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

Lecture – 44
Ternary Phase Diagram-II

Students we have been discussing on Ternary Phase Diagrams in the last class, I just started on the discussions on the ternary phase diagram. The first thing I told you is that in a ternary phase diagram there are two composition variables which are independent, because there are three components A, B and C, so there will be there three compositions variables XA, XB and XC. Where, XA, XB and XC represent the mole fractions of individual elements.

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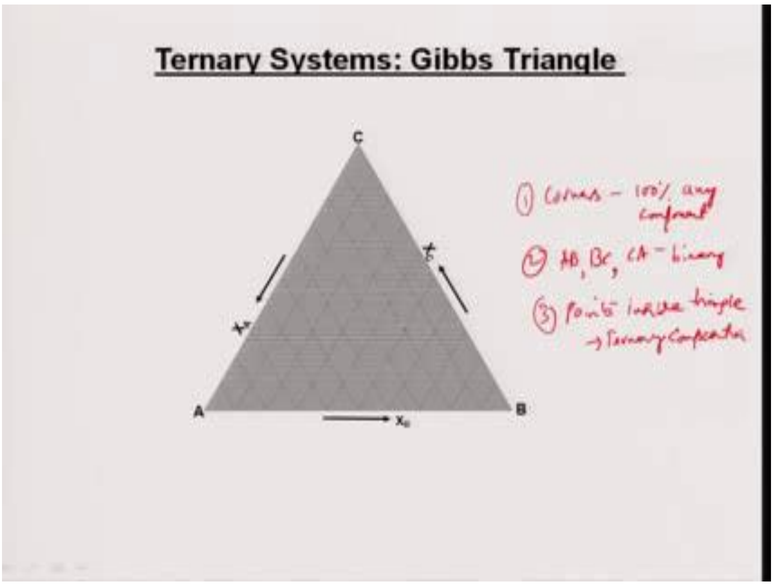

Now, as you know that XA plus XB plus XC is equal to 1. So therefore, because of this equation only two composition variables are independent, where the third one is dependent. As you see in the binary phase diagrams there are two variables; one is a temperature, other one is a composition. Pressure is always kept to be constant. Similarly, in ternary phase diagram also we keep the temperature constant at a 1 atmospheric pressure. So, we have a temperature as 1 of the variables and composition as the 2 variables. Therefore, the phase diagram will be a three dimensional structure or three dimensional plot.

Now how we generate that thing, so I start with the composition. Composition is represented by using a triangle known as the Gibbs triangle. Gibbs was a well known a very profound scientist who has given many relationships in thermodynamics to honor that this triangle is named after him. So, Gibbs triangle is an equilateral triangle. All the three sides of a triangle have equal length and angle subtended by these two sides is basically 60 degrees.

Now question is this if that is the case if you have three sides being the equal of the equilateral triangle represents you the compositions. As you could see here that you know this is represented here you have a point A, B and C, and three sides AB, BC and CA that is the equilateral triangle. So, how would you represent the compositions? The each of these corners of the triangle represents 100 percent of the pure component A, B or C; that is a point 1.So, corner represents a 100 percent of any component.

Now, come the sides. You have three sides AB, BC and CA. Each of the sides represents 1 binary, because as you know there are three components A, B, C so there will be three different types of binaries AB, AC and BC; so each of these sides will represent binary composition. If I follow on AC line or AC side; so AC is the side will represent compositions of A and C only there will be no B, B will be 0. Similarly AB will also be, similarly BC will also b. So, there are three different sides of a different different side AB, AC and BC.

Now, each of this sides will represents as I told each binary component. If that is the case then what about the point inside the triangle; points inside the triangle will represent ternary composition. Ternary composition means, each point inside the triangle will tell me composition corresponding to A, B and C. So, any alloy having containing A, B and C have to be represented by the point inside the triangle. These are the three important aspects you must remember. So, that is how we actually generate or we can plot the compositions on this Gibbs triangle.

