Phase Diagrams in Material Science Engineering
Prof. Krishanu Biswas
Department of Material Science Engineering
Indian Institute of Technology, Kanpur

Lecture - 13
Solidification of eutectic, hypo-eutectic & hyper-eutectic alloys & their morphologies II

Well, see in the last lecture I discussed you how eutectic alloy will solidify.

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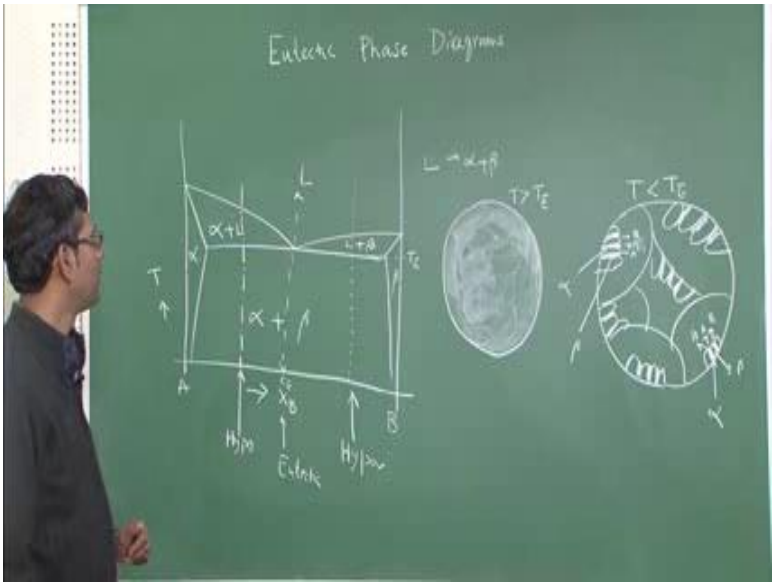

Now, let us move onto the hypo eutectic alloy first. I hope it is clear for how things will happen. I have again showed you this picture as a temperature below eutectic transformation temperature. This is what they called colony; colonies will form and you can get this fine microstructure. So, let us now start for the hypo eutectic alloy, what I mean to say this one as you see here, if you cool down this alloy from the liquid state. This is complete liquid state as you cool down this alloy nothing should happen below this eutectic temperature.

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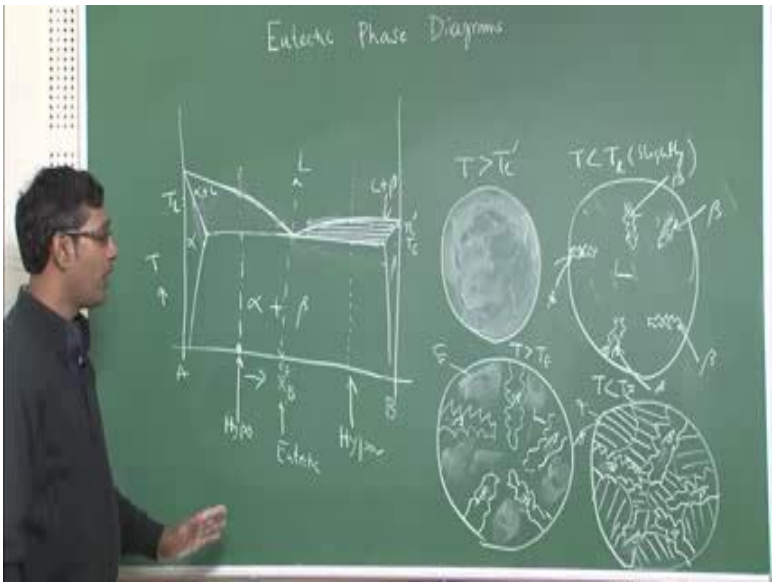

This is the liquidus temperature TL or the melting temperature of this alloy anyways full thing will become liquid nothing should happen. So, this is what is the picture above TL everything is liquid. Now, if I drop the temperature slightly below liquidus what will happen? This will be inside this alpha plus liquid phase field. I have done little bit here suppose here. So, this is just below the liquidus temperature, but I am within the liquid plus alpha phase field so that means, alpha will nucleate because alpha is the only solid alpha is the only solid present. So, alpha will nucleate and form and grow in a liquid.

