**Defects in Materials**
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**Lecture - 01**
**Introduction**

Dear students, today this being the first class I will introduce something about what is defects in material, why it is important to study this course. The first question which comes is that why a turn defects are necessary, what is the importance of these defects, do they have any role to play in the behavior of the material these are all the aspects which one has to consider.

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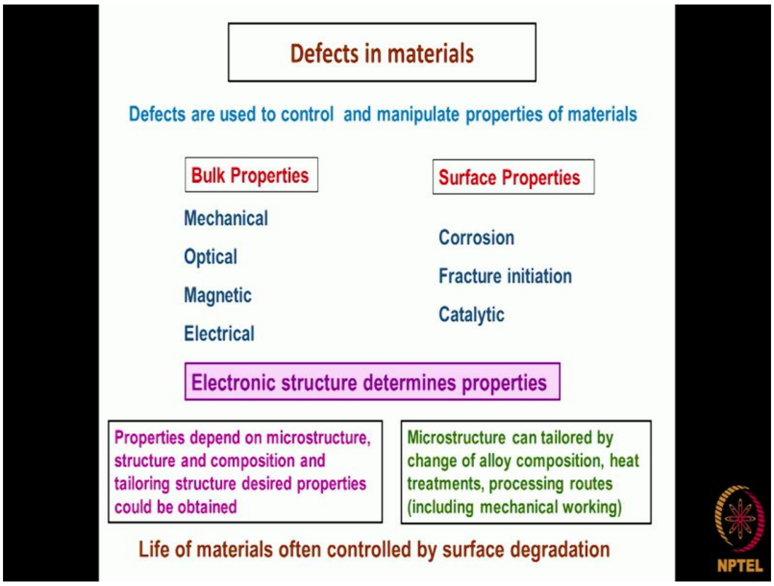


So, if you look at it if a material does not have any defect, it properties are fixed and then this defect is of no use that these material is of no use because we cannot process this material, we cannot shape it to different form all these things we do in a material because this contains defects. So, essentially what it means is that defects can be used to control and manipulate the properties of the material. What are the types of defects which we can have in a material: one there are various types of defects are possible which we will come to later, before that what are the types of properties which these defects affect; one the bulk property of the material, two and the surface property of the material also what are the bulk of this material effects let us have a look at it.

One the mechanical behavior of the material, that is various mechanical properties can be affected by introducing different types of defects which you already know that by performing a material by mechanical means by doing a mechanical testing by introducing a lot of defects into the material, we can make the defect we can make the material stronger, but at the same time reduction density. Similarly by introducing defects into optical materials we can have what we known as a different color centers. So, that we can change the color of the material optical properties can be drastically changed.

Similarly, the other properties which we can change are the magnetic properties of the material that is a material which is a soft magnetic material, by deforming it we can make it into the hard magnetic material. Similarly the electrical properties like electrical resistivity of a material can be changed by introducing defects into the material. What are the surface properties which we can control? The one which comes to a foremost is the corrosion in behavior of the material that is by controlling composition or impurity on the surface of the sample we can alter the corrosion behavior of the material.

Similarly, catalytic property is another one which can be not only controlled can be changed also depending upon the type of defects which are being present on the sample surface, the type of crystal structure which it has; similarly fracture behavior of the material also depends upon the surface properties or here we will say that the grain boundary properties. If we have a mono layer of a impurity which is present on the surface of the sample, or on the grain boundaries then the ones which are there on the grain boundary can determine whether the material behaves in a intergranular way or intragranular way.

So, essentially using ACM we can find out whether material has failed, but unless we know what causes the fracture behavior we will can be determined only by knowing what are the elements which are present on the surface, where they are located, which side they are occupying all these positions determine how the material behaves. All these property changes are basically controlled by electronic structure of the material, that is essentially the electronic structure is the one which determines the properties of the material, this is one aspect of it which we will not be going into any detail or we will just exclude this in this present set of lectures, this forms part of a physics course.