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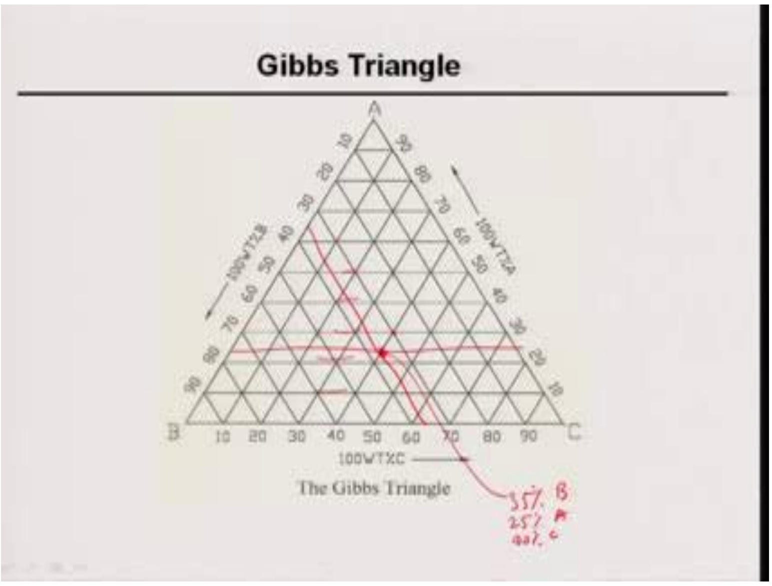

So, I told you also that there are very distinct ways of dividing this triangle and what are the ways. First is that you can divide the triangle by using this lines which are parallel to either BC AB or AC. So, any line parallel to BC will represent composition of A. This are the lines particular you see 1, 2, 3, 10 lines each one representing 10 percent; 10, 20, 30, 40, 50 up to 100 percent so that you can reach 100 percent near the corner.

So, any line parallel to AC will take the compositions of B, any line parallel to CA will tell me the composition of B, so that is how. Now if I want to know the composition of any point what I do, suppose this is the point I want to know the compositions or let us say not do that let us do that this one. So, what I do I draw a parallel line respect to the AC so this will tell me the B compositions. How do you know B is like this, this is 10 percent B, 20 percent B, 30 percent B, so this is 35 percent of b very easily I can get. It contains 35 percent of B; weight percent of b.

Now, how do you know what is the composition of A, I draw a parallel line with respect to BC correct. This will tell me A, A is like 10 percent, 20 percent, 25 percent; 25 percent is A. So obviously, if I know A and B, C’s automatic 35 plus 25 is 60, so 40 percent will be C. That also we can measure. C will be coming from parallel to this. So you can see here this is 10 percent, 20 percent, 30 percent, 40 percent this point is line is 40 percent of C. So, that is the easiest way of measuring compositions. Let me erase these things because we will use.

Now, as I told you this by sites that will BC will tell you the composition of B and C. So, that is very simple in binaries also suppose this point this point contains 45 percent of C and 55 percent of B that is how we can do. There is another way of representing composition that is it what I told you here.

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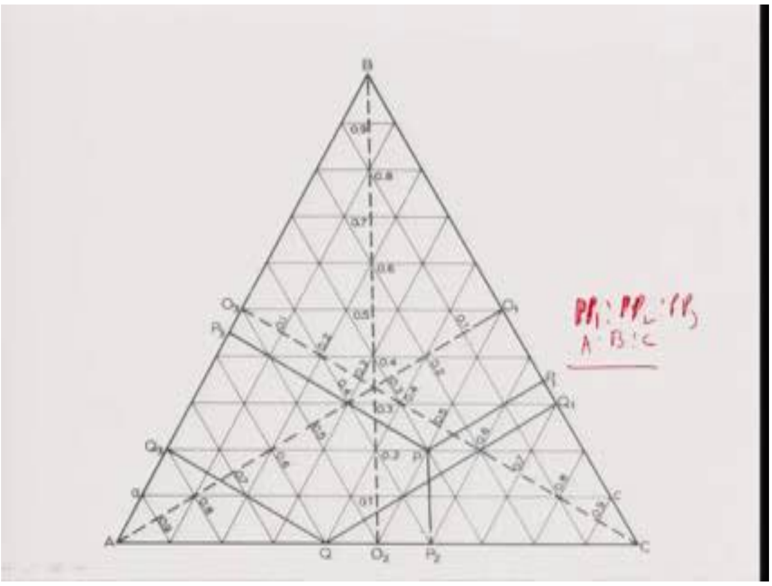

Suppose, if I want to know the compositions of point P or if I want to present some compositions which are known that also can be done. So, what I do is that I draw vertical lines 1, 2, and 3; three vertical lines here. The vertical lines corresponding to PP 1, PP 2, PP 3, there are three vertical lines. This is what I discussed in the last class also. So, now, PP 1 this is opposite to A, this will actually tell me the exactly percentage of A will come to know how to ratios we can easily obtain how to get the composition will tell you later.