So, alpha nucleates here a different position suppose in the liquid; obviously, not one alpha will nucleate many, many and these alpha things will grow like a dendrite, why it will grow like dendrite that is because this is the most common structure which forms a solidified product as a dendrite a tree like structure, here like a tree you have seen Christmas tree. So, this is like a Christmas tree a form like tree like structure. So, they will grow and become.

So, these are the alpha dendrites going in the liquid, they will keep on growing till the eutectic temperature I reach. So, I was little bit below the eutectic liquidus temperature and this was the picture. Now, this will happen from these temperature two above eutectic temperature nothing will happen, but one things I must tell you, let me just remove this things and tell you, this is my alpha plus liquid phase field. Let me just tell you what will happen as you go down the temperature I already discussed you that the

liquid composition will change like this, solid composition will change like this is solidus of alpha, this is the liquidus of alpha, please do not forget that this is solidus, this is the liquids, this is also solidus.

Now, because the temperature is dropping the solid composition will be given by solidus given by liquidus. So, these are the some different tie lines I have drawn, tie line means line parallel to the x-axis. So, as each tie line this is solid composition this liquid composition, solid composition, liquid composition, solid composition, liquid composition, but what you observe the liquid composition is keep on increasing in B concentration XB concentration.

Solid composition will also keep on increasing in XB concentration and when the temperatures reach TE the composition also reach CE. So, at TE we will have a solid alpha and the composition of the liquid; let me draw it again for, as you will not be able to understand. This is just above TE, just above TE you have this dendrites which I have grown much bigger. So, just above TE will have at this liquid whatever present here this liquid will have concentration same as CE concentration same as concentration of the liquid is going down this way. So, as at the will above the temperature eutectic temperature concentration will CE.

So, now if you cool down below the eutectic temperature little bit what will happen? This liquid whatever present here in the liquid, this will transform in the eutectic reaction they will undergo eutectic reaction and because of that you will have eutectic micro structure. So, eutectic will form again I am drawing lamella eutectic here. So, white, black, white, black, this one also let me draw here also. So, what you have is specifically alpha dendrites.

This also alpha alpha dendrites and in between the alpha dendrites you have eutectic, the liquid which have present here are undergoing eutectic. So, this is what will happen when you cool down the liquid, which is cool down the alloy, which is a hyper eutectic composition that is what you see for aluminum silicon alloy, aluminum silicon hyper eutectic hyper eutectic alloys. We will have aluminum dendrites and in between you have eutectics, this is exactly you have seen in MAC structure which I have shown you. So, question is this if I buy the concentration from these to this from these to this; that means, little less than eutectic and till this point this is exactly will happen only thing

will change is that volume fraction or the amount of this alpha phase, and the eutectic will change. Let me also tell you this alpha which form as a dendritic way above the eutectic temperature is known as a primary alpha.

Primary alpha remember that or pro eutectic alpha; pro means before. So, this alpha which forms above the eutectic temperature is dendritic manner in the liquid is known as primary or pro eutectic alpha, please do not forget that and in the eutectic also we have alpha and beta. Suppose, this is alpha and this is beta, the black one, the white one is beta, the green one is alpha, at the way I have drawn this is called eutectic alpha. This is called pro eutectic alpha or dendritic alpha. You got very clearly, you to think about it eutectic alpha and pro eutectic alpha or primary alpha. So, primary one will come as a dendrite and eutectic one will come as a lamellar or rod whatever when the mormology morphology of eutectic.

But normally as lamellar eutectic aluminum silicon, it will come as acicular eutectic. So, in the whole microstructure is connected with the phase diagram. This is the beauty of that, see if you understand the phase diagram nicely you can you can generate the microstructure and control it and if you can control the microstructure; that means, you can prepare, you can get any properties you want correct. So, I hope it is clear to you that how these things will happen. Remember that here also you can have coring; I told you coring in alpha, here it is possible to have coring in alpha.

What is the meaning of coring? Alpha dendrite which will form I to go back to the discussion on copper nickel isomorphous system. Look at the video lecture, which I had given earlier there you will see that this alpha dendrites are core, core means the composition exist in alpha dendrites same thing can happened here also because of coring. Suppose, this is the concentration of the alloy, we can change the phase diagram and phase diagram will be looking like this, I have drawn solid line and in that sense the solidification will get over lower than the eutectic temperature because this is the temperature here.