And as you know the properties depend upon; one microstructure, crystal structure and composition and tailoring the structure, desired properties could be obtained in the material. How are these microstructures can be controlled? Microstructures can be tailored by changing the composition of the alloy, by heat treatment, and various process in routes like mechanical property, various types of microstructures could be obtained and this way we can control the property of the material. And in fact, the life of a component essentially life of any material which we wanted to use is often controlled by surface degradation, and not by bulk property changes. So, that is the reason why understanding the surface property of the material is very important.

Before going further let us look at what are the defects which are there in the material.

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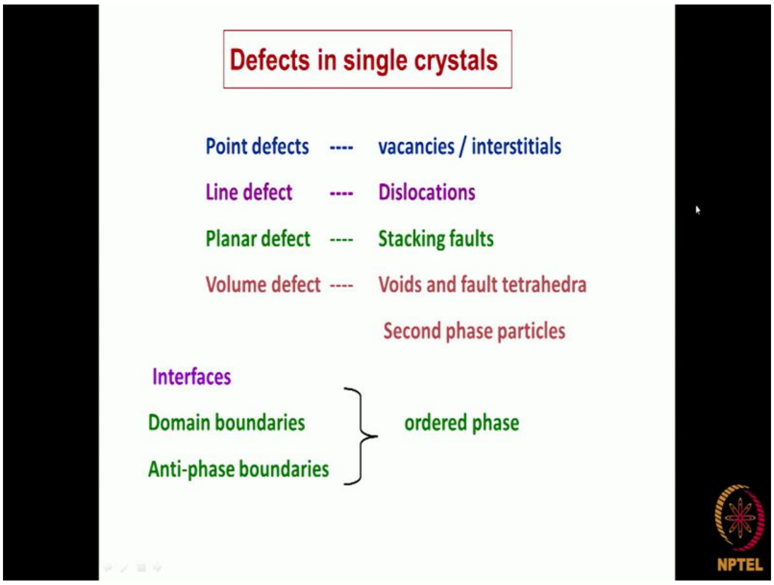


Generally when I talk about defects in the material, I always start with looking at simple structure; simple structures means that microstructure essentially is a single crystal is the best one which one can think of, what are the defects which are present in the single crystals? One point defects which are there; what are the point defects they are vacancies and interstitial, then the other type of defects which are present a dislocations which are lying defects in the material.

In addition to it we have planar defects which are one striking fault, there are other types of defects which are there are various interfaces which are present between different phases, they also control the property of the material, they are also quite often these defects are planar defects; and then another most important defect is the volume defect. The volume defects essentially could be voids in the material, are you to be stacking fault head tetrahedral, are you to be second phase particles which have been formed within the material and they are distributed in different ways at different locations, and how they are presented different locations that decides the property of the material.

So, this also could be considered as a defect in other ways a perfect matrix. The interfaces are the possible interface are one our domain boundaries, another anti phase domain boundaries these are all the two defects which are present in ordered faces what are these types of defects these I will come to later and during the course of the other lectures.

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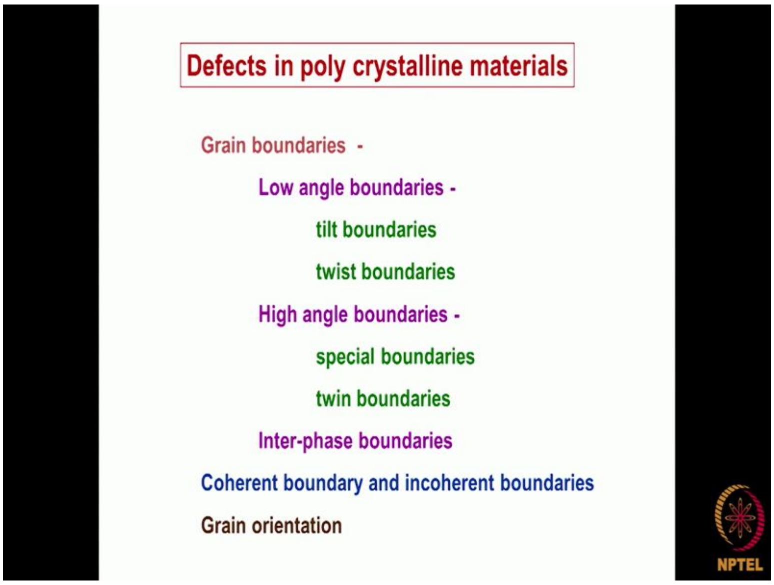