So, if I take ratio of PP 1 versus PP 2 versus PP 3 so they will tell me ratios of A is to B is to C. Now to know the compositions what I do here.

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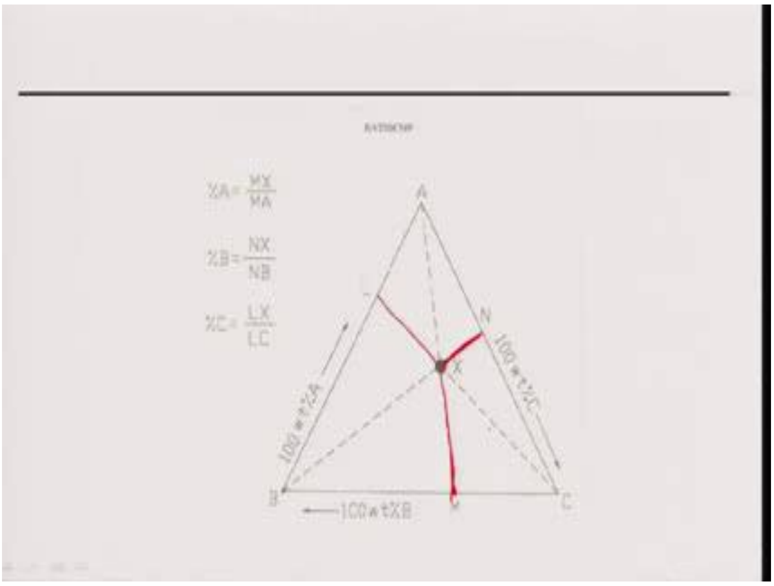

Let us go there to other compositions. Suppose this is the point X. I draw normal to AC, normal to BC, normal to AB; the three normals and each of the three normals are sitting on these curves. Now question is this to know the compositions of A I take the normal which is sitting opposite to the point A, so here you see XM is just the normal sitting opposite to A. So, A concentration is basically XM divide by the AM or MA, MA is a whole thing just like a lever rule opposite arm. Similarly if I know the compound the composition of B I go to the opposite thing of B that XN divide by BN. Similarly, if I know the compositions of C I to the length XL divide by LC, that is what is done.

So, there are three ways of measuring compositions I told you. And you can use any of these two to represent composition suppose some alloy contains 50 percent A, 20 percent B and 30 percent C. So, you can actually do use any of these three techniques to put on this chart.

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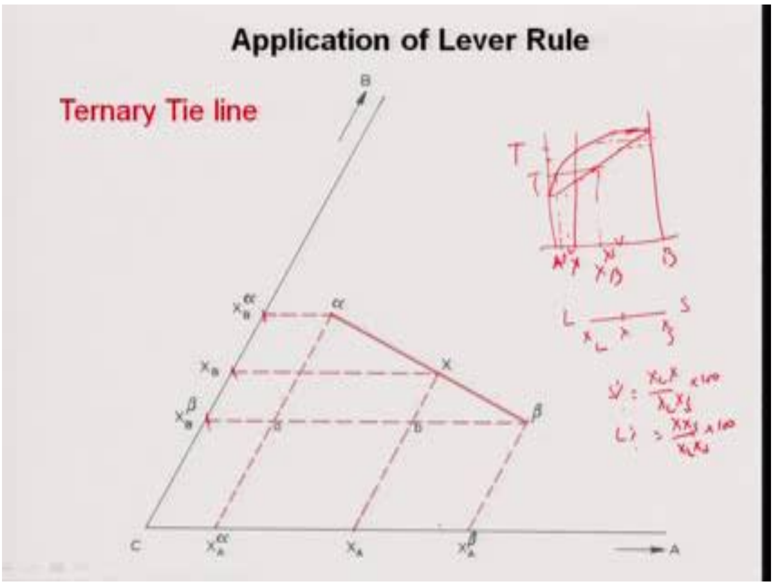

Now, what I am going to do is this next 10 - 15 minutes before is that I am going to talk about the tie lines and the tie triangles in ternary phase diagrams, because these are the important. I hope you remember what is a tie line in binary phase diagram let us start with that. Let us start with a binary tie line. I draw a binary isomorphous phase diagram like this temperature versus XB pure A pure B.

