NPTEL
NATIONAL PROGRAMME ON
TECHNOLOGY ENHANCED LEARNING

IIT BOMBAY

CDEEP
IIT BOMBAY

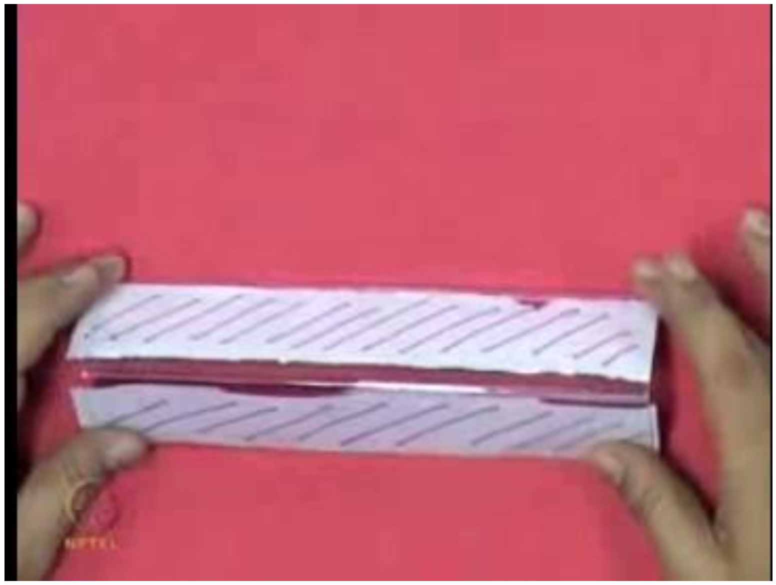
Phase field modeling; the materials science, mathematics and computational aspects

Prof. M P Gururajan
Department of Metallurgical Engineering
And materials Science, IIT Bombay

Module No.3
Lecture No.13
Stability

Welcome, we saw that spinodal is defined as the boundary between unstable and meta stable regions in a two-phase region so in order to understand what is this meta stable what is unstable what is stable we can use the mechanical analogy which is due to Khan himself so it is there in one of his lecture soul some point we will see the reference to it and for doing this mechanical analogy.

(Refer Slide Time: 00:44)



I have sourced this triangular prism okay it has three sides one side I have marked with red lines the other side I have marked with blue lines and this third side is open but you can imagine that this is also close to end with green lines for example okay so if you take this triangular prism now and this is at its stable equilibrium because if I try to push it like this it will fall down right it will fall down to the same shape I can push it in whichever way I want it will always fall down to this sliders.

Why does it do that it does that because the system is trying to minimize its potential energy the potential energy is given by MGH where H is the height of the CFG with respect to some reference so let us take that this is the reference on this sheet on which this is sitting and from there you measure the CFG when I do like this the CFG increases which means the potential energy increases so the system falls down so whichever way I perturb it then it comes down to its equilibrium position so this is an example of stable equilibrium.

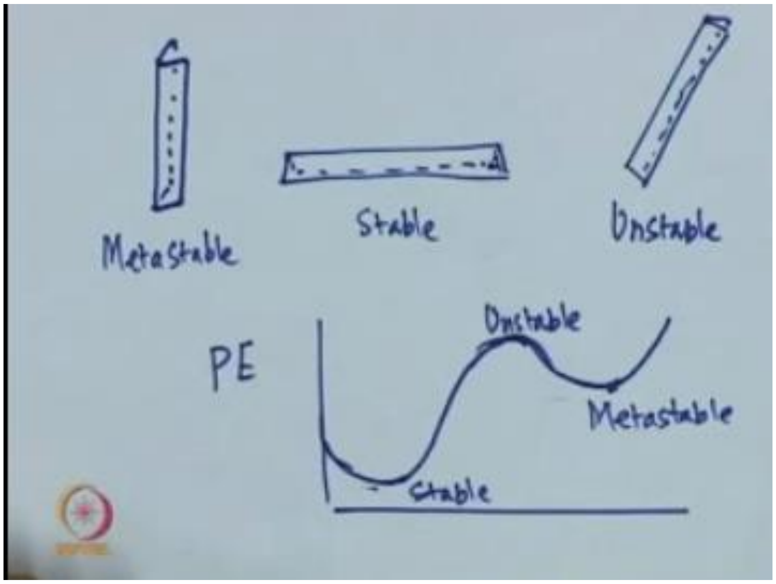
Let us consider this if I push it a little bit it does come back to this position so this is also a minima right if I if I put up a little bit then it actually comes back to the same position like in the earlier case however if I perturb it a lot then it does not come back right it falls in to one of the other equilibrium right all these three sides when it sets on it will have the same CFG so that is the most stable equilibrium.

