Phase Transformation in Materials
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Lecture - 01
Brief Introduction

Dear students, let us start the first lecture of this course. This is basically a online course, so therefore you need to be very clear about what you are going to learn, and how you are going to be evaluated. First of all this is a course on phase transformation in materials, and I will be teaching all the lectures, and it is a 30 lecture course; that means, there will be 60 25 minutes lecture, and every week will be, I suppose to, I am not sure now about 4 to 6 lectures. So; that means, about 2 to 3 hours of lectures. So, myself is Professor Biswas, and I am a faculty member at the Department of Material Science Engineering of IIT Kanpur.

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So, that is the details about me, my email address is available on the screen, you can daily write to me whenever you have any serious problems. And in addition to that, to handle the course exams, and also grading appear answer sheets, I know this will be done online, will be taken care by the teaching assistance.

So, two of my students, they will be handling that. So, they are actually the main person, will be handling your questions to my, write first one is; Kushbu, Kushbu Tiwari is my

PG, and second one is Reshma, Reshma is also my PG student. So, they will be handling all your the questions in the discussion forum; obviously, they are very difficult, and I will also participate, and also they will be handling your question paper and grading. So, my task will be to deliver all the lectures, and then this will be uploaded in to NPTEL website. So, that you can observe and read or listen online, whatever way you can think about it.

Nowadays also there is another provision, all my lectures, whatever I am speaking will be again taken down or written by some experts. So, we are in the process of finding out those experts on my earlier course on phase transformation materials. Similarly we will do it for you also. So, that you do not need to listen, you can actually read all this lectures notes. So, before that happens we are going to only listen these lectures, available on the NPTEL forum.

And also you can ask questions in the discussion forum and so that is about it, and there email address are given and I have carefully removed the phone numbers, because this is where things become very difficult to handle. So, if you have any questions, you can ask them, ask me also or you can put it on the discussion forum, you know like any things in life, every course has an objective and this objective has to be very clear before you start the course.

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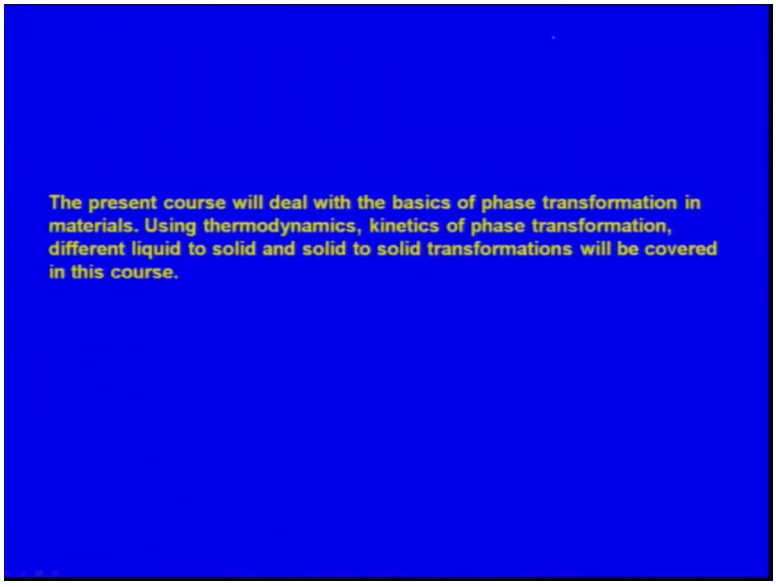

So, present course actually will deal with basics of transformations in materials, and as I said in my introduction video already, you have seen probably that phase transformation is everywhere present in the normal, whether you are talking about materials ceramics polymers. Or you are talking about real life phase transformation is present, that how do we deal with phase transformation; that is what you will be taught, because that is what is important in your endower to learn phase transformation.

So, using these three things; one is your thermodynamics, then kinetics and some basic aspect of material sands like crystal structures and interfaces. We are going to study various solid to solid and liquid to solid phase transformation, as you know this is our subject and covering that in 30 lectures is not an easy task.

