Phase Equilibria in Materials (Nature and Properties of Materials – II)
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Lecture – 35
Ternary phase diagram (cont.)

So, good morning; welcome again, to this new lecture on the Phase Equilibria. So, we had in 35th lecture today.

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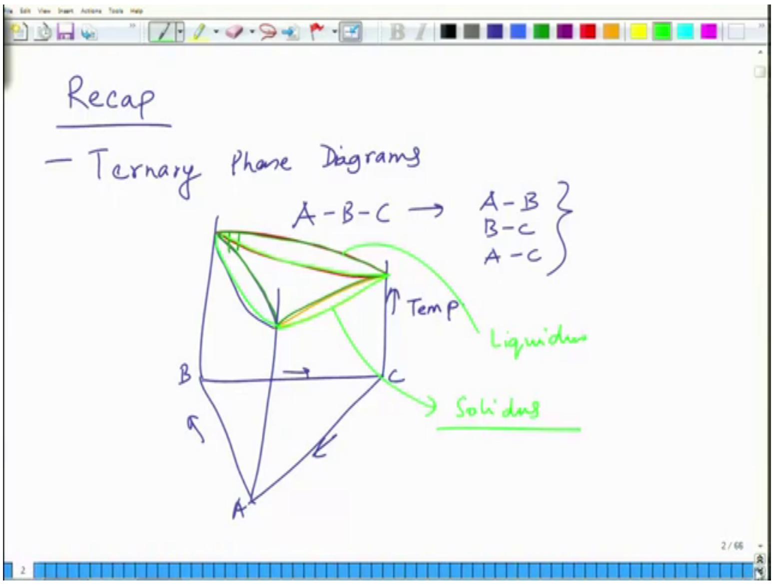

So, I am just going to give you a brief recap of past lecture. So, as far as recap is concerned we discussed we started discussing about the Ternary Phase Diagrams. Ternary phase diagrams are basically 3-dimensional phase diagrams which have three components. So, it could be three elements or three compounds which make you know binaries between each other like if you have A-B-C, three components then you will have basically it is a mixture of three binaries A-B, B-C and A-C and these three binaries when they are put together so, you might have a situation like this. So, this is first binary, this is second binary on the back you have third binary. So, you have A, B and C.

So, these are composition axis and on the y-axis you have temperature and so, you can have for example, one phase diagram here let us say this is isomorphous between B and C this is another isomorphous between let us say B and so, this is isomorphous between A and B on the left on the back you have isomorphous between B and C on the front you have a isomorphous between let us say between A and C and on the top of it you will have a surface which is so this surface on the top this is the liquidus surface, ok. Whereas, at the bottom you have the this one if you connect these together this is the solidus surface. So, you have 3-dimensional surface.

So, you have a surface basically giving you it is a contoured curved surface which will be a liquidus and the on a similar fashion at lower temperatures you will have another surface which will be curved in this fashion and that will be solidus. I mean they may also touch each other somewhere in between either giving you a maxima minima depending upon the phase diagram, but for a simple isomorphous system you may have one surface one curved surface giving you liquidus another curved surface will give you solidus. So, this will be liquidus and the one here will be solidus.

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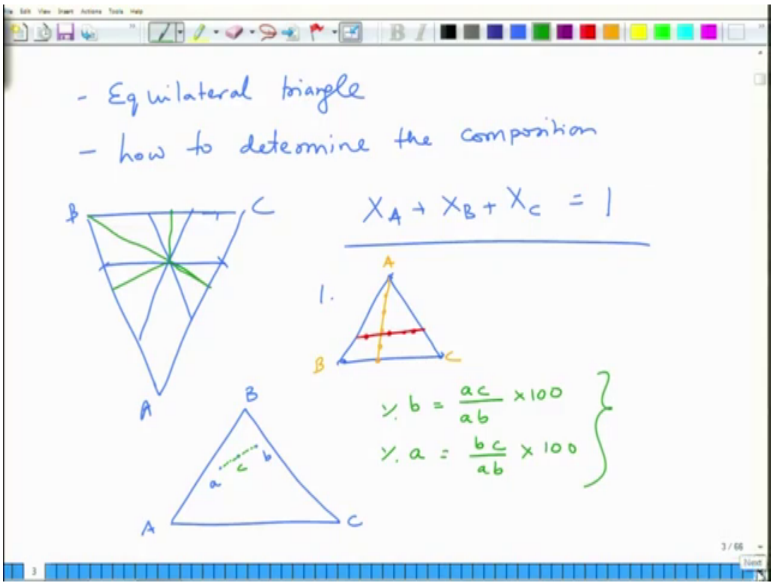

So, it is a free 3-dimensional phase diagram a ternary system and basically you draw it in the fashion of equilateral triangles. We saw how to determine the composition. So, for that we saw that if you have ABC then if you draw a horizontal line per to BC then this line will give you composition of A, similarly if you draw horizontal line parallel to AB it will give you composition of C. Similarly, if you draw A horizontal line parallel to AC it will give you composition of B and remember X A plus X B plus X C should be equal to 1.