From defects in poly crystalline material; most of the materials which we use in service are all poly crystalline materials not single crystals. So, in a poly crystalline ma what is the difference between a single crystal and a poly crystalline material? Poly crystalline material is nothing, but different types of single crystals which are oriented in different directions, but they are dying together by some interfaces which we call it as the grain boundaries. These grain boundaries could be either low angle boundaries.

There are again some sub classifications are tilt boundaries, twist boundaries then there are high angle boundaries are there, and there also we consider some special boundaries and twin boundaries and there are if different phases are there the interface between these phases also generate boundaries they are called interface boundaries, and some of the boundaries like some of the twin boundaries could be coherent boundary or it would be an incoherent boundary. So, these are all the types of defects which we have to consider.

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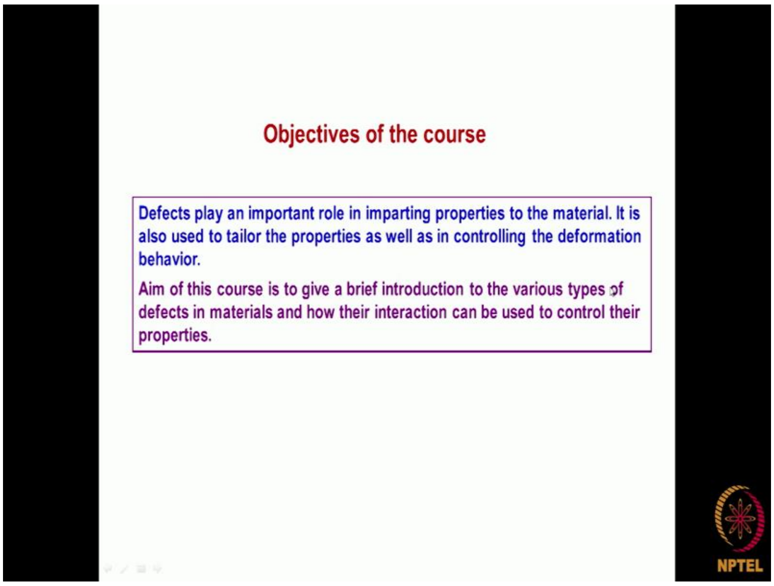


So, as I mentioned earlier what is the objective of this course? The objective of this course is to give a brief introduction to various types of defects present in materials, and how their interactions could be used to control the property of the material.

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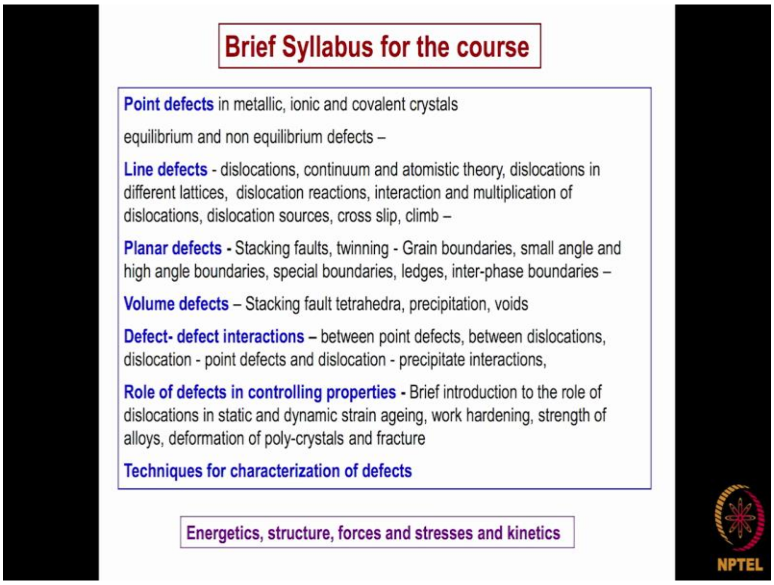