Now what will do, I draw a tie line; this is a tie line. What a tie line does it connects the solidus with the liquidus, this is the solidus this is the liquidus I connects that solidus with liquidus. So, what is it tell you it tell me the liquid composition and solid composition. So, I can draw many tie lines and I can find out so. In fact, whenever you talk about composition solidification of the alloys suppose I have to talk about solidification of this alloy I just follow the tie lines to know the composition of solid and liquid phase. Same thing can be extended in ternary.

Suppose, I have an alloy with the composition given by point X. Here I am showing only one corner of the Gibbs triangle. You see here this is point C, this is point A, this is point B, A will be there I am just showing you the one corner so that you can realize it nicely. Now if you look at this X; X is this. In alloy X is separating in to two phases; alpha and beta. So, alpha composition is given by this point or beta composition is given by this point.

Now, how do you find out what is the volume fraction of alpha and volume fraction of beta. That is what we do using tie lines right how do you do in binary. Very simple, suppose I am just showing it for this so let me just erase this then only it is easy to show you otherwise you are you will get confused. Suppose I have a alloy composition X and it is at the (Refer Time: 11:42) temperature T 1. Therefore there is a solid, there is a liquid, there is a solid; and this is my solid composition, this liquid composition, this is my solid composition. So, I write down this is XS this is XL. So, this is my line this is X this is XL this is XS, sorry this is XS because this is the next solidus XS, XL.

So, now if I want to know liquid and if I want to know solid what I do. If I want to know solid I tell XL X divide by XS XL in to 100, this is my solid percentage. Liquid percentage is what? Liquid percentage is opposite term X XS divide by XL XS in to 100. That is what I do. Same thing I can do it here also, but before that we have to know the compositions and we do not need all A, B, C, we can use one of this. Suppose if I simply want to use B compositions, so what I do? I do parallel lines with respect to the CA. So, I draw parallel line like this; one parallel line passing to beta another parallel line passing to point X and third parallel line passing to point alpha. These parallel lines if I extend they will heat this CB curve or CB sides at this points.

So, they will tell me the compositions of B in beta phase and tell me compositions of B in alpha phase and composition of B in (Refer Time: 13:19) alloy. Now I can do the same thing. I can use this line 1, 2, 3 points, I can use these same lines with this different points, I can use that same lines with these different points 1, 2, 3. And use the same mathematics which I did just now for binaries.

That is the analogy. Analogy is very clear; one can actually use same analogy. Only thing you are doing extra job which you do not need to do in binaries is that you have to draw this parallel lines to measure compositions, but remember you have to know only composition one of the species either A or B or C you do not need to do for everything. Similarly, suppose if somebody may say I will not do draw parallel lines with respect to AC I draw parallel lines respect to BC. So, if I draw the parallel lines respect to BC I will the next time that that will heat this AC line or AC side at XA alpha XB beta and XA, these three points.

Now using again this as a tie line this is extense of a tie line what we are doing is the projecting. Frankly speaking mathematically we are projecting this inside line on to each of the sides and getting the compositions. And again using this compositions we can use the mathematical rule of lever rule apply that get a composition volume fraction of the phases, very very very clear right.

So, you can have a situations where one alloy with the fixed compositions separate it in to two phases, then this is very nicely done. But in ternary system this is very very very very very low problem situation. In ternary alloys you will most of the cases will have more than two phases. In that case you cannot apply tie line concept.

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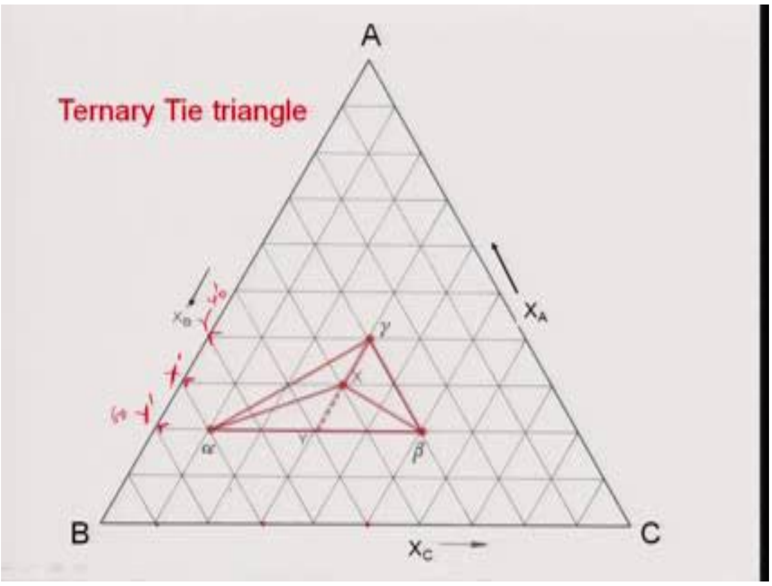

