Materials Science and Engineering

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Lecture – 17
Equilibrium cooling of eutectic system

Hello friends, so in the previous lecture we discussed about equilibrium and non equilibrium cooling in a system and we took isomorphous system as an example. Now moving forward we now want to see the again the micro structural development in a different system ok, the just to try to understand that in different systems what will happen if you do cooling and you have this phase transformation what type of micro structures will be there and isomorphous so iso isomorphous system it is very simple you will have liquid phase then liquid plus solid and the solid phase.

So, only 1 phase will be there for all the compositions, but for different systems you will see that now there is large difference in the what type of microstructure will develop for different compositions. So, now we will take an example of A eutectic system, we have already seen a eutectic system and not too complicated the concept too much right now we will consider equilibrium cooling of A eutectic system; that what will happen if I do equilibrium cooling, what type of microstructure will be there or what type of phases I will see in a microstructure at different compositions that is the idea ok.

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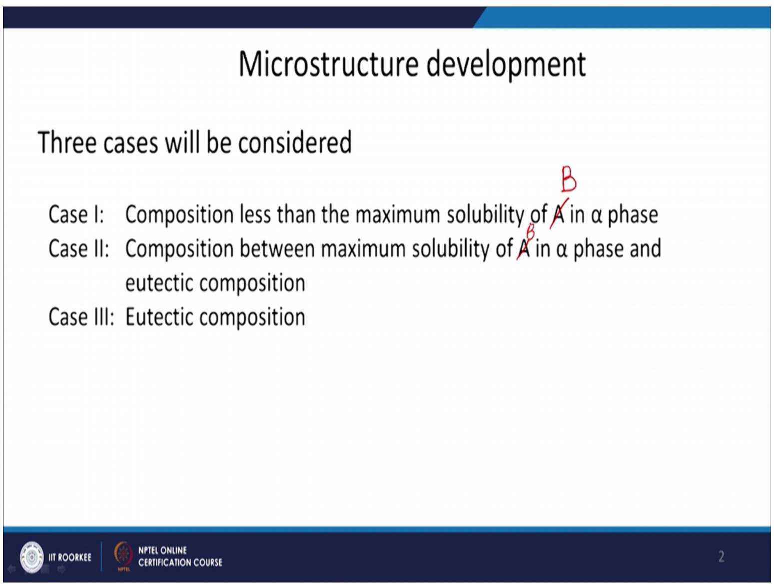

So, in this we will consider 3 cases case 1 is composition less than the maximum solubility of A in alpha phase ok, that whatever is the maximum solubility composition should be less than the maximum solubility of actually it should be B here. So, I am cutting this maximum solubility of B in alpha phase ok, then composition between maximum solubility of A in alpha phase and eutectic composition ok. So, again I will take A out of here and make it B ok, maximum solubility of B in alpha phase and eutectic composition and case third is your eutectic composition ok.

So, we will consider these 3 cases here and try to understand that what type of microstructures will be there ok, when I have all these variations ok. So, case 1 this is my if you see this is again our eutectic phase diagram.

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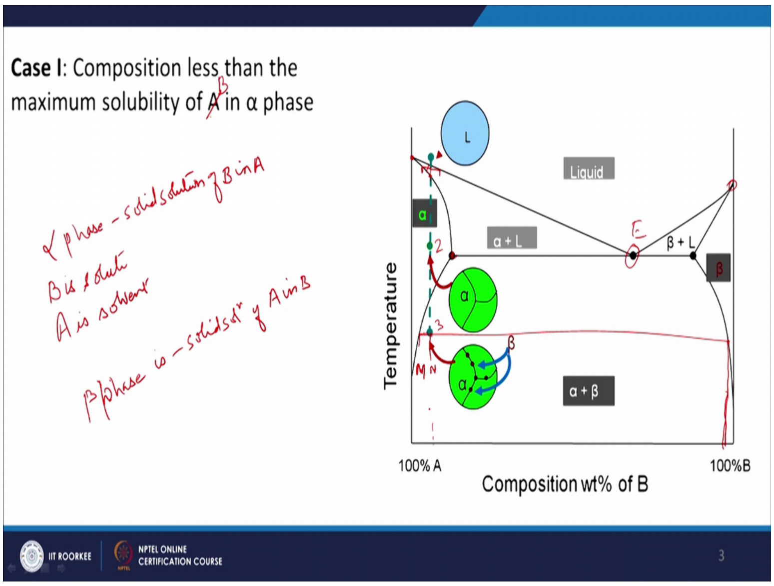

So, you have melting point of A here you have melting point of B here ok, you have A eutectic point here where liquid is transforming into alpha and beta phases; you have alpha phase here you have beta phase here and you have A alpha plus beta phase region here ok. In between as I told you earlier also between any 2 phase you should have A 2 phase mixture. So, between alpha and liquid, you will have alpha plus liquid between beta and liquid you will have beta plus liquid ok. So, this is your whole overall eutectic phase diagram and the eutectic reaction takes place here.

