Hello and welcome to manufacturing process technology Part -1 Module -4.

(Refer Slide Time: 00:20)

Today we are going to talk about the basic materials related to engineering.

(Refer Slide Time: 00:24)

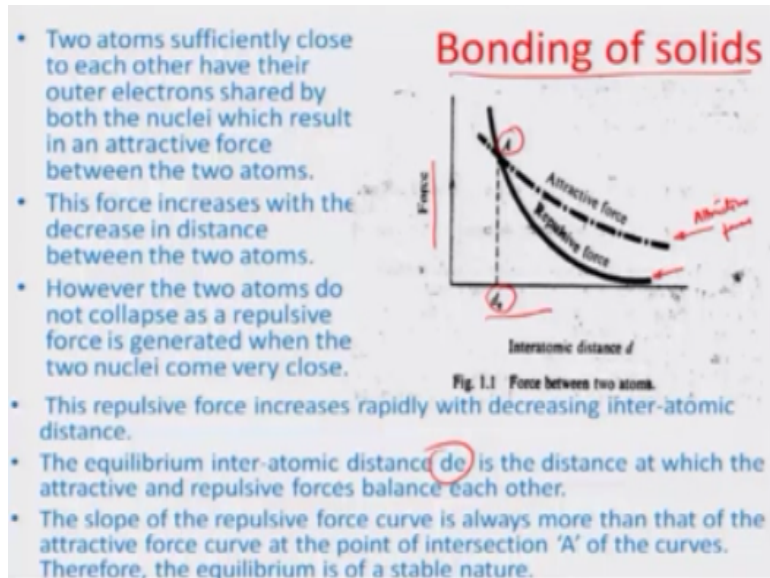**Manufacturing Properties of Materials**

Structure of Matter: ✓

Material properties are a function of the basic molecular structure. ✓

Solids are known for their capability to retain definite shapes and thus the bonding mechanics between the molecules forming a solid is very important. ✓

Cover a small topic on structural materials also discuss about the material properties as a function of the basic molecular structure, also as you know the solids are known for their capability to retain definite shapes, and thus the bonding mechanics between the molecules forming a solid is very important thing. So we are going to actually cover that aspect in this particular topic.

(Refer Slide Time: 00:55)

- Two atoms sufficiently close to each other have their outer electrons shared by both the nuclei which result in an attractive force between the two atoms.
- This force increases with the decrease in distance between the two atoms.
- However the two atoms do not collapse as a repulsive force is generated when the two nuclei come very close.
- This repulsive force increases rapidly with decreasing inter-atomic distance.
- The equilibrium inter-atomic distance (de) is the distance at which the attractive and repulsive forces balance each other.
- The slope of the repulsive force curve is always more than that of the attractive force curve at the point of intersection 'A' of the curves. Therefore, the equilibrium is of a stable nature.

Fig. 1.1 Force between two atoms.

So let us look into the basic theory of bonding between solids. So let us say you have two atom of systems, and these atom systems are sufficiently closed to each other, and have their outer electron shared by both the nuclei which results in a attractive forces between the two atoms. The force increases with the decreasing in the distance between the two atoms or the two atoms do not collapse.

They remain at a certain equilibrium distance where there is a repulsive force as well which is generated because of the nuclei coming to close to each other and there is a attractive force between the electrons of one and the nuclei of other. And these two attractive and repulsive forces they are in equilibrium with each other, so that is really the position where the two atoms would come and be stabilized and we call this equilibrium as stable equilibrium okay.

So obviously why we call it stable equilibrium as a different issue that if suppose we have to plot the force let us say between the atomic system per minute the distance between them. And you can see that the attractive force is given by this dotted lines right about here, and the repulsive force is given by the solid line. And you can see that beyond the point of equilibrium A which is corresponding to distance D between two atoms, the repulsive force suddenly increases and the attractive force slope at the attractive force may not be that type.

So therefore, if the two atom systems are to be taken closer then the equilibrium distance the repulsive force would out grow and would like to go back. And similarly, at the other end of the equilibrium let us say for example if you cross D and increase the D the attractive force becomes
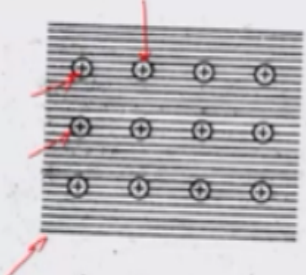
relatively larger in comparison to the repulsive force. One the reasons why this system is really a stable equilibrium.

So the equilibrium inter atomic distance D is really that the distance where the attractive and repulsive forces are balanced, and you have already seen that this balanced point is really a stable equilibrium point for two systems when you are talking about bonding of solids. So the mechanism that we talk just earlier is only one reason why the atomic system should want various possible other interactions which are also known as covalent bonding where there is a sharing of electron between the atoms we should make the atomic system stabilize.