What you should do is you should apply what is known as tie triangle concept. To give you an example; suppose you have an alloy composition given by X. These alloys are separating in to three phases; alpha beta and gamma. And you want to know what is the volume fraction of alpha, beta and gamma right that is what your task is suppose. As I told you in the last case what did I tell you that if I have an alloy the composition X separating in to two phases alpha and beta and the compositions are like inside the triangle then I can measure the volume fraction of these phases alpha and beta using the same lever rule what we have used, but I have to do some constructions and those constructions is very simple I told you.

Now, as I told you that this an alloy separate into two phases is very low probability 1. Most of the cases alloy will separate into more than two phases. This is situation where an alloy separated into three phases, an alloy composition X separated into alpha beta gamma. And you have been asked to measure the volume fraction of these phases at a particular temperature. How will you do it? Well, very not difficult. First thing what I will do? First thing I will do is that this is called a Gibbs triangle that is why it is called a tie triangle. First thing I do is that these point gammas is connected to x and extend up to y.

Now listen carefully. This is my tie line correct so I can measure the compositions of this point, this point and this point by drawing parallel line respect to BC, so I draw parallel line here, here one, here another one, here another one correct this is my gamma this is my X, let us write gamma prime x prime and y prime. So, I can apply the lever rule here and measure the volume fraction of gamma and also volume fraction of suppose a fictitious phase y. I can do that because that is a tie line.

Therefore, this y then I can assume first job is that you extend this line to alpha beta so that it hits the point y. If it hits the point y then I can measure the volume fraction of the phase gamma and volume fraction of the phase y. Now question is this; so that means what I have done this alloy X has been separated into two phases gamma and y, but that is my assumption. Now y is again separated into two phases alpha and beta.

So, now I can simply do this math. Suppose I have 60 percent y and 40 percent gamma, I can use this as a tie line alpha composition, y composition and beta composition. And then whatever percentage of alpha I get I multiply that with 60 percentage that is how I can calculate alpha, beta and gamma. So, you understand if you have three phases or two phases very easy. Once you have four phases things will be very very complex. Actually you can use two tie triangles, but let us not discuss because I do not want you to getting confused into that. Let us think about three phases because as I know in a ternary system maximum number of phases present will be four not more than that f is equal to 0 corresponding to four (Refer Time: 19:13) phases. So, what is the reaction which is possible, suppose eutectic reaction in a ternary system liquid going to alpha plus beta plus gamma.

So, alloy of X composition liquid will vanish and form three solid phases. So, basically you are measuring these volume fractions of three solid phases, you do not need to measure volume fraction of liquid present. If it is required I will tell you how to do that, it is a require detail discussion but it is possible. So, what did I tell you in a very light way, because these are things as I go alone you will forget that is why I have to tell you again and again.

First thing I am telling you only the composition aspect. How to measure compositions? How to plot compositions on the Gibbs triangle? So, whenever you listen these lectures please try to take a print of Gibbs triangle from internet site or even books, xerox copy of that. Then look at it when you are listening this lecture and try to contemplate that you are listening lecture also you are doing the math’s or plotting it simultaneously, then that will help you because in ternary phase diagrams people gets scared quite a Bit, but this is not difficult that is a easy. One has to understand the basic things very well then you can do it.

So this is what is important, we will discuss what are the issues of ternary tie triangle for this things in the next class, but let me just before I end this class. Before I end I will like to tell you that now I have given you Gibbs triangle, told you not given you I told you Gibbs triangle plot compositions.

