Introduction to Materials Science and Engineering

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Lecture – 66
Phase diagrams: Introduction

Today let us begins with very important topic in Mechanical Science and that is Phase Diagram. So, this will constitute sought of chapter in our material science course and we will spend quiet some time on phase diagram. Let us begin with an introduction to the phase diagrams it is best to introduce phase diagram with an example. So, let us take an example as an.

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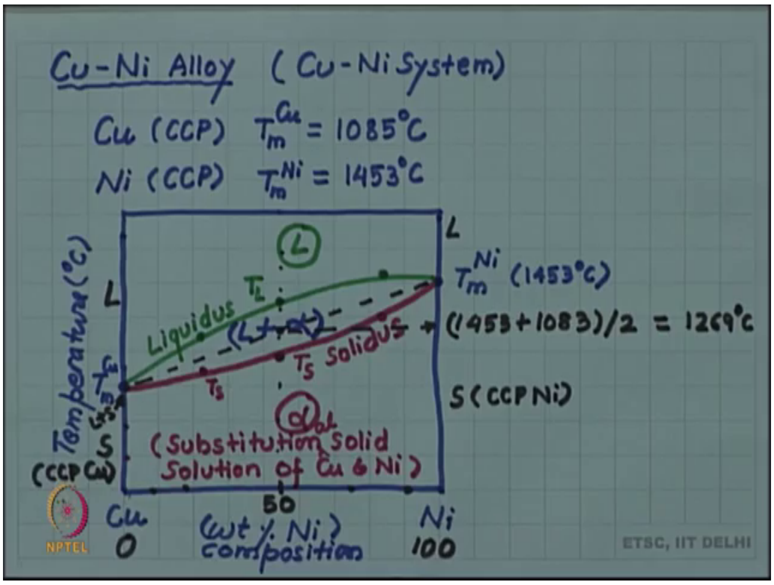

Example; copper nickel copper nickel alloy in phase background jar din or phase background terminology alloys are also sometimes called systems. You can say copper nickel alloy or you can say copper nickel system.

Now, let us look at some basic fact about copper and nickel. Copper is cubic close packed in crystalline structure, and it melts at the melting point the melting point of copper is 1085 degree Celsius a nickels also cabby close pack and it is melting point is higher melting point is 1453 degree Celsius. So, if I simply look at let us say if I look at copper and let me considered this vertical axis there is pageant temperature.

So, this is my temperature in degree Celsius. So, this is my temperature axis and on this temperature axis, let me mark the melting point of copper. So, that is there which is 1085 degree Celsius. So, I know now that above this melting melting point the phase which will be present will be the liquid phase. So, you have liquid their and belong the melting melting point, I have solid and at the melting melting point you will have both the liquid and solid. In particular I do not have space here, but let me try to include liquid plus solid at this point.

So, only at that point only at melting point, but two phases will be equilibrium. So, in sense I already have this one's dimensional phase diagram were temperature is only the variable and which temperature varying; I know the there is critical point called melting point above the melting point. Liquid phases stable below the melting point, solid phases this stable and at the hating point both liquid and solid phases can be equilibrium now let me look at.

Now, let me look at nickel and I create a similar one demonical phase diagram for nickel. So, again I have temperature axis and the melting point is higher. So, if I have same temperature is scale for this. So, 1453 will be plotted at higher point and that is melting point of nickel 1453. So, gets like I have cop one dimensional copper phase diagram with temperature has only my variable off course I have could not draw the sense it is a single variable and use if have only one variable you plotted it has x axis, but I am plotted with has the y axis you will soon realize y. So, because x axis I need for compensation.

So, on this temperature axis again, there is melting point above the melting point you have liquid phase this of course, be liquid nickel now and below you have solid phase which will be solid nickel. So, it will be cubic close packed nickel. So, this solid age CCP nickel were has this solid was CCP copper. Now let me use as x axis; let me join this with horizontal line, which now gets me compensation axis and let me use this compensation axis has let me call that weight percent nickel as my compensation.