So, this will be coming down like this way and it will modify the whole reaction. So, let us not discuss and complicate the stuff right now, but I will tell you that the possibility of actually real life situation. This will be the actual thing happening that is means you have a extended solidus line like this because of coring effect and solidification temperature

will go down to the eutectic temperature which is possible, while this is the advanced topic I will not discuss much it is not there in books also, but this is possible.

Now, let us go back or sorry not back go to the hyper eutectic concentrations and I remove these things. Now, this picture little bit, but I will not remove the whole thing I will explain it how things happens. So, again here alloy composition is suppose this one, I have discussed these dotted line is a hyper eutectic, you see nothing will happen above the liquid temperature. Here, the liquidus temperature is this T dash L I have written because this is TL, I have marked T dash L is the eutectic temperature, here for this alloy and nothing will have above this temperature everything will remain as a liquid.

So, above T dash L everything remains as a liquid now. So, as you go down the T dash L slightly, you will have beta dendrites forming instead of alpha. So, this dendrite will be beta, these are all beta instead of alpha, beta dendrites will form I am clear because this liquid is in liquid is in equilibrium with beta equilibrium with beta. Please remember this liquid with beta therefore, if you cool down the liquidus temperature beta will nucleate and go and it will go like a dendritic manner.

Again in a solid in solidification situation and same these dendrites will keep on growing from this TL start TL 1, TL dash to TE this temperature range from these to these, temperature range from here to there. It will grow and they will become bigger, these are all beta slightly above the eutectic temperature this is what is the microstructure. Now, as you see here as I can draw here again the tie lines like this, let me just remove this liquid plus beta, phase field. So, this is liquid plus beta.

So, I can draw these tie lines like this and as you see here as the beta grows the liquid concentration will change along with this lines I will describe this is the liquidus of beta and this is the solidus of beta, because of liquidus. So, beta like this the liquid concentration will keep on decrease in B concentration because B is reducing this side. So, because of that it will reduce, on the other end beta solid beta because also will decrease this is little bit confusing, but this is what exactly happens in the actual stuff. So, liquid will be lean in B and finally, as T temperature liquid will have concentration of CE because this is going down. So, that will happen these liquid will have concentration of CE concentration.

So, just below the temperature again same thing will happen, the liquid which is present will be become eutectic correct. So, these are all beta dendrites beta dendrites and eutectic which is dried between will become like a eutectic lamellar eutectic between alpha and beta.

Similarly, what I have discussed to alpha these beta dendrites are called pro eutectic beta a primary beta. On the other hand, beta which is like this white line they are known as eutectic beta. So, you have clearly understood that hypo to hyper only difference is that dendrites are changing in the hypo concentration dendrites are alpha in hyper concentration dendrites are beta that is the only difference microstructure remains same. So, in aluminum silicon this is what I exactly showed you for hypo aluminum silicon alloys you have aluminum dendrites and aluminum silicon eutectic presence.

On the hyper one you have silicon, silicon does not go as dendrite, but it goes like you know specitate phase silicon and dendritic phase of aluminum silicon, this is what exactly happens. So, by these picture by these way I can explain all my alloys which will solidify only one thing I am not discussed which is I will do it right now, which is little bit complex.

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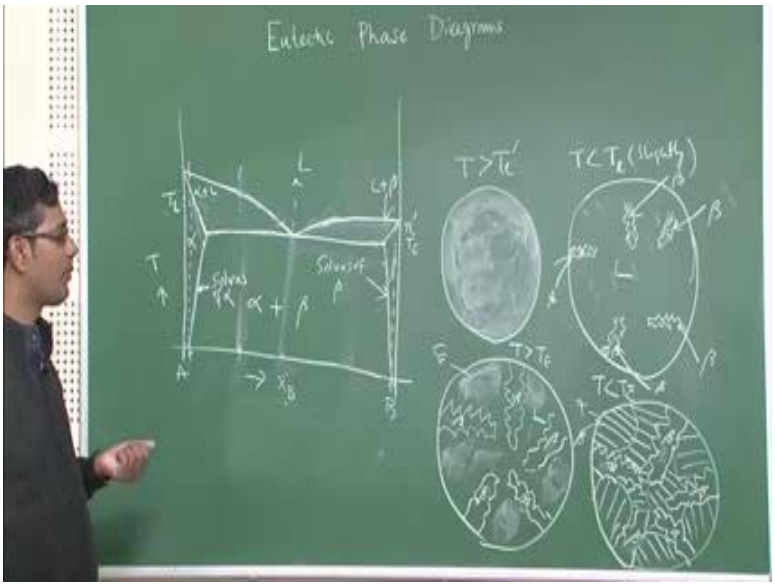