There is another method that can be drawn as that is the altitude method which means altitude of a equilateral triangle. So, if you have a you can take the altitude for example, this is the altitude and this altitude is sum of this that and another. So, these are three altitudes which can which you can take to be. So, these three altitudes will be equal to the overall day altitude of the equilateral triangle and they will also represent compositions.

So, nevertheless X A plus X B plus X X C must be equal to 1. So, the corners represent the pure materials, the sides represent the binary systems and somewhere anywhere in between the triangle you have a ternary system. So, and we looked at basically we are looking at certain rules. The first rule that we looked was if you take a line for instance here in this case and if I draw a line like this and let us say if this is ABC and along this line the composition of A remains the fraction of B and C remains the same. You can vary the composition of A along this line, but as you move further away you will increase decrease the amount of A, but the fraction the ratio of B and C remains the same. So, that was the first thing that we discussed.

Then we discussed that if you have this line for example, if you draw another line like this and since this line is parallel to BC along this line the a if you if you move the alloy along this line anywhere you will change the proportion of B and C, but you will maintain the constant amount of A. And then we looked at the third rule that was the lever rule and so, if you have if you have a so, this is for instance A, B and C and if you mix two alloys let us say a and b then the third alloy which forms as a result of the resulting alloy let us say c is the is falls on a tie line which is it joins a and b.

So, it is a straight line joining A and B in between depending upon the proportion of A and B you will have C line and this is the percentage of for example, your b phase will be equal to ac divided by ab in to 100 and percentage of a will be equal to bc divided by ab into 100. So, this is nothing, but lever rule that we saw in practice alright.

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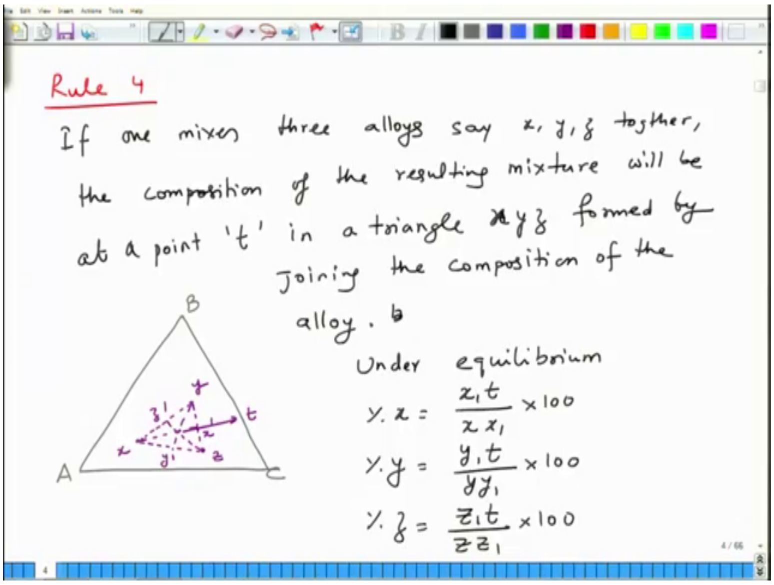

Now, now let us move on to another few more aspects. So, we will first go to number 4. Rule number 4 says that if you have three alloy if one mixes three alloys let us say you know x comma y comma z together the composition of the resulting mixture will be at let us say in this case so, if I draw a triangle this fashion, ok.

So, this is the projection that you have and let us say you have a alloy x somewhere you have y and somewhere you have z and if you mix them together you form. So, you make a triangle by connecting these two and the alloy that forms let us say lie somewhere here let us say this is the point t such that so, when you draw let us say projections. So, this is let us say x prime this is y prime and this is z prime.