So that is known as stable equilibrium because that has the least potential energy in the case where the triangular prism is standing it does have a minima about this standing position but that minima is having still higher energy as compared to the one where it is lying down like this so the second one where it is in this kind of standing position is known as the meta stable many or meta stable equilibrium, if I keep it in a fashion like this for example if I am trying to you know make it stand on one of these corners.

Then I do not any small perturbation will always make it fall to the minimum one of the minimum I mean it does not have to fall only on this side can fall on this it can fall on this or it can fall on this okay so it is a triangular prism all three sides it can lie on all or equivalent so if I keep it something like this then it is going to fall into one of these positions okay so it will it will always fall into one of these positions okay.

So that is known as unstable equilibrium now let us try to understand it more in terms of the potential energy okay so what do I have I have these three cases okay.

(Refer Slide Time: 03:57)



So I have something which is like this right and this is meta stable and the other hand I have something which is like that okay so in that case it is stable and if I try to stand this on anyone of these then it is unstable because it is going to fall to either this or this and most of the times is going to fall that is not this because of the way the structure is in terms of potential energy and in terms of the configurations if I look at so there is this and then there is this okay, so this is meta stable this is stable it is unstable.

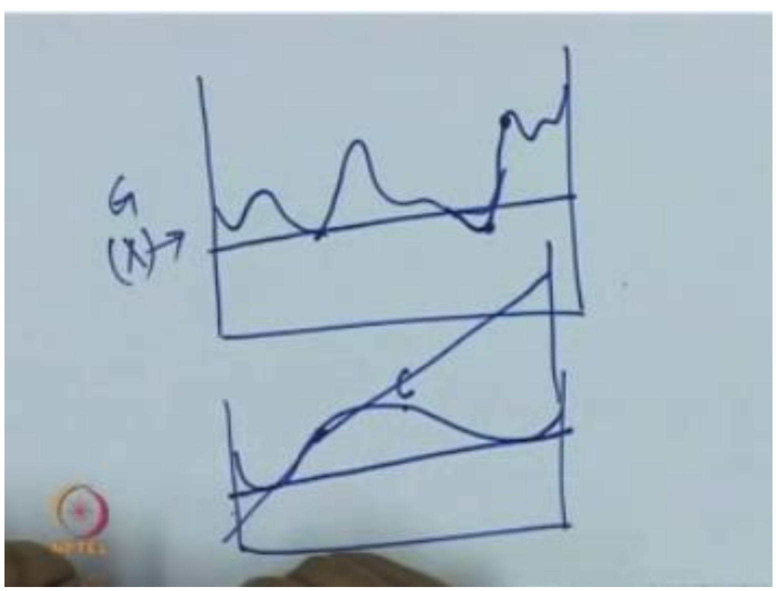
So what is happening when you are like this you know when you have this and when you are pushing it a little bit here and there if for small pushes right the system still finds that this is the minimum energy position so it comes here but when I am taking this and when I am pushing it to beyond a point when it reaches some configuration like this there is going to fall like this so it is going to reach this configuration when I am pushing it too far and then it falls in this.