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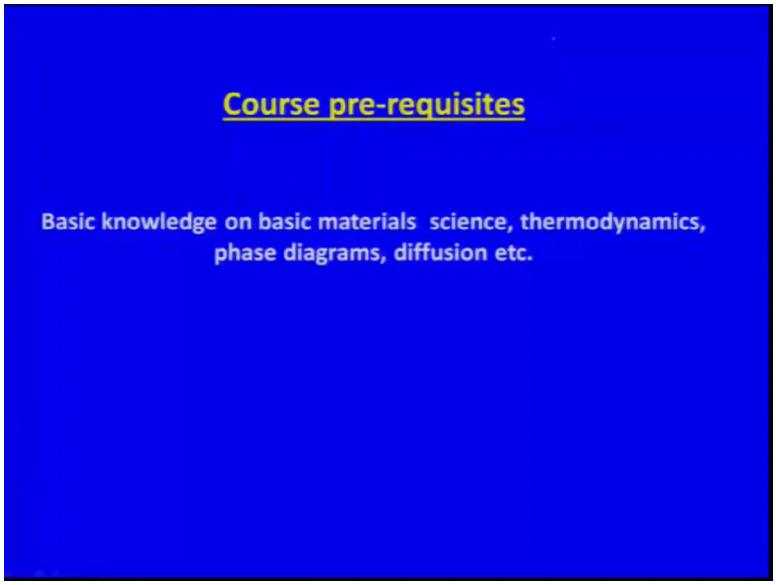

Obviously, we must be selected, we cannot teach you everything and to learn everything you need to have some basic idea, what I put it as course pre requisites, and this pre requisites are should have preferably, should have some basic knowledge on basic material science, that most of the students in methodology or material science normally have thermodynamics, especially with thermodynamics functions and their relationships, and then some idea about phase diagrams and diffusion ok.

So, I have already checked on different courses in NPTEL, but by mean, by different person is that there are some courses, which are videos, some courses which are web, some courses which are massive open online. So, basic material science is already being

taught by some faculty members. Thermodynamics is already being available and phase diagram, I myself was developed a course nil, just one year back, diffusion is also partly taught. Therefore, you can actually clear your doubts while reading these lectures.

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Topic Sl. No.	Topics	No of Lectures (50 minutes lecture)
1. Introduction	Introduction and classification of phase transformations	1
2. Gibbs free energy change calculations	Calculation of ΔG_V for various transformations (polymorphic & solidification, precipitation, massive, eutectic & eutectoid)	2
3. Interfaces	Nature of inter-phase interfaces and their energies.	2
4. Nucleation	Theory of nucleation, Homogeneous and heterogeneous nucleation (surfaces, grain boundaries, edges and corners, dislocations).	3
5. Solidification	Solidification: pure metals and alloys, constitutional supercooling, dendritic growth	2
6. Growth	Theory of thermally activated growth, interface controlled growth (polymorphic and massive), diffusion controlled growth (one and three dimensional), coupled growth (eutectoid and discontinuous precipitation).	5
7. Transformation kinetics	Transformation Kinetics, Johnson-Mehl and Avrami Models. Isothermal Transformation diagrams.	2
8. Precipitation	Precipitation and precipitation hardening (Al-Cu), Oswald ripening.	3
9. Recrystallisation and grain growth	Recrystallisation and grain growth.	3
10.Martensitic Transformation	Martensitic transformations	2
11. Isothermal and continuous cooling transformations	Isothermal and continuous cooling transformation diagrams for steels and basis of heat treatment.	3
12. Spinodal decomposition	Spinodal decomposition.	2
Total		30

This is the full, rather all the description of the all the lectures, I do not know whether everything is coming in this scheme or not, but any way most important thing is that, we are going to talk about some very at the beginning, where we going to talk, give you some idea about free energy, because that is the thermodynamic part of the phase diagram. So, we will show you the calculation of delta G of various transformations then we will talk about quad derivative of interfaces. Interfaces means, liquid solids grain, grain interface inter phase interfaces, this are all parts of thermodynamics.