So, basically the resultant alloy the composition that is written mixture will be at a point let us say t in a triangle a b sorry x y z formed by joining the compositions of the alloys, and you draw the straight lines they are not curved lines. So, it is as if you know it is at the center of the gravity. So, it is like point falcom at you have you have a body whose falcom lies at t and it has you know some must attached at it is corners like x y z and which basically represent the alloy compositions.

So, under equilibrium conditions the percentage x is equal to x 1 t divided by x x 1 in to 100. Similarly, percentage y is equal to y 1 t divided by y y 1 into 100 and percentage z is equal to z 1 t divided by z z 1 into 100. So, this is all coming from basically properties of the triangles. So, generally in see by ternary system we do not look at the 3D diagram we are mainly looking at various sections isothermal sections, vertical sections and so on and so forth.

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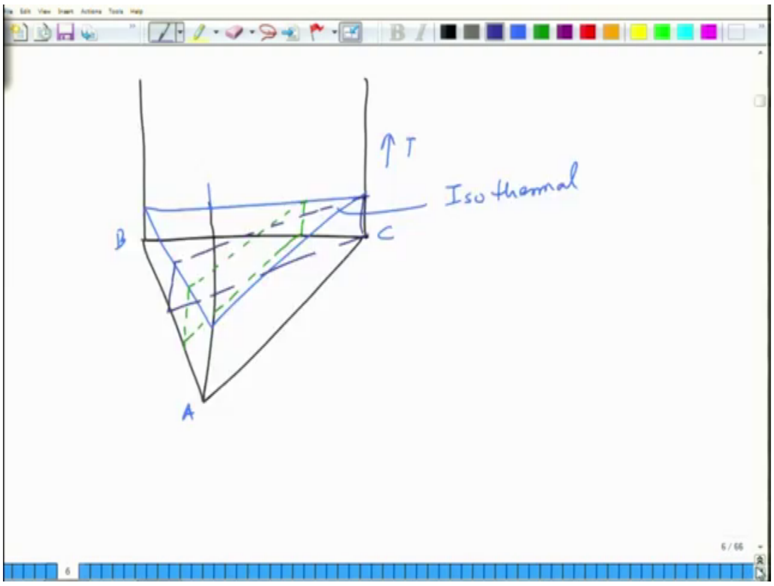

And, when you put these sections together so, you can have a if you draw a ternary phase diagram for example, like this, ok. So, the sections could be you know horizontal section like this. So, this would be high isothermal section because you have T here and ABCs are here. So, this is the isothermal section.

You can have vertical section. So, for example, you can have a section like this. This is a vertical section you can have another vertical section like this for instance. So, there are various vertical sections which are possible. So, if you by looking at these various sections you can understand ternary diagram so little better.

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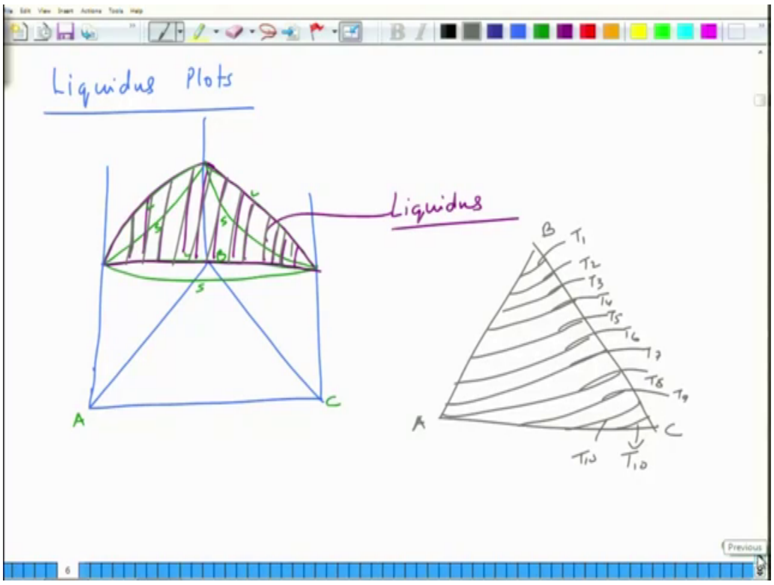

So, so, these sections are for instance you can have liquidus plots. Now, liquidus plots as I just explained to you. So, if you draw let us say a ternary phase diagram alright. So, you have so, let us say one part of the phase diagram is this. So, this is let us say A, B and C another part of the phase diagram is something like this and this is the BC part of the phase diagram which is like this, alright. So, you can see that this is liquidus, this is liquidus, this is liquidus and this is solidus, solidus, solidus.