So, I will write E here to signify that this is A eutectic point. So, now we will see the composition less than the maximum solubility of again I will say this is B in alpha phase and that is the point which is this 1 ok. This is my maximum solubility of B in alpha phase ok. So, alpha phase is the phases which. So, which is A solute solution of B in A, so my B is A solute and A is solvent ok, so this is my alpha phase. So, alpha phase is A solid solution of B in A B atoms are in A, A atoms are more B atoms are less. So, A atoms is A solvent B atoms is A solute so alpha phase.

So, when we say phase means it is not A pure in terms of solid phases when we talk about it is not A pure pure A is pure A ok. If you add anything it will be A new phase and that we have to define that in that phase what constituents are there ok. So, alpha phase you can see that the solubility of B is varying as A function of temperature. So, I can add more B atoms in A ok, at A higher temperature and as you go to lower temperatures the solubility of B in A is decreasing ok. So that means, B atoms would like to come out of the solution ok.

So, now we want to have A composition c naught which is lower than the maximum solubility of B in alpha phase ok. So, I am starting with A liquid phase here ok, so I have heated my material I have gone to A temperature above which is given by the liquidous line here. So, my whole system is in liquid phase right now and from there I have started cooling down ok. So, you can understand that in between it will have as we saw in the isomorphous system suppose I draw A tie line here, you will have liquid and alpha phase.

So, alpha phase will have composition given by where this tie line is cutting the solidus line and liquid composition will be given by the composition where the tie line is cutting the liquidous line and you can also find out the fraction as we did earlier also and when the composition when my this cooling crosses the solidus line, the whole liquid is transformed into solid phase now ok, now I am in the alpha phase region here. So, now I have A alpha phase throughout the solution an alpha phase is A solid solution of B in A ok. So, it is shown here, that though the whole volume is now solid phase which has alpha grains and of course there is A boundary between these grains.

Now, if we keep on cooling ok, so the up to this point it is very similar to what we saw in isomorphous phase diagram ok, that you whole liquid transform to solid of 1 phase. Now once I as keep on cooling and my cooling crosses this solvus line. So, this is A solvus line between the alpha phase and the alpha plus beta phase region ok. So, as soon as it crosses the solvus line now you can understand that now B the solubility of B is going according to this curve here and my composition is more than that ok. So, you can understand this for example, at this point if I draw A line here you can understand this is my composition of the alloy and my alpha phase can take only this much number this much weight percent of B atom ok, though the overall composition is this much.

So, this much amount of B atom has to come out of the system because my system cannot take this much B atoms. So, these B atoms given by you can say this let us say let us call it some point let us say MN ok. So, the composition difference given by MN ok, that has that much amount of B atom has to come out of the system and how they will come out of the system these B atoms if you see the next equilibrium phase which is there it is between the equilibrium and this region is between alpha phase and beta phase. So, these B atoms will not come out as B atoms ok, they will come out as A beta phase; that means, A beta phase is beta phase is solid solution of A in B.

So, here B is solvent and A is solute, so B atoms will not come out as B atoms only they will come out in form of A phase and that will be given by that whatever is the equilibrium at that point. So, this is at this point at this temperature the equilibrium is between alpha phase and beta phase. So, all the B atoms will come out in form of beta phase and beta phase is A also has some solubility in B here. So, this much solubility of A atoms is there in B, you can consider that it may be around 6 percent or 7 percent of A can go in B ok. So, this B atom will come out in form of beta phase.

Now, to form this beta phase you need A kind of A nucleation site and that nucleation site will be provided by the boundary between the alpha grains ok, so all these beta atom the beta phase will nucleate at these boundary. So, at point let us say I call this point as 2, the point 2 this is all 1 single phase was there, at point 3 there some beta phase some B atom wanted to come out and they came out in form of beta phase. So, you can understand that beta phase has more of B atom and less of A atoms and alpha phase has more of A atoms and less of B atoms.