Then you have to go in to kinetics that is the nucleation, because nucleation is what the starting point of phase transformations. Therefore, theorem nucleation homogeneous, heterogeneous nucleation, and nucleation on the surfaces grains, and even clan corners gen edges, every where it will be dealt with, as you know nucleation itself is the subject. So, there that we must be very, you know you have to very careful about what you are going to talk about it is. I will not be able to tell you every detail of the nucleation, but whatever element we will discuss, then we are going to start the first of the phase transformation; that is on solidification.

As you see here, solidification is a liquid to solid phase transformations, then we will talk about growth during different aspects; like thermal activated growth, interface controlled growth, diffusion controlled growth, that is why you need to know as well as coupled growth, and you take to array, you take the transformation. Then we will talk about little bit about transformation kinetics in terms of different models Johnson Mehl and Avrami models, and some amount of gas thermal phase transformations. Then we will simply go on to different solid phase transformations; like precipitation recrystallisation martensitics spinodal decompositions, and we talk about isothermal and continuous transformations; that is itself will be sufficient enough to call off 30 lectures ok

So, this is important that you know what we are going to be taught at the beginning so that you can prepare yourself. So, we are going to follow exactly the same way, things are given on the right side. I have also listed down number of lectures will be spent on each topic.

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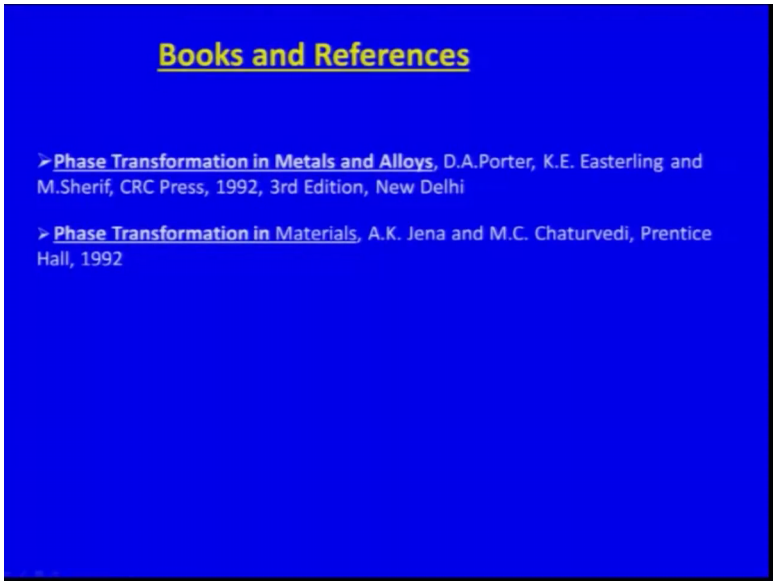

Now, comes in very important aspects, because in a massive open online course, you will be exposed to video lectures or the online lectures. You must have some amount of you know text book knowledge. So, therefore, two important text books which are carried from our library, is this first one, which is here, is written on that is phase transformation in metals, and alloys classic text book by D A Porter and K E Easterling, and the recent edition also has come with a new author, are all the problems are solved Mr Doctor M Y

Sherif. This is available in India not very expensive book, you can read that and the other book is written by two of my past colleagues. Although, I have never met them, but through IIT Kanpur; this book is phase transformations in materials, and by professor A K Jena and professor M C Chaturvedi both were at IIT Kanpur.

So, when this book is written, there were, Jena was in Kanpur. So, these two books will be a basic text book for the course, and anyone, any of these books will be good for you. You can by these books or you can actually copy from different libraries in the different parts of the book. You can copy from different libraries, or if you want, you actually even you know get by that on different online stores correct. So, that is about the basic part of the course. I think before I could move on to the next portion of my lecture, why the phase transformation is delivered.

Let me tell you, you will be given assignments on every week, and I think assignments are normally uploaded on Thursday, and because Monday to Wednesday will be exposed to the lectures, and after that you will be, I will be my T S will be uploading the assignments, and you will be given about one weeks time to complete the assignments, because assignments will be online. So, the questions will be multiple choice types, or may be fill in the blanks type as assignment will have a weightage of 50 percent weightage, and at the end of this semester you will be taking an some exam, and we are planning to have it online. So, far if I do not change my decisions or something else is happens, otherwise it will be online, and that will be having a 50 percent weightage.