When you connect liquidus together so, this surface the top surface consisting of liquidus. So, this surface on the top this will be essentially the liquidus surface. This liquidus can be projected on to a surface.

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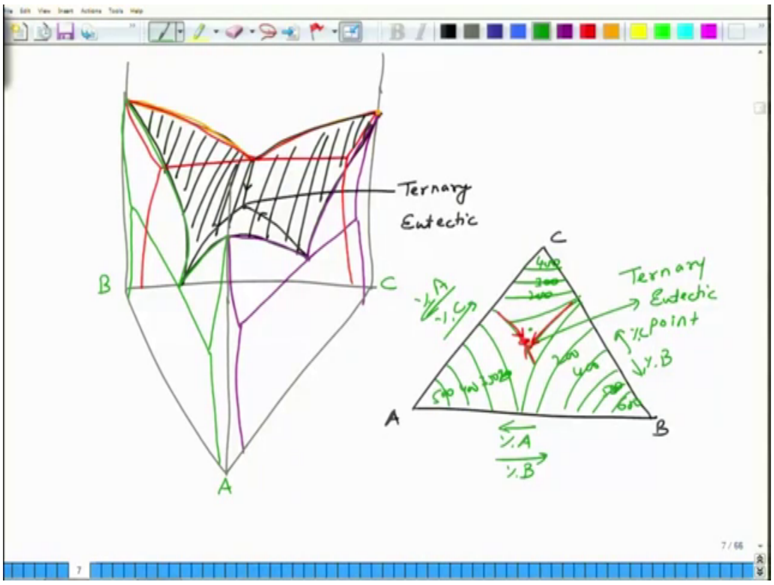

So, for example, if you have a system such as, the one which I am going to draw with little complex so, let us say a surface like this. So, basically what you can do is that this surface can be represented by let us say these lines. These lines are nothing, but constant temperature lines. So, you draw constant temperature lines on the surface. So, generally it will start from one end. So, went all these constant temperature lines you can project them in 2D. So, and these would be there for example, lines.

So, depending upon the melting points so, let us say if C has the highest melting point and B has the lowest melting point. So, this would be T 1, T 2, T 3, T 4, T 5, T 6, T 7, T 8, T 9, T 10, T 11. So, this is basically by picking up the constant temperature lines on the surface you are projecting them on the 2D plane. So, this is what is the liquidus plot. So, it allows you to visualize the liquidus.

Similarly, you can draw a section at you can do the solidus you can do the same for the solidus as well. So, you can have a liquidus plot like this, you can have a complex phase diagram for example, let me draw a little bit longer lines here. So, let us say we have a phase diagram which is let me see; so, if you have and let us say this that is somewhere here.

So, you have a similarly for this side you can draw another eutectic phase diagram. So, similarly on this side you can draw another phase diagram which is that the eutectic, so, connect this line. So, let us say so, these are the corners are A, B and C and you see three ternary diagrams one between AB, second between BC and third between AC. Now, on this ternary diagram, if I connect the points lying so, these are the melting points of AB and C and if I connect only the liquidus lines.

So, this is liquidus use this colour liquidus; that means, different colour. So, this is liquidus, this is liquidus, this is liquidus, this is liquidus and this is liquidus and these eutectics will meet somewhere here, and this will form let us say a ternary eutectic. So, this surface which is shown on the top is essentially the. So, the first that represents the liquidus surface of a ternary eutectic.

So, on this you can drop isotherm constant temperature contours and when you project them in 2D. So, let us say this is ABC eutectic thing. So, now you can start. So, this has so, if the previous case it was like this there was no nothing very complicated there you just know the constant temperature lines on a 2D diagram and they just show the temperature profile. So, this is the profile of the surface.

In this case since you have a ternary eutectic somewhere in the middle there is a dip in the middle. So, what happens is that you draw the tip isothermal lines. So, they say this is how you draw and that is how they start merging into each other. So, somewhere in between you will have a eutectic somewhere. So, these lines they basically merge towards each other to form let us say eutectic, ok. So, various lines merge toward so, form give you a eutectic. So, this is. So, for the sake of it let us say this is 400 300 200 this could be for example, 500, 400, 350, 300 and you know 200 or this could be for example, 650, 500, 550, 400, 200 and so, and this will be the so, all the three lines merge to the contours merge to give rise to a ternary eutectic point somewhere in the middle.