But before that I remove this part it will not complex, it little bit different from these two. So, I remove all this things now and I remove that. So, I have discussed with you eutectic, hypo eutectic, hyper eutectic alloys, but there are one set of alloy here which is

like this which does not go eutectic reaction, here also it does not go any eutectic reaction. So, any alloy concentration any alloy composition which has concentration less than these one, these point or this point will not undergo this reaction. Please remember that and these two lines you see here this is one curve or line whatever we called is better way they are known as solvus; this is solvus of alpha, this is solvus of beta. Why it is called solvus because this tells you the concentration of solid alpha as a function of temperature.

So, you can see here at a eutectic temperature, it contains largest amount of solid B at wind temperature. It contains least amount of solid B same thing is valid for beta temperature, it contains largest amount of solid A at room temperature, it contains least amount of solid. So, it is very clear that these two alloys or these set of alloys will not undergo any eutectic reaction they will solidify just like isomorphous alloys I discussed with you exactly that way. So, in nutshell I can say there are actually here there actually five different alloys one to hypo eutectic hyper eutectic.

So, if you want to discuss the whole thing you have to discuss five different alloys which I have done in my whole discussions. Now, the only thing I will now discuss is go back to my slides and with your knowledge which I have discussed. Now, I will again go back and discuss. So, this microstructure and tell you how they are formed.

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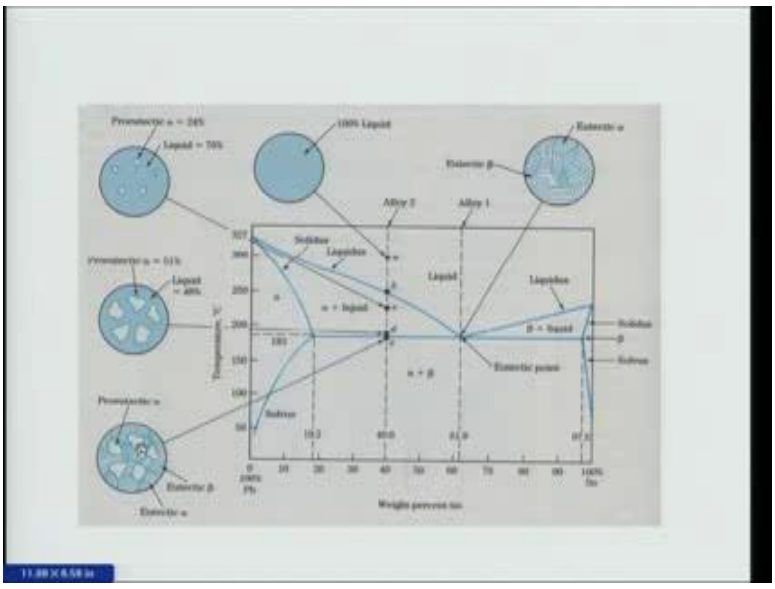

So, let us now start with this picture as you see here this is eutectic alloy which as lamellar microstructure of different grains. Here, you can see here different grains of lamellar type 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 grains are there, but on the other hand hypo eutectic alloy you can see, suppose this alloy two which is the hyper eutectic alloy if we cool it down from the liquid at 0.8, there is a complete 100 percent liquid and just below the liquidus temperature, this is the liquidus temperature.

You have eutectic alpha present even the values of volume fraction volume has checked again amount fractions are given, which we will do in the next class, calculations rather we will apply lever rule to calculate that. So, you can see here from point B to point D what has happened eutectic alpha phases grown like dendritic manner and rest of the liquid were remained. So, I just above eutectic temperature TE or A at point D the liquid will have concentration given by this point CE or here is basically 61 percent, 1.9 percent in.