So, when B atoms are coming out they were all would like to come as beta phase because, they can have more B atoms and some A atoms will be there and that will kind of decorate this boundary here. So, this is the kind of microstructure you will say in case 1 ok, where composition is less than maximum solubility of B in alpha phase ok. Now the next condition of course, you please remember that we are talking here about equilibrium cooling only ok, so we are following the equilibrium phase diagram.

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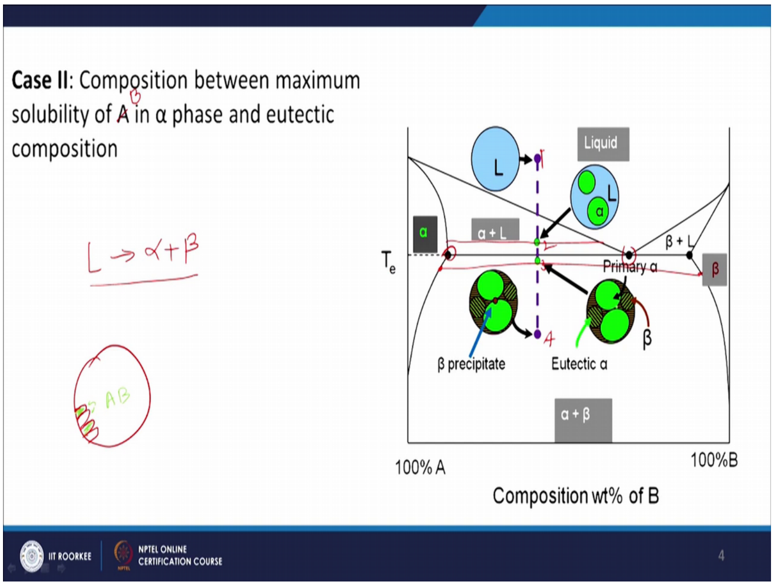

Now, the composition between the maximum solubility of B in alpha phase and eutectic composition ok, so it is between this point here and the eutectic composition here again we are starting with A liquid phase ah, let us call this as point 1 ok. So, the whole volume is liquid phase here and we are cooling ok, so when the it crosses the liquidous line here your alpha phase will start nucleating ok.

So, at point 2 here you have A lot of alpha solid phase is there and some liquid is there which can be of course, again can be you can find out using tie line and using lever rule. Then you cross the point from 2 to 3 just below the eutectic point here. So, what will happen when the you cross this from A point just above the eutectic temperature to just about below eutectic temperature.

So, at this point you have some solid phase and some liquid as soon as you cross this eutectic temperature, whatever liquid is there the all the liquid will transform to eutectic mixture and that is the alpha and beta phase in lamellar fashion ok. We have not discussed these aspects aspect till now, but right now let me take it from me and then I will discuss that why it is so ok. So, eutectic is I already we have discuss is A invariant point where the transformation takes place at A constant temperatures, so liquid will transform into solid at A constant temperature.

So, at point 3 or the at a point just above the eutectic temperature, suppose I suppose you take consider that point 2 is just about the eutectic temperature. So, let me draw A tie line here ok, so this is this gives me the composition of alpha phase this give me the composition of liquid phase, this arm length divided by the total arm length will give me the fraction of alpha phase, this arm length divided by the total will give me the fraction of liquid phase.

So, I have at least this much fraction of this much fraction of liquid phase available, which as soon as I cross this eutectic temperature that will transform into A2 phase solid phases alpha and beta. So, initially I had only alpha phase which was nucleating as you we shown here with these 2 circles here and as soon as this transformed from second to from a temperature above eutectic temperature to A low temperature below low eutectic temperature, all my liquid transformed into some eutectic mixture which is the alpha and beta mixture and why we are getting alpha and beta as you can see at point 3, if I draw A tie line ok. You will get composition of alpha like this and beta like this and the fraction of alpha and beta can also be can also be calculated.

Now, alpha this eutectic mixture which is the transformation is like that liquid transform into alpha and beta phases ok. So, there will be 2 alpha phases know, 1 when this transformation is taking place another which is transforming before the eutectic reaction took place ok. So, to distinguish between these 2 alphas the alpha, which is transformed before the eutectic reaction is called primary alpha here and the eutectic the alpha which has formed afterward is called eutectic alpha and of course eutectic beta that will come out of the come out of the that will form from the liquid phase ok.