So, this is the compensation x axis is the compensation and the unit which I am using the compensation is weight percent nickel ; obviously, copper has 0 weight percent nickel, if I write here 0 weight percent nickel and pure nickel itself is 100 weight percent nickel. So, the compensation access varies from 0 to 100 and if I take any point if I take any point in between. So, that will be 50 percent nickel. So, any alloy any alloy of copper or nickel which I make will be some point in this axis you can have 10 percent 20 percent, 50 percent, 70 percent, 90 percent and so on. So, any alloy which I make will be some point on this axis.

So, entire copper nickel alloy system is represented on this x axis from copper to nickel. And in particular let us me focus on my attention on this 50 percent alloy. Now just like can I draw phase diagram for this 50 percent copper, 50 percent nickel alloy, I had the one dimensional phase diagram for copper were only important point was the melting point of copper, I had one dimensional phase diagram for nickel were only important point was the melting point of nickel and I knew all the phases above melting point it is liquid below the melting point it is solid and at the melting point liquid plus solid.

Now, I similarly ask what will be the phases or what will be the melting point the critical melting point for 50 percent nickel. So, it is some were on this line and not knowing anything about the system let us assume that we do not know about the system anything has here. So, what we can try to do is to do her any interpolation. So, I try to do limier interpolation between this to melting point.

In other words I am assuming that melting point varies linearly from the melting point of copper to melting point of nickel as I vary the compensation then; obviously, the melting point of this alloy 50 percent alloy which is of my interest at the movement. So, this melting point will be predicted exactly in between the melting point of copper and nickel. So, I will get the alloy melting point the predicted melting point has just the mean value of these two melting points which will be 1269 degree Celsius a which is the reasonable not knowing anything is a reasonable production that copper is melting at 1083 nickel is melting 1453 degree Celsius.

So, at an intermediate temperature at an average temperature of 1269 degree Celsius my alloy 5050 alloy 50 copper, 50 nickel alloy will melt at this temperature, but when I do the experiment actually experiment I will find that liquid as start appearing at a temperature lower, then what I predicted. So, below 1269 the melting actually begins let me call at temperature for the movement as T S. So, melt actual melt melting begins at a temperature TS less than the value predicted by this linear interpolation. Again another interesting thing is that, when I was melting the pure copper and it was solid solid an till melting point it was solid and at the melting point liquid started to appear an when I give further heat to this copper the temperature did not raised you know above the latent heat.

So, the heat was not increasing the temperature it was only converting more copper into liquid. So, the latent heat concept was there for pure copper and similarly for pure nickel. So, the entire melting for this pure components entire melting happened at one temperature, but this happens not to be the case for this alloy, if I do the experiment an alloy I will find that all those melting is started at this TS, if I give more heats the temperature rises as well as more liquid forms, if I give further more heats it still more a liquid forms, but along with more liquid forming temperature is also rising. So, finally, I find the 100 percent liquid appears at higher temperature, then my mid temperature and let me called that temperature TL.

So, I find that our prediction was incorrect all those we were a still in the sense who are write that we are predicting an intermediary temperature, but new feature appeared that melting unlike pure component melting is not happening at one fix temperature with latent heat involved, that melting is happening over range of temperature melting is starts at TS and melting complete at TL; if I do this for different alloy compensation, then I will find suppose instead of 50 percent. Now, I make 25 percent alloy and I find were the; liquid first begins. So, I plot TS for that and similarly was 100 percent liquid forms. So, I make TL for that and similarly for 75 percent I have TL and I have TS.

Now, if I do experiment. So, all different compensation and find the TL temperature and the TS temperature for all of them, then I can I find the TL varies as a function of compensation. And similarly the TS varies as the function of compensation and this boundaries we call TL is called liquidus boundary in TS is called the solidus boundary. We have special terminology with which you should become familiar.

So, now, essentially what I am saying that for alloy the melting happens overly range of temperature about TL you will have pure liquid phase for any compensation above liquidus temperature you will have single liquid phase below TS no melting will happen and you will have a single solid phase solid phase in phase diagram is usefully represent by Greek letters.