What is briefly the syllabus for this course? We will be talking about point defects in metallic materials, then in ionic and covalent bonded crystals. In metallic materials it is much very simple it either in a particular place whether the defect is there are that is a atom is absent, are a pattern or that atom which has been remote from a lattices, it has been put into an another site which is called as an interstitial vacancy ok only these two we have to consider it.

In addition to it in a metallic material we have to think about if you add impurities what are the sites this impurities go, because at small concentrations these are also can be considered as point defects whereas, when we take the case of ionic materials in addition to the presence of absence of ions at the lattice, the charge balance also has to be maintained. That is very important for ionic as well as go under bonded materials, so this gives rise to some differences in the type of defects which has to be produced in the material, all these things we will talk about whether the defects are equilibrium defects are non equilibrium defects, and then also that this energetics of these defects, what are the types of stresses and strains these defects produced in the material all these aspects we have to consider.

Then about the line defects when we talk about, we will talk about dislocations then on the continuum and atomistic theory on that basis we will describe dislocations wire and then we will talk about the stress field and strain field around the dislocations, the energetics of the dislocation, forces which these act on the dislocations and also the forces which is between the dislocations which we have to consider. Then what are the types of dislocations which are produced in different types of lattices, the type of when two dislocations move how do they interact, what are the type of dislocation reactions which can take place, how dislocations multiplication takes place in the material, what are the different types of sources which are there in the material, different type of dislocation kinetics if we located the class slip climb all these processes will have to be considered, we will be looking at all these aspects.

Planar defects if you consider stacking fault is one defect, which we have be looking at in great detail then twinning is another one where it is a twinning is more we can say that it is like a bulk defect, but the interfaces are the ones between the twin and untwint region which we is very interesting. Then grain boundaries as I mentioned they are planar defects, small angle boundaries are high angle boundaries, then about special boundaries, let just interface boundaries these are all the all aspects we will be considering it. Volume defects essentially which are present are as I mentioned stacking fault, tetrahedral, precipitation voids in these aspects I will be mostly talking about stacking fault, tetrahedra will not be going about precipitation and voids.

Another important (Refer Time: 12:04) we having understood about the different type of defects; point defects, line defects and planar defects, we should know about the interaction between the various types of defects. Especially between point defects and dislocations why we consider everything with respect to dislocations, because that dislocation is the one which is extensively used to control the property of a mechanical property of the material, control the deformation behavior of the material because of this we should know about how the dislocations interact with point defects, and also the interaction between dislocations and dislocations and also between dislocations and precipitates these interactions also will be considered.

The another important aspect which we have to consider it is how does this defects especially the dislocations control the work hardening behavior, strength and deformation of poly crystalline materials and fracture this also will be covered, then lastly I will mention about some techniques which have to be used to characterize these defects, to quantify these defects that also will be covered during this.

In all these when we study about the defects they essentially the things which you should know about that defect is the energetic. What is the energy which the defect introduces into the material, whether it increases or decreases the energy of the material, what is the structure of the defects, what are the forces which are acting on these defects are the forces which these defects generate, stress and strain fields around the defects, and kinetics of the defects these are all the various aspects which will be covered in this course.

But when we want to talk about defects in a material the first thing is that we should have a reference standard.