So, it is slightly more clearly basically. So, you have essentially you have the temperature lines coming from A side temperature lines coming from the C side temperature lines coming from the B side the contours and these contours merge together somewhere in the center to give you a ternary eutectic point. So, this is how a liquidus of ternary eutectic well. So, this is percentage A percentage B on this you will have percentage C this will be percentage A. So, this is this basically useful to determine for example, the freezing point of the alloy. So, you can see that if the eutectic falls here you know that this is the minimum temperature that you will have in a ternary eutectic system and there is the minimum freezing point of the alloy.

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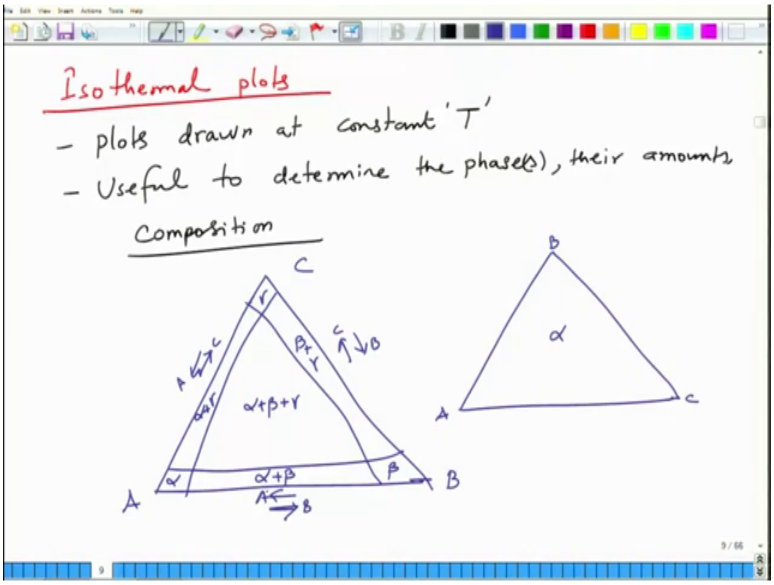

And, this also deter this also helps the identifying the primary phases that form during solidification you know ternary alloy that again. So, the next thing that we do is to basically look at the isothermal plots ok. Basically these are plots drawn at constant temperature. So, and these are useful for predicting various phases useful to determine the phase and their amounts compositions etcetera.

So, you can have for instance situation like this in which. So, if I take a cross section the previous diagram at a lower temperature. So, in this let us say if I take a diagram somewhere at this point. So, let us say this is the t one then what I will see is that if I project it in 2D is it yes if I take it in 2D what I see is that. So, this is A, B and C. So, you can have line of A is something like this you know you know B is something like this and line of C is something like this. So, this would be for example, gamma phase field, this would be beta phase field this will be alpha phase field between these two you will have alpha plus beta alpha plus gamma beta plus gamma and then you will have alpha plus beta plus gamma the three phase field and the hence and you can vary the compositions in this direction

So, this would be A, this would be C, this would be A, this would be B C this would be B, ok. So, this is how you draw the isothermal plots. So, they are drawn at a constant temperature taking a section and this allows you to determine. So, for example, if you draw you know isomorphous system you know isomorphous system at low temperature you will see only alpha phase. So, this is the isomorphous completely miscible system if you go to high temperature you will see only liquid at lower temperatures you might see liquid and solid. So, that depends alright.

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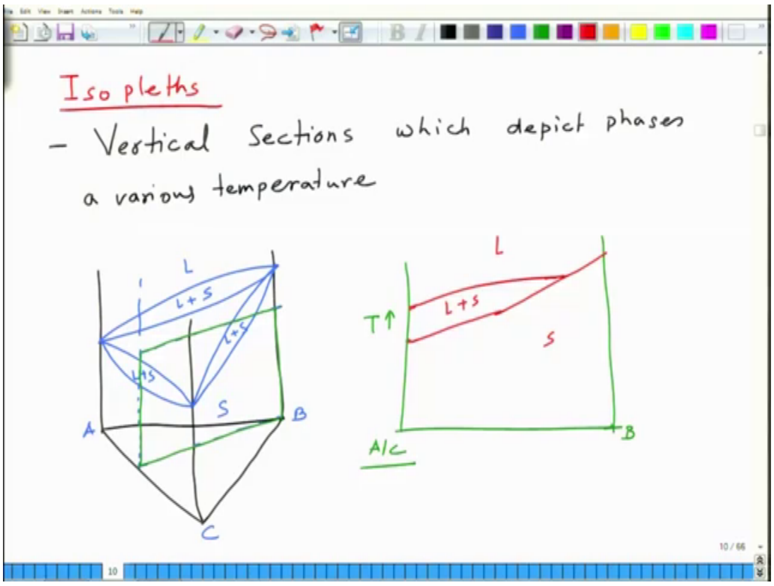