So, once you cool down below eutectic temperature, this is solidified like a eutectic the liquid which remained or an along with dendrites of alpha will present that is what it is called pro eutectic alpha or primary alpha, and the other one as eutectic alpha same thing will happen on this side for a hyper eutectic, in a hyper eutectic situation except alpha beta will present other than alpha beta will present while the eutectic will remains the same.

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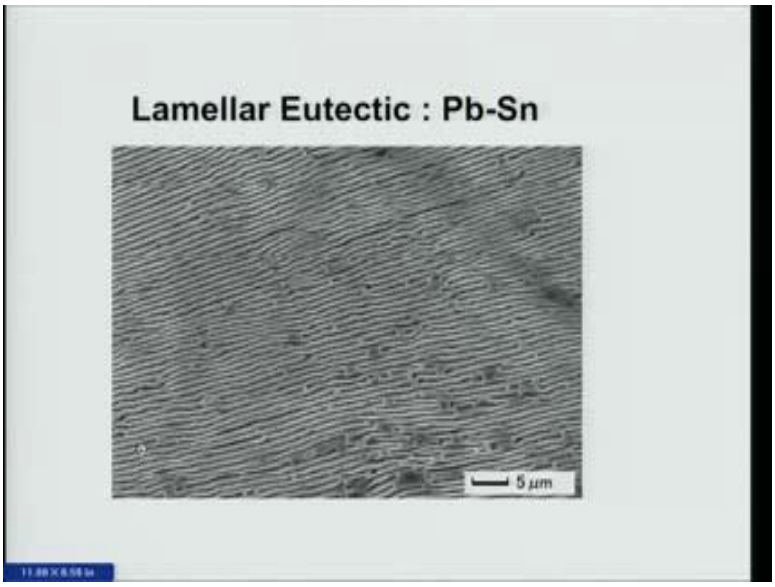

Now, let me just go back; this is the lamellar eutectic if we take complete eutectic composition will form a lamellar one. Now, you can also form a rod. So, let me just go back to the aluminum silicon yes.

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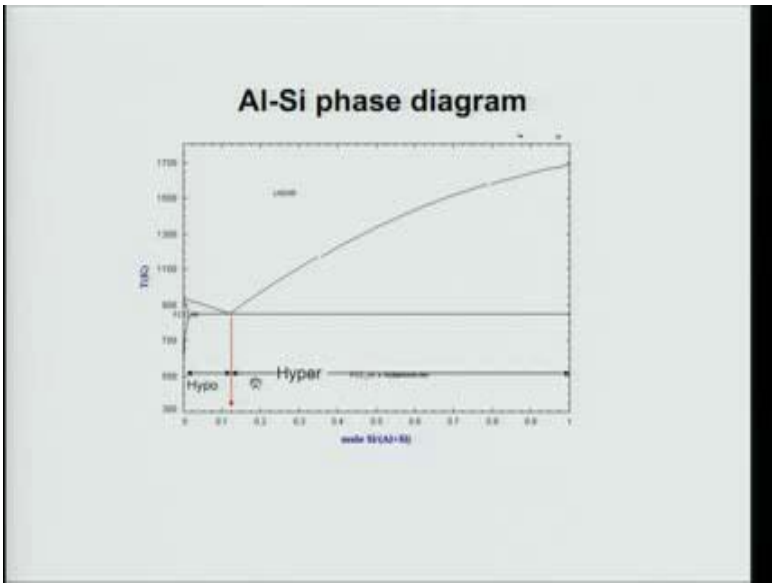

This is the aluminum silicon phase diagrams very interesting and it is widely used. You see here, this is hypo; this hyper eutectic alloys silicon is pure on the right side. So, hypo one let us see.