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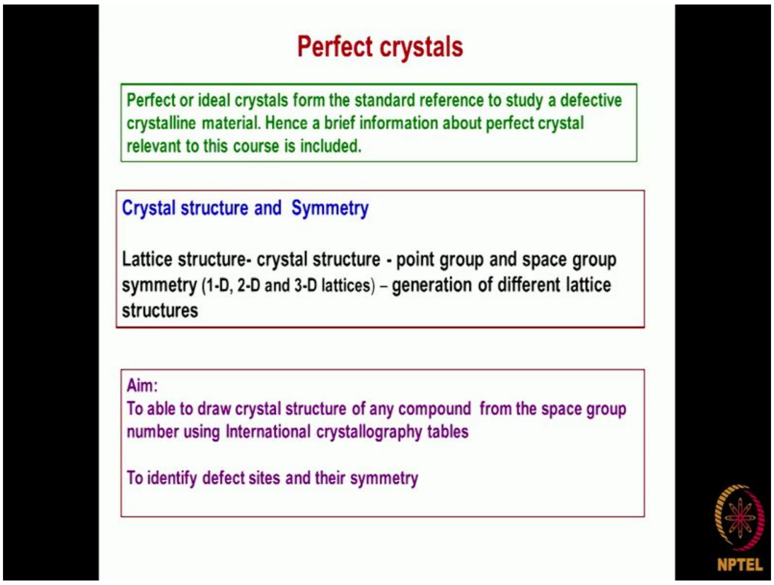


What is the reference standard which we can have? A perfect crystal is the one which we can have a sort of reference standard to study how defects are present in the material, what are the locations at which these defects are present that we can talk about it only when we know a defective material. A defective material is an ideal material and study of the crystal structure of these materials is what forms part of crystallography.

We have brief introduction to crystal structure and crystals symmetry I will cover, especially the lattice structure, the crystal structure, point group and space group symmetry and the generation of different lattice structures that is from one dimensional lattice how two dimensional lattices can be generated, what are the types of how many types of lattices will come from 2-D planar lattice to 3 dimensional lattices, Bravais lattices how many can be generated and how they have to be generated all these aspects will be covered.

What is the ultimate aim of studying of these perfect crystals is that if you look into most of the literature, generally they give the space group symmetry of the material and the some number. And if you look at this one has to go to international union of crystallography and data tables, thus tables give information about the crystal structure, graphical representation of the difference symmetry elements, and the general points around it and what are the special points at which atoms can be kept satisfying the particular space group symmetry. If you understand this table we will be able to generate the any type of crystal structures whatever we look for we will be able to do it.

This is exactly what I wanted to cover during this preliminary first few lectures, I will be talking about this how to generate crystal structures or how to construct crystal structures and then once we know what the type of crystal structure which we are studying, then one can identify the various types of defects which are present in the crystal.

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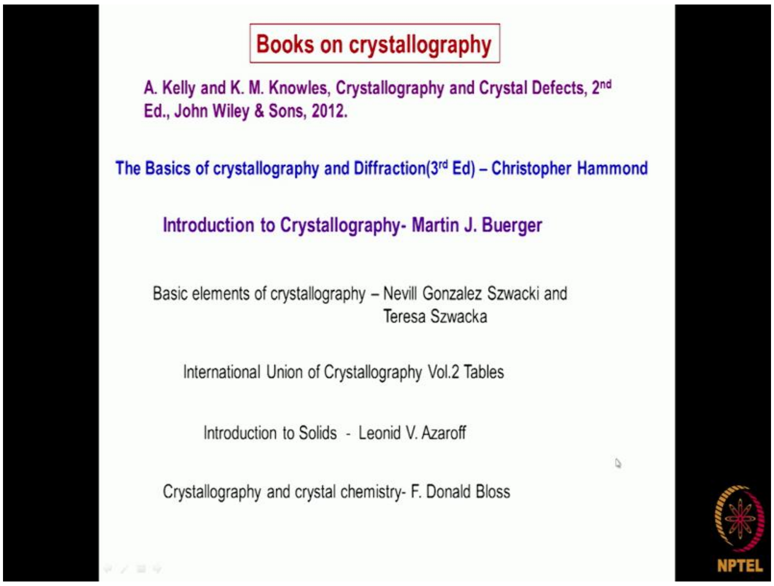


What are the sides edge which these defects could come, and what is the symmetry associated with these defects these are all the aspects which will be covered.

