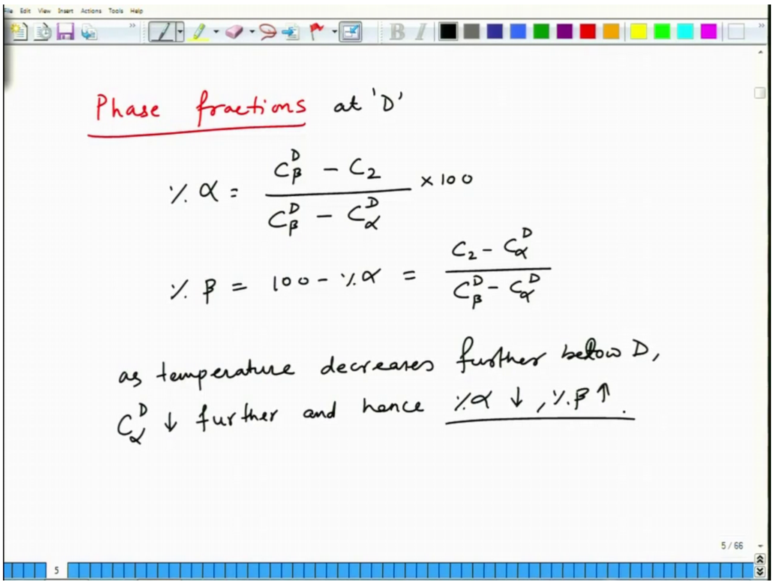

So, when you apply lever rule So, phase fractions at D at D you will have percentage alpha will be equal to C beta D minus C 2 divided by C beta D minus C alpha D into 100. And percentage beta will be equal to 100 minus percentage alpha which is equal to C 2 minus C alpha D divided by C beta D minus C alpha D. So, as you can see that as temperature decreases further below D, you can see that C alpha D decreases further. And hence percentage alpha decreases and percentage beta increase, but the microstructure remains nearly the same.

However, so you will have these precipitates of beta formed in matrix of alpha and alpha has the major phase because the composition is have to be eutectic alpha is the major phase the tiny precipitates of beta present within the grains of alpha. So, this is how the microstructure of an alloy of composition C 2 which lies between the solid solublilities at of B and A are eutectic temperature and at low temperature.

So, you within the solid state itself at point C alpha it is 100 percent alpha when you are in the only alpha region whereas, you decrease the temperature solid solubility of B and a goes down which means also alpha becomes thinner in B. And as a result the composition of alpha becomes more a rich and closes B out in the form of beta and hence upon D you form a mixture of alpha and beta, which proportion of alpha and beta increases a proportion of alpha increases as you decrease a temperature.

So, this is how the microstructure will form in case of point in case of C 2 composition. Now let us look at microstructure evolution in case of C E 3 again.

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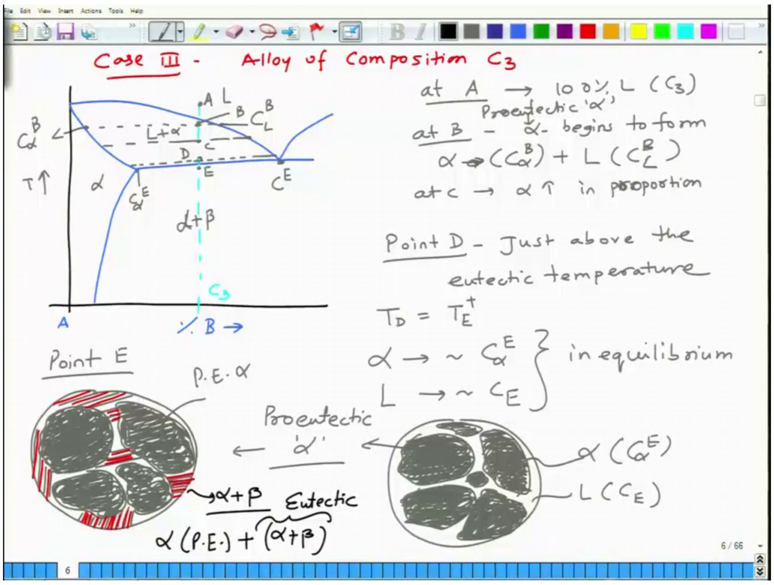

So, this is case 3 alloy of composition C 3 and that you define what C 3 is this is C 3 ok. So, if I again draw the zoomed in part of the phase diagram, we are standing at about this point this is C 3 composition and we have the phase fields liquid liquid plus alpha alpha and liquid plus alpha plus beta ok. Now again let us look at point A. At A you have 100 percent liquid of composition C 3, which is same as before at B. At this point alpha begins to form. So, at B this is point B.