Although I am not keeping any pass marks for this course, but you can interdentally consider, if you are getting less than about say 30 percent of the marks. Then you will not be able to pass this course, and those who will be successfully completing this course by taking exams and getting good marks, will be given certification from the NPTEL as you know. So, that way I expect that you will be very serious learner, and you will be also able to solve these problems. If incase you have difficulties, you can always discuss, you can always use the discussion forums, or you can write emails, you can always bring it to the instructor, all the T S. So, that we can make it clear to you; that is very important, because unless and until you know the things very well, you will not be able to answer the questions.

Now in the next few slides I am going to talk about what are the relevance of phase transformation materials development. Then why do you study in any course, I know that many of you do not exposed by the instructor in the same way, you must have an idea why you are studying this course, what is the need. Well phase transformation is as I said is represented environment, ok.

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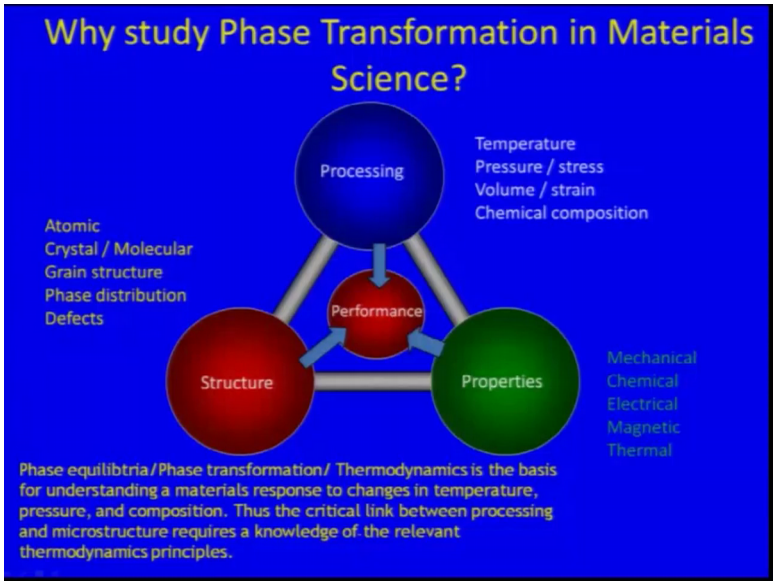

This slide I have taken from the literature, you know that is what I am going to answer to you why study phase transformation material science, you know what we are actually we look material for the application in any case. Finally, we have to think our application unless and until this material is applied engineering point of view. We do not find any reason to study scientific point of view, one can study. So, application means we must know that properties, all kinds of properties.

So, there is a physical, mechanical, electronic, electrical, magnetic depending on the applications. So, property or properties of a material are estimated very rigorously to find potential applications. This is true for even a new materials, when its developed. So, now, question is these properties as I said mechanical, chemical, electrical, magnetic thermal. You can even list on many more properties of the material, depends on structure, and that is why actually real problem comes. Structure has land scape, you can simply say atomic structure. Atomic structure is the smallest structure you can think about it, atom and nucleus.

In fact that is what dictates most of the properties are to material, but that is not all, that is what in to, this is what you must know very clearly that is not all.

So, structure means, it can be atomic structure, molecular structure, grain structure, phase trans distribution and defects. So, we have, basically I have listed down from the bottom up the atom is smallest theses, and then we have grains and other things. So, you must have. I am stressing again you must have an good idea about this structures to correlate with the properties, because it is important that the properties are primarily dictated by the structure.

So, if I know the structure I can dictate the properties. So, you got the correlation right. Very logically speaking we made materials, rather we use processing techniques to make materials, and these processing techniques allow you to control structure processing technique, means what you can start with the liquid and solidify, that is what is solidification. You can start with the metal piece deform by rolling forging exclusion, whatever different means. So, you actually process or you can actually deposit thin film. You can actually, you surface treatment techniques, many things we do in the real. Now processing of materials they have a direct connection with this structure.