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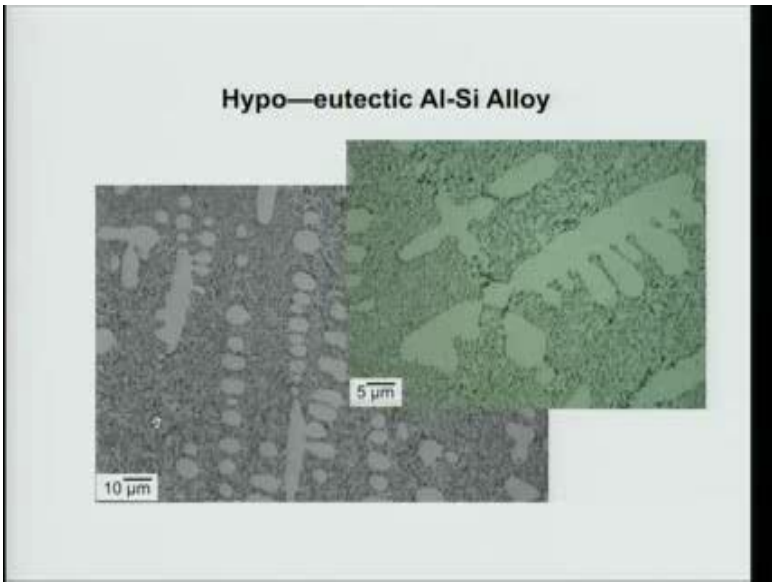

Hypo one will have aluminum dendrites and the aluminum silicon eutectic exactly the way I have shown you. So, these dendrites have form and grown above the eutectic temperature. So, it is of primary aluminum dendrites and this eutectic which is there in between in between you have eutectic which is raw, sorry acicular type of or type silicon goes like a middle layer. So, this is what the eutectic same thing is shown here long aluminum dendrites and you have fibers.

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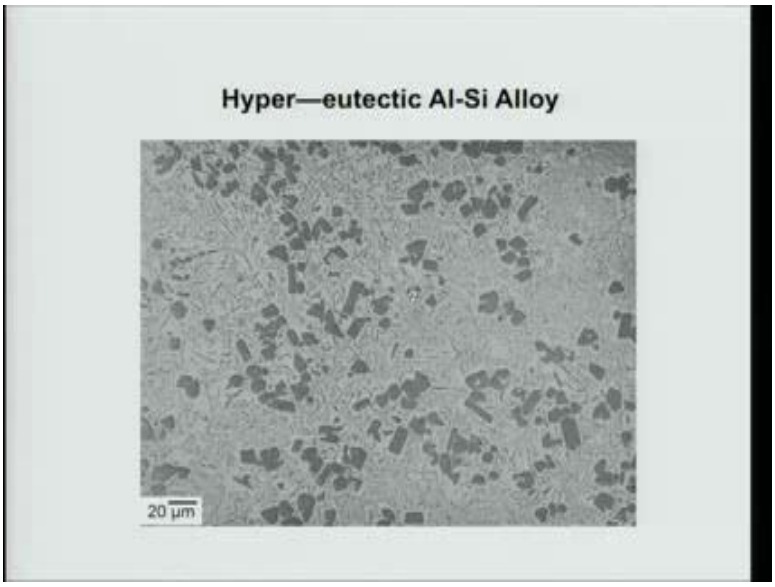

Now, if I take a hyper eutectic I told you hyper means there will be no alpha aluminum or aluminum. It will be silicon as a dendrite that is what you can see here silicon has a dendrite and silicon does not go like aluminum dendrites because silicon is a metalloid its goes like a dendrite. You can see here sharp faces, very sharp faces some they have triangular, some are rectangular, some have even pentad, this kind of all kinds of faces are possible and in between that we have eutectic between silicon aluminum.

So, here these silicon which is present as a big grey thing is called primary or pro eutectic silicon and the silicon which is there in the dendrites are eutectic, sorry not eutectic are called silicon. So, there are two different types of silicon; one is eutectic silicon another one is primary silicon, similarly here also a primary aluminum and eutectic aluminum. It is very clear that this is the way the microstructure will form in eutectic phase diagrams.

So, with this I just want to say that this is very important lesson and you must rather try to understand whatever I have told you. I have discussed very manner please try to understand because eutectic is a very, very important alloy system in material science and if we understand this alloy system very well because the most of all alloys which use in real life like cast iron aluminum silicon and lead tin they are actually eutectic alloy systems.

So, if you know the phase diagram and understand the microstructure formation very well then you can actually control them, that is the basic idea of such a kind of course, and which you should be able to understand. With this I will; in next class I am going to discuss with you little discussion of aluminum silicon eutectic and their modification and finally, I will also draw that for free energy composition diagrams, so that you can understand it.