So, composition is C alpha C liquid B this is liquid and this point is C alpha B by the way this is temperature axis. So, alpha begins to form. So, alpha of composition C alpha B is in equilibrium with liquid of compositions C liquid B and you can find the fractions using the lever rule. And this alpha, so what microstructure will be same.

So, as if you reach point C for instance, so this is point C the alpha will increase in quantity and liquid will decrease until you reach point D. So, at C, I find increase in proportion and this composition changes which you can determine using tie line rule. The moment you reach point B, so, I will not draw the microstructure at ABC because you have to be convergent with them. So, and you can draw there you can return in their composition and phase fraction using tie line lever rule when you reach point D, which is just above the eutectic ok. So, T D is basically T E plus, if you decrease our eutectic temperature.

So, at this point what you have is alpha of composition nearly C alpha E, which is this point and liquid of compositions CE. So, alpha of composition and C alpha E and liquid of composition C E. These are in equilibrium and the moment you go below this point the moment you go to point E, so basically what you have at this point is you will have basically alpha. So, this is so, this is alpha of composition C alpha E and very little liquid is left of composition CE just above the eutectic temperature.

So, you can determine the phase fraction of and this alpha is called as pro eutectic alpha ok. So, this alpha which will begins to form as called as pro eutectic alpha or primary alpha and when you reach point E when you reach point E. This alpha remains as it is, but the liquid undergoes this eutectic reaction and it converts into a mixture of alpha and beta. So, the microstructure looks something like this. So, you have this alpha grains. So, these are a very similar one. So, you have these alpha grains let me try to draw them actually little dark.

So, these are alpha grains which are absolutely dark phase grey phases. Am making it absolutely because they are eutectic feature phase slightly it looks like. So, this is alpha. So, alpha will be; so, this is the pro eutectic alpha of composition C alpha E and then liquid converts in to a mixture of alpha and beta. So, this appears as this eutectic mixture which is of the form of platelet us.

So, you will have this platelet us of alpha and beta. So, the platelet us will appear as if you have these grey and red plates. It is like parallel plates of alpha and beta growing together. If we microscopically look at it if we zoom it up, so basically what you have is so, before this is basically mixture of alpha plus beta. So, eventual microstructure at point E is alpha, which is pro eutectic plus alpha plus beta which is eutectic mixture. The phase wise both the alphas are same both have similar phases this alpha is same as this alpha is just that the morphology of this alpha, the appearance of this alpha is different from the appearance if alpha which is present in the eutectic.

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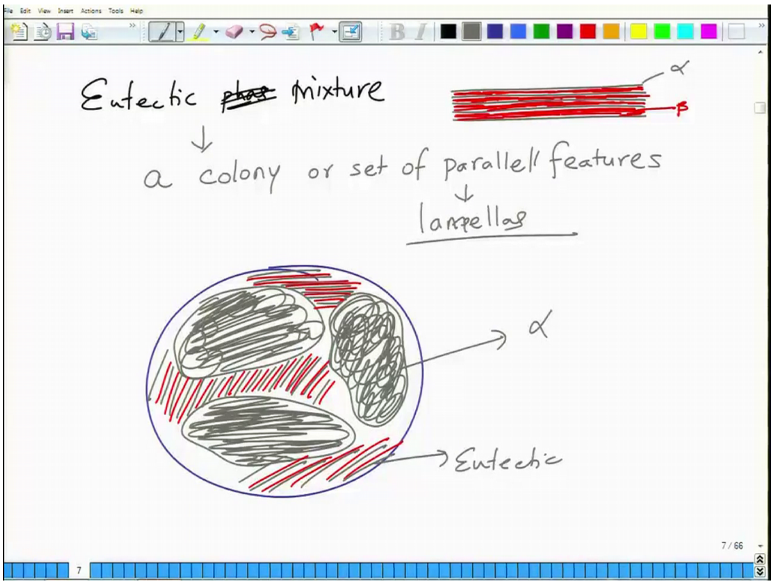

So, in the eutectic so, within the eutectic phase eutectic is not a phase mixture within the eutectic mixture you have these parallel plates of and this is alpha let me just draw it again. So, these are parallel plates of alpha and beta. So, red one is beta here and the grey one is alpha. So, eutectic mixture is basically colony or set of parallel, parallel sorry features which is called as lamellas. So, these are alpha and beta lamellas which grow parallel to each other. So, if you look at the mixture of and the pro eutectic the if you look at the microstructure of pro eutectic composition, you have this phase which is alpha phase which is present like this ok.

So, and between these regions of alpha sorry and between these you have these plates of alpha and beta growing parallel. So, this is one orient they can grow in different oriented orientations. So, this alpha and beta could be like this similarly here. So, this is basically what is the eutectic and this is what is the alpha phase. So, I will come to some more details about this eutectic transformation in the next lecture, but what we have done in this lecture is to look at the phase evolution in eutectic phase diagram in the hypo eutectic region and of 3 compositions.

Thank you.