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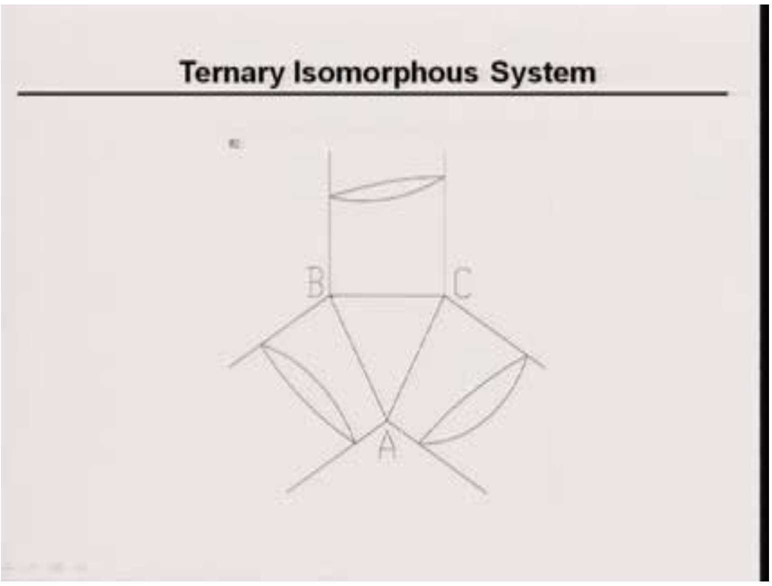

Now I can just put a vertical axis temperature vertically like this on these things. So, once you put a vertical axis this is a temperature, so you have three compositions XA, XB, XC and vertical axis temperature. Now you can plot the phase diagram inside of it. So that will show you that suppose there are three components A, B, C and three of them are forming isomorphous phase diagram binaries BA forms isomorphous, AC forms isomorphous, BC forms isomorphous.

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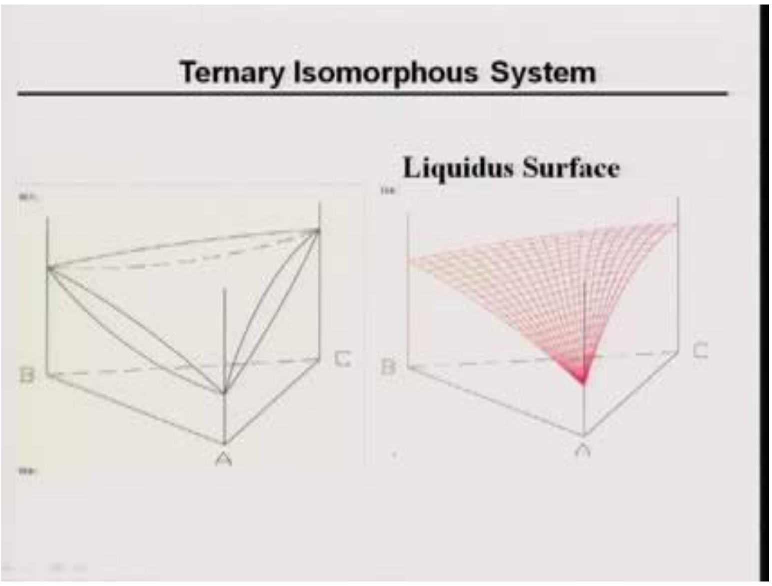

How the phase diagram will look like? Phase diagram will look like this. A three dimensional lens (Refer Time: 21:37) you can clearly see. I do not know whether you can visualize it. A three dimensional lens (Refer Time: 21:41) is basically it is like a cone cell like this cone cell like that, can you see that cone cell like this. Therefore, the phase diagram is also very simple.

Now, our basic purpose will be to understand what is there inside and this is very simple case that is why you can see it and we can understand it very easily, but there will be complex diagram inside it. For those we cannot simply see the three dimensional picture and understand. What you mean this two dimensional sections because we are very comfortable with two dimensional sections. Human beings are very comfortable with two dimensional pictures although we ourselves are three dimensional, but we are very comfortable with two dimensional pictures, we are very very comfortable.

Anybody even not from mathematics background they can physic background or science background can understand two dimensional picture. The moment we start talking 3D pictures they have to meditate and think that is become difficult. So, that is why for very complex things we will take sections across this diagrams, sections can be horizontal sections at a fixed temperature because vertical analysis temperature so horizontal analysis fixed temperature or we can take a vertical section also.

So, few things which I have to teach you in next class is first I have to tell you what are the rules and regulations of the tie lines whether they are same or not, second is vertical horizontal sections. Please remember these are all I draw nicely in the books of Alans Prince, but I will try to explain more slowly so that you can understand things very easily. With this I will just finish this part of this lecture, in next lecture we will take up other issues.

Thank you.