A structure has a direct link with the properties. So, as you see here, these actually are variables for the processing temperature pressure or stress strain or volume, and chemical composition for the alloys, you can change chemical composition by making different alloys. So, these are my variables in processing, and by applying these variables or combination of variables I generate, or I make materials and manufacture materials, and this processing variables controls the structure, and structure controls the properties. So, therefore, these three are linked, very clearly they are linked, they are not separate or they are not independent things, they are connected to each other. These are the (Refer Time: 16:15) of these three important pillars of material science, processing structure and property.

But finally, where do we look for. Finally, we look for what is known as performance. If you are studying in a course syllabus in a course, you are finally, evaluated on performance. Similarly, materials are evaluated in terms of performance, if I put a tire in your car; that means, the major performance is the tire should be able to drive the, take the car from one place to another without any problems, but you know tires should vary,

from a summer to winter in the foreign countries, in the ice, tire which will travel on ice are different.

So; that means, performance indeed are actually connected to all these three things, processing structure, and the properties, and that is what is important this chart, which is very famous in material science. You will find in many books as known as the material tetrahedron, because they are actually looks like a tetrahedron. Finally, where does the phase transformation comes? It is in the structure, we modify the structure, we modify the atomic structure, we modify grain structure, we modify the various by phase transformation. So therefore, phase transformation are directly linked with processing, and also indirectly connected with the properties, and that is why it is a very important course in the material science engineering. You must understand that without knowing the, or phase transformations you cannot control material properties ok.

So, phase transformation or phase equilibria or thermodynamics is the basis for understanding a material response to change in temperature pressure composition. I must accept this is slide I have taken from web, this is not mine, thus the critical link between processing and microstructure requires knowledge of the relevant thermodynamics principles, and they are the basis for phase transformations. So, you understand now why we are actually studying the phase transformations.

Now question is this, can I relate it to real applications, I have taken four applications again directly taken from the internet sites. First one is in air plane, air plane is the very important mode of transport from one part of the world to other part.

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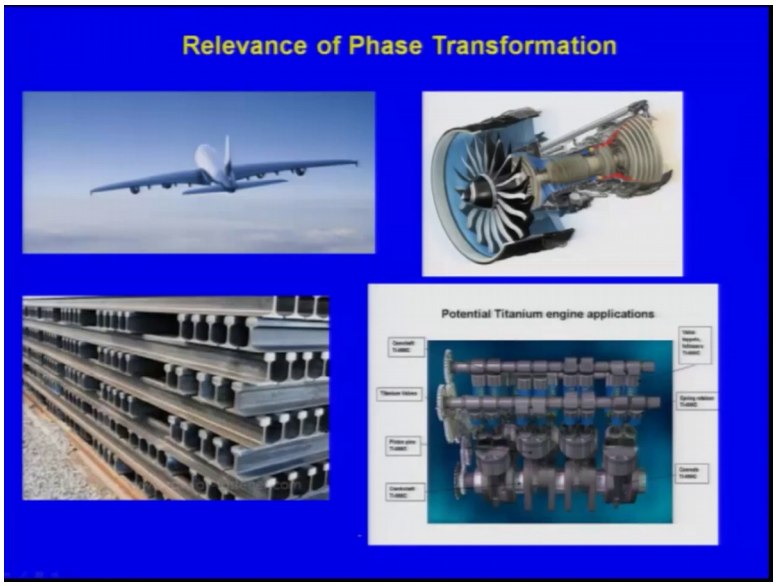

And you know the material which is used in the air plane is an aluminum copper alloy. If you do not know, you can actually check on the books. This is the classical alloy aluminum 4.5 to 4.7 percent copper known as dual lumen in the trend name, and this is a very stable alloy from 45 degree Celsius to minus 65 degree Celsius or even minus 80 degree Celsius. I do not know how many of you read news that there is a research laboratory in the southern Hampshire; that is in Antarctica, and sometimes, if somebody yield in the research laboratories in winter time, they are actually taken from that place by plane to the different country, especially in Southern America and such parts, but it will be extremely cold minus 60 to minus 80 degree Celsius temperature. So, a plane flying there, the material has to be stand such a low temperature.