So, these are isothermal plots and then we determine another thing which is called as iso pleths. Isopleths are basically vertical sections which depict phases at various temperature, ok. So, for example, if you have again if I go so, if I draw now of let us say a simple phase diagram, ok. And, let us say so; this is the A, B, C. So, you have liquid and this is liquid plus solid liquid plus solid and liquid plus solid here you have solid and on top you have liquid. So, let us say if I draw a section which is something like that ok, do not worry to is essentially by create a vertical line like this and then I take a section which is bad.

So, let us say I take a section like this. So, I can see that this is the section that I am drawing all right and you can see that if you now project this in 2D. So, you can see that you are going. So, this is the section you started from pure B and you have gone to sum A by C ratio, sum A by C ratio and you can see the phase field varies. So, as this is the temperature axis you can see that somewhere here you have starting from liquid plus solid and then you go to this regime. So, you have phase diagram which shows liquid the that to plus solid you might have a situation in which something like this let us say. So, you have sorry what very neat. So, we have a situation something like. So, in this phase you have. So, you have completely solid regime here something like that. So, you have liquid you have liquid plus solid then you have solid.

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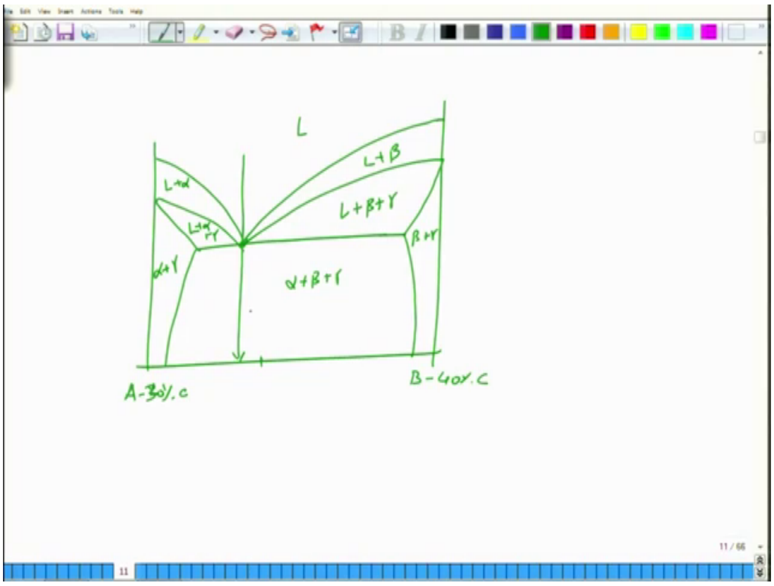

So, something like this you may encounter the, if you want to see something in the binary phase diagram in the binary phase diagram it is it may appear let us say something like this. So, you have let us say A some let us say 30 percent of C and this point is B 40 percent of C. So, so let us say if we go to section in this diagram ok. So, we go through a section like this, ok. So, this is the section and if you raise this section take a vertical section and draw it if you take a vertical section and draw it you might see something like this.

So, let us say you have a alpha. So, something like this let us say. So, the phase boundaries may not actually in these things isopleths are not actually phase diagrams they are not complete phase diagram there only sections. So, as a result you will see phase boundaries doing all sorts of funny things they may not complete the. So, this is L L plus beta L plus beta plus gamma this is beta plus gamma this is alpha plus beta plus gamma this is let us say L plus alpha this is L plus alpha plus gamma and this is alpha plus gamma. So, you can see there is the vertical section starting from A alloy containing A 30 percent of C and B 40 percent of C and this is how it will vary and somewhere in between it will have certain composition which shows a minimum point transforming from liquid. So, this is the eutectic composition of ternary showing you a minimum melting point.

So, these are the isopleths which basically depict the change in phase type as the temperature changes for a fixed A and B ratio. So, these are certain characteristics of ternary phase diagrams that we have discussed this is these characteristics allow you to depict ternary phase diagrams and imagine phase diagrams in a better sense and they better way and they allow you to study the microstructure revolution phases their compositions etcetera in a more meaningful manner. So, we will do further discussion on ternary phase diagrams in the next lecture.

Thank you.