So, let me write this as alpha and since this alpha you can see this alpha will contain both solid as both copper and nickel. So, it is solid solution and copper and nickel are of the almost same size. So, they make substitution solid solution. So, this alpha s is solid, but let us write it in detail the detail a substitution solid solution of copper and nickel and recall Hume Rothery rule that, now we are have substitution solid solution from write from one end the another end. So, this fact is related to Hume Rothery rule, then this is possible only if the two solid have the same crystal structure and here we are fortunate that both copper and nickel are actually CCP.

So, this kind of continuous substitution solid solution is possible. So, alpha is here below TS you have single solid solution alpha above liquidus you have single phase liquid in between this two reasons in this length shape reason you will have both solid and liquids phases. So, you will have liquid plus alpha. So, this completes have phase diagram of copper nickel system were the x axis is the compensation which is starts from 0 percent nickel which is pure copper to 100 percent nickel, which is pure nickel the y axis is the temperature which starts from some low temperature to some high temperature including the melting points of both the components and we have two boundaries.

In this phase diagram one liquidus boundary above which liquid phases stable solidus boundary above below with solid phases stable and lance shape region between liquids and solidus were both phases are his stable. So, this is the phase diagram of copper nickel, because it is telling us what phases are in equilibrium at what different compensation and temperature. So, let us end this video with sought of definition. Since we have already concrete example of phase diagram, but let us the; definition what is called equilibrium phase diagram.

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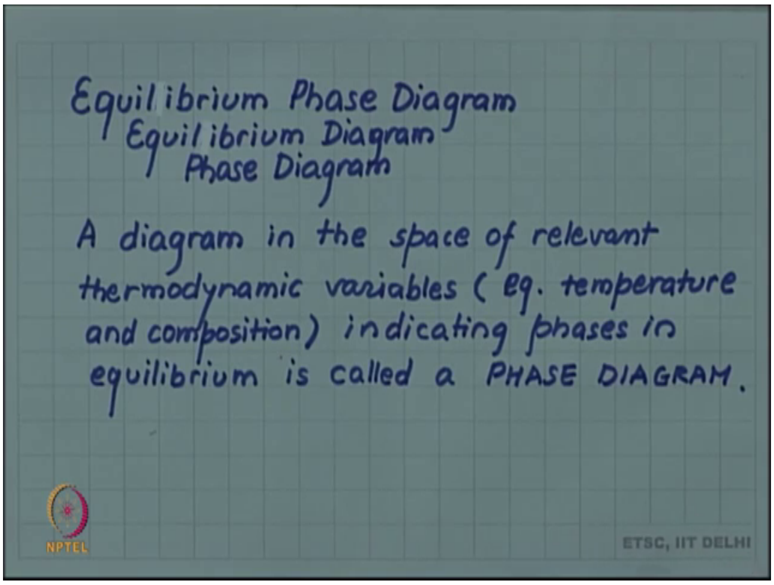

So, in full actually it should be called equilibrium phase diagram, but sometimes it is short end to equilibrium diagrams which means the same thing for some times more commonly to simply phase diagram which is; what we have utilizing phase diagram. So, let us make an attempt to define this.

So, a diagram what we saw? Let us the phase diagram of copper and nickel was a diagram in temperature and compensation his space. So, we have thermodynamic variable in space of which we make diagram so, diagram we trying to journalize it little bit more to include other kinds of phase diagram. So, diagram in the space of relevant thermodynamic variables just make it concrete and connect it with our example.

So, our in that diagram the relevant thermodynamic variables was for example, the relevant thermodynamic variable we considered was temperature and compensation, that the definition as written comedic other phase diagram were for example, if you want to study the effect of other variables. So, I pressure or electric or magnetic field on what kind of phases you get.

So, you can have those variable as part of your phase diagram. So, diagram in the phase of relevant thermodynamic variable indicating phases in equilibrium is called a phase diagram. So, the for nickel copper diagram which we give on a example sd our first example and we what with a example more as we go along. So, that is our stranded example for our fast part of the course to; so, in that example we saw that it was a diagram in temperature compensation is phase and it was telling me a different compensation in temperature what phases are equilibrium.

So, this is the job of an equilibrium phase diagram. So, we can take this as the definition of the phase diagram.

Thank you.