So, this wonderful material which is prepared long back, is used for the plane body and important phase transformation, which is happening here is a precipitation of certain phase in aluminum alloys, and this precipitates provide the strength from high to low temperature. If you travel carefully on the planes, you will find especially in the wings deviated join, and this deviated joins are very strong and low temperatures, because of the precipitation. So, we are going to discuss about that.

Next one, which is very important on the right side is air turbine basically, it can be used in the plane, the high speed plane, or in when in power generators and they contained nickel based super alloys. This wonderful material, this is nickel aluminum alloy, with

consisting of many other elements, which I will not discuss in detail now, but again the real high temperature properties, because this is turbine. So, therefore this has to be instant high temperature, high temperature properties, equi based properties of this material is basically, because of precipitation of N I 3 A L type L 1 to precipitates what we known as in a nickel matrix FCC matrix, and this unique precipitates actually provide the strength the, that is; that means, precipitation is very important aspect to understand. So, that is what is will be part of silvers.

Then on this side, left side I know may be your right, this is the rails which is used to as a phi splay on the railway tracks. This actually steels, basically the steel of perlite what you known as if you do not have any idea perlites. Perlite is nothing but a UTech (Refer Time: 22:00) transform product of gamma solution of carbon in iron. Therefore, you must know how this transformation happens, whether we can control it, because the properties of the rail depends on that, and remember rail is what is allow you to allowing us to move trains.

So, therefore, they are subjected to stress temperature, harsh environment and many other things. So, they must have combinations of properties. So, that they can start the purpose, and this is basically done by controlling the phase transformations on the right side. This is the end, the last example is basically the titanium based align engines, remember this engines are not used in car. They will be used in planes or may be in some other strategic applications like TURB, like the submarines and so.

So, these engines actually have many plus like titanium valves, titanium MMCs springs titanium MNC cramps, many others things springs, and there are titanium aluminites. You know titanium out of these all 13 m alloys the most important alloy, which is extensively used in titanium 6th aluminum 4 vanadium, and it we can control the micro structure of these by many ways creating alpha titanium, alpha plus beta titanium, beta of titanium alloys.

So, the properties will vary depending on whether its alpha alpha plus beta alpha or beta, remember alpha is hexagonal prospect structure, beta is BCC structure. So, titanium actually room temperature below, what to 882 degree Celsius temperature is basically alpha above that it is this, I mean BCC structure. So, one can actually play around in the

temperature zone by again controlling the prosaic parameters, to create different kinds of structures to get different properties.

So, all these applications, do not think that they are similar alpha alloys or beta alloys alpha plus beta alloys, they can be combination of many of these, then the actual real problem is, how do I control this micro structures by controlling the processing parameters. So, remember these four examples are not exhausted; one can find many examples in the real life, as I told you in my first introduction lectures. The basic example you always find is in the country India, when hot summer days you want to drink cold water. So, you can always put the cold water inside the fridge, and get it cooled, but it is, real advantage is that, if I take a glass of water and add a ice cube taken from the deep freezer, immediately the ice cube will start melting it down or getting dissolved in the water, both are actually H2O; one is solid H2O and the other is liquid H2O.

Therefore, by melting it down the heat is getting transferred to the liquid, and then the water gets cool down. You will enjoy the drinks. So, this is the example which is present, which you are actually doing it, but what is important for you to understand how these transformation happened, how these solid become liquid, liquid become solid, whether it is very simple or not. Remember what is from the most complex systems in the world and no unlike metal like more complex. So, let me just stop here, before I go to the next part of the lecture or the next class.

So, you understand in a nutshell that phase transformation is basically very important from the perspective of material science and technology, and many of these products which you are actually using these, their properties are controlled by controlling phase transformations. We can do that by using different processing parameters, temperature stress strain compositions, and by doing that we alter them micro structure, the atomic structure, and by doing that you will create a different properties.

So, that is the relevance of phase transformation course, and which will be exposed to in the next subsequent lectures.