Then what are the books on crystal which I am use using for this course. The one book which I use extensively for introduction to crystallography is a Kelly and Knowles, which is crystallography and crystal defects; the second book essentially basics of crystallography and diffraction Christopher Hammond this is also a very nice book, another is introduction to crystallography Martin Buerger, this is a book where talks about all the various types of symmetry spine group and space group symmetries are explained very nicely, then other book is basic elements of crystallography by Neville Gonzalez, and Teresa Szwacki.

Then an another is the international union of crystallography volume two tables itself one should refer to, then introduction to solids by a sort of this book also gives a lot of information about the crystallography. Then another nice book is especially which work from chemistry people if they are interested crystallography and crystal chemistry, where Donald Blass is a very nice book.

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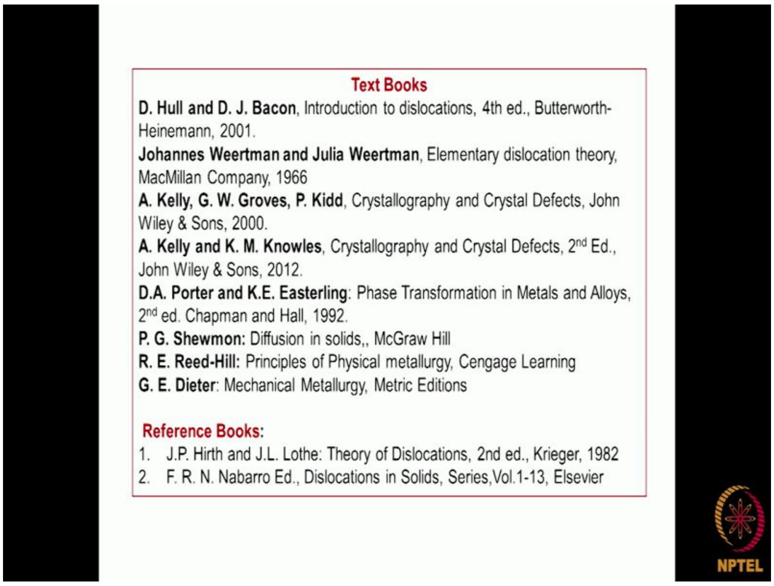


What are the textbooks which are used for generally for dislocations and other defects in the material? One: hull and bacon introduction to dislocations fourth edition, then Johannes Weertman and Julia Weertman, they have written a very nice book it is a very old book, but it gives all the basic information about the dislocations; especially the stress field and strain field forces on dislocation these aspects are covered very nicely, this is one good book.

Another Kelly Knowles and kid this is crystallography and crystal defects, are it is the same as Kelly and Knowles; Kelly and Knowles book is essentially nothing, but the updated are the second version of the Kelly and groves book, then porter and Easterling book on phase transformations gives lot of information about the various types of crystal interfaces between materials. Defects in materials to some extent is covered in Shewmon, Reed Hill give some information about the defects in crystal and materials overall about general mechanical behavior of the material dieter is a good book.

If one wants to go into detail to an advanced level, Hirth and Lothes book on theory of dislocations is a very nice book. Similarly Nabarro has edited dislocations in solids, that are many volumes are available in the excellent treatise on various aspects of dislocations and dislocation behavior in material is covered in this book. These are advanced books these two, but they form as a good reference book for anyone who is interested to study defects in material.

If you have any questions you can post it to me I will try to answer it. Anyway, I had given my email id and my telephone number is also available.