Now when it is in this kind of stable equilibrium it does not matter how much I push it is always going to go and fall into one of these equilibrium positions so this is how we define meta stable unstable and stable, stable is something that can resist all perturbations that you give right so if it is stable then that has the least energy between stable and meta stable there is not any difference meta stable also if you give perturbation so it will try to go back to the position except that when it is meta stable there is another equilibrium position which is lower in energy than the meta stable one okay.

Stable is basically the least energy possible configuration of all the configurations okay meta stable is locally stable but globally it is not stable because there is something else which has lower energy than that so given a chance from here it will actually fall here unstable is the configuration where it is not stable against any perturbation any small this thing it is going to put it into one of the meta stable or the stable states.

In the case of a system which is undergoing spinodal the same thing is happening in the case of a system that is undergoing spinodal when the system is in the homogeneous composition state it is like unstable state it has higher energy the system would like to fall into one of the meta stable or stable states that is available okay, in fact we are going to show it as part of the next module that.

(Refer Slide Time: 07:40)



If suppose you take any property okay and in this case we are looking at actually free energy but it could be any generic property okay, as a function of composition okay if this property you know has so let us consider a generic X property so it has some strange dependence okay soon composition if you have something like this you can show that whenever you pick some composition and you want to know so suppose this is something okay.

So that is the common tangent and so it is like this and when you have a system like this you try to make something from this you try to prepare composition of this for example then because this point lies above this tangent that you have drawn that will be meta stable and if you have a region which is like this and if you try to prepare something like this which is lying below the common tangent that will be unstable so this we are going to prove okay.

As you can see in the case of our free energy versus composition diagram which was like that so you take a common tangent so any point that lies above basically becomes unstable okay so if you take some composition and if you draw a common tangent and you try to look at the other point which you are trying to prepare from this weather that point lies below or above this tangent is what is going to determine whether it is going to be unstable or meta stable okay.

So we are going to do it in a slightly greater detail and more properly in the next module but in terms of the mechanical analogy so you have to think of the region where G double prime is less than zero or where the conservative free energy with respect composition is less than zero is basically an unstable region it is like standing the triangular prism on one of its corners and when you have the free energy with respect to composition the second derivative of it is positive that is equivalent to making the prism set or lie down.

Because local fluctuations if you do locally the potential energy of the system increases so it tries to resist that in the same way in the system which we are considering in a binary system any local composition changes are going to increase the system is free energy so the system is going to resist that it can overcome it can go to the most stable equilibrium the least energy configuration but for doing that it has to overcome a barrier okay.

So that is what we mean by spinodal so miscibility gap and spinodal in both the system would like to face separate into a rich and be rich regions in the meta stable region for undergoing this phase separation the system has to overcome a barrier in this spinodal region it does not have to overcome any barrier it can do it spontaneously which means in the meta stable region the mechanism of phase separation is by first overcoming the barrier that is known as nucleation and then growth which is driven by diffusion.

On the other hand in the spinodal region because there is no barrier to be overcome the entire transformation is completely driven by diffusion so this is what we are going to discuss in greater detail in the next module we will start with this derivation we will show that this common tangent at any point on the curve that lies below the tangent will be unstable and any point that lies above will be meta stable and then proceed from there, okay. Thank you.

NPTEL
Principal Investigator
IIT Bombay

Prof. R.K Shevgaonkar

Head CDEEP

Prof. V.M Gadre

Producer

Arun Kalwankar

Digital Video Cameraman

&Graphics Designer

Amin B Shaikh

Online Editor

&Digital Video Editor

Tushar Deshpande

Jr. Technical Assistant

Vijay Kedare

Teaching Assistants

Arijit Roy

G Kamalakshi

Sr. Web Designer

Bharati Sakpal

Research Assistant

Riya Surange

Sr. Web Designer

Bharati M. Sarang

Web Designer

Nisha Thakur

Project Attendant

Ravi Paswan

Vinayak Raut

NATIONAL PROGRAMME ON TECHNOLOGY

ENHANCED LEARNING

(NPTEL)