If you go from the point 3 to point 4 ok, you can see that my solubility of A in beta phase in A in B or solubility of A is varying like this, so it is coming down ok. Similarly the solubility of B in alpha phase is also coming down. So, from alpha phase the beta precipitate should nucleate as you go from 0.3 to 0.4 ok. So, additionally this 1 more transformation will occur as I am going from 0.3 to 0.4 ok. Now let me also explain that why you get this kind of alternate layers of alpha and beta ok, suppose you have A liquid phase here and some nucleation has taken place and you are just crossing the eutectic point ok.

So, what will happen that when you are crossing the eutectic point my liquid has to transform into both alpha and beta simultaneously ok, so a very convenient way to do that is if I have both alpha and beta layers close to each other ok. So, basically it is alpha and beta then you have another alpha and beta and so on ok. So, let us say this is my alpha the green 1 and without any color is the beta.

So, how it this transformation takes place you get this alternate layers of alpha beta alpha beta and so on ok, the liquid contained some overall composition of some composition which consists of both A and B atoms and now these A and B atoms have to be redistributed in alpha and beta phase, you can see that alpha A phase has lower amount of B atoms and beta phase has higher amount of B atoms.

So, the from these liquid at A atoms and B atoms have to be separated out in alpha phase and beta phase. So, the A atom should go preferentially here and B atoms should go preferentially in beta phase ok. So, this redistribution has to take place in the liquid phase between the 2 phases and this can happen only when you have both the phases coming very close to each other. So, that this redistribution between the of A atom going there B atom going here and this flow of A and B atom is taking place in the liquid phase between the 2 alpha and beta and that is how they are growing ok.

So, for growth they need the alpha phase needs more of A atoms beta phase needs more of B atoms for the growth, so this redistribution takes place in the liquid phase and this takes place very easily if both the phases are coming very close to each other and that is why when you have eutectic transformation where from liquid you get 2 fix mixture at A constant temperature ok. So, this redistribution is easy if you both the phases are coming together and that is why you can see that all the eutectic mixture is shown as laminar microstructure here and now third is your eutectic composition of course.

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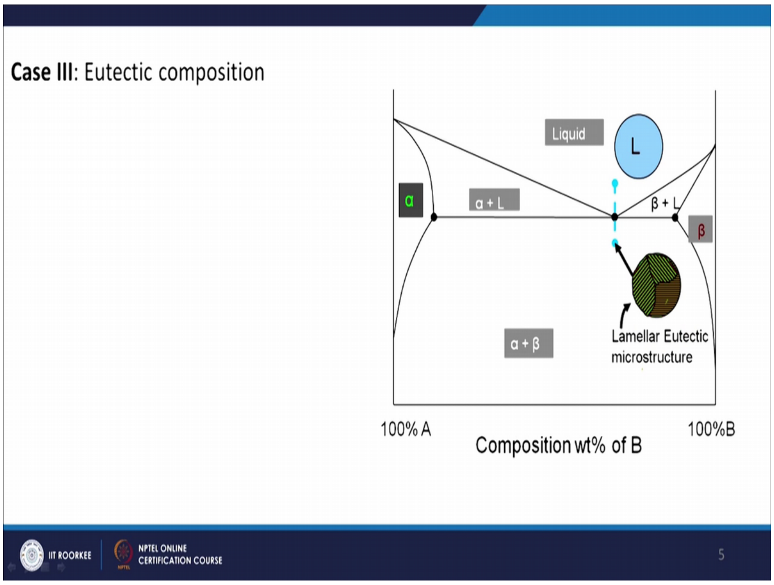

So, in this case if you have the overall composition which is at A given by your eutectic composition then from liquid phase ok, at A constant temperature the whole of the liquid phase will transform into the solid phase which contain both alpha and beta phases in A lamellar fashion ok. So, these are lamellar eutectic microstructure ok.

So, I have already told you that why you should get this kind of lamellar ok, because the redistribution of A and B atoms become easy between the this alternating alpha and beta phases and that is how they grow and then there will be growth from some other direction then there will be growth from other third direction where they meet.

You will have some kind of boundary in between them which where they are colliding with each other and they are stopping in their growth and so that kind of boundary will be there and that is how you get A complete eutectic my microstructure in the given volume of liquid ok.

So, with that thank you we have discussed the how the microstructure develop at different composition of A eutectic phase diagram under equilibrium condition and in non equilibrium condition you can add another factor in that that there will be lot of composition variation in the microstructure.

Thank you.