(Refer Slide Time: 03:26)

So in a given solids one or more bonding mechanisms may be simultaneously also active and the nature of bonding mechanism depends on the electronic structure of the atoms which are evolved. And some mechanism and solids may be something like lets us say metallic bonding, Vander Waals bonding so on so forth. So as we all know that metallic bonding there is a large number of free electrons which are present.

And then there are different atomic centers which are there typically they are the nuclei centers. And this atoms of free electrons they formulate a common electron cloud they move through a bulk orbital which also a conduction band of such metals. So the rest of the system consist of positively charged ions you see reflected here of positive charge ions for example, which are in these places.

4

And then the electrons, the C of electrons move around in the common orbital. So this is one way where the metals are normally participating and the metallic atoms are normally participating in bonding, and also because of this electrons the metals develop something call the luster and shiny surfaces as we have seen commonly.

(Refer Slide Time: 04:45)

So having said that the other mechanisms which are systems like alloys etc, where similar bonding mechanism would interplay. And the problem is when the atom becomes inert in nature and they have, let us say filled up outer most orbital's, then in that case the sharing can really not take place and this results in something called very, very weak short range force attraction which is also known as Vander Waals bond.

The origin of this force is attributed to a rapidly fluctuating dipole moment. And I will just show you how this Vander Waals bonds would work.

(Refer Slide Time: 05:26)

Bonding in Solids

- The figure shows two molecules at a distance 'd' each of which has a symmetric charge distribution.
- All the three different overall configurations of the charge distributions, shown in figure, lead to the development of an attractive force though individually the molecules are neutral.
- This force is inversely proportional to d^4
- This type of bonding is very weak and is active in weak and low melting point materials such as paraffin and plastics.
- It is obvious that the strength of the bond controls the properties, e.g., melting point, of a material.

(b) Origin of van der Waals' force

So let us look at the figure right here which talks about the origin of such bondage. The figure shows two molecules at a distance d, and each of which has a symmetric charge distribution. So let us say there is a tendency of the one of these atoms to have negative charge towards one end and positive charge to another end. So there is some kind of the symmetricity in the charge distribution.

There can be many such forms of symmetricity for example, this case 1, this is case 2, this is case 3, where you can see alternate charges of opposite type facing each other an alternate charges of same type being in alternate flanks between the atoms. So all the three different overall configurations of charge distributions lead to the development of an attractive force through the individually, the molecules are neutral.

But then there is some kind of a force which develops between this negative charge center to positive charge center for example. Or even when we are talking about criss cross interaction between this center and this center or this center and this center so on so forth. And this continuous throughout the crystal, throughout the solid where these atom pairs are available you think of it as if there are different pairs of such atomic system, so one end of the solid to the other.

So obviously there are going to be some forces because of these charges and if you look at single atomic system it does have something about dipole moment, because of this charged separation, and might do this dipole moment can also available to variation if you subject such atomic

systems to external fields or magnetic fields or something like that. So they are going to be these dipoles formulations in such atomic systems.

And what people are absorbed is that, if this is really the cause of the bonding the force varies inversely to the distance to the power of four between such atomic systems. And therefore, this bonding is very, very weak, and then the distance force is slightly away the reduction of the force is substantial. And so, therefore this type of bonding is very weak, and it is active in weak and low melting point materials.

And this can be something like paraffin wax or plastics or these kind of materials where generally you find the melting point to be quiet low. And one of the reasons are that whichever is the metallic bonding system which is stronger in this case the bonding forces they vary as the inversely proportional to the distance to the power of four.
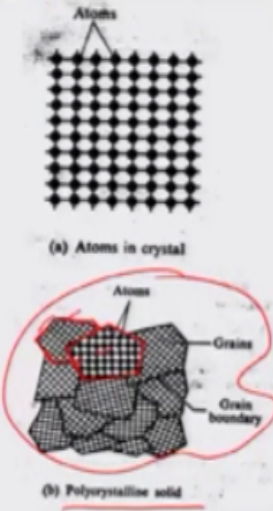
So a little bit of atomic vibration would lead which is actually proportional to the amount of thermal energy that you are delivering to the system it will lead to the separation between the atoms or enable the atoms to be come into the fluidic state or flow state and which is the cause of a lower melting point of such materials.

So it is obvious that the strength of the bond controls the properties for example melting point of the material, so that is how the Vander Waals system of the bonding would work.

(Refer Slide Time: 08:50)

And typically when we talk about metallic systems there the atoms formulate certain organized patterns and you can call it that this arrangement of atoms is earlier long range order and such systems are known as crystals okay. So typically there is a certain arrangement, a basic arrangement which is the smallest unit and you can think of it that this unit is assembled especially with respect to each other block by block, so that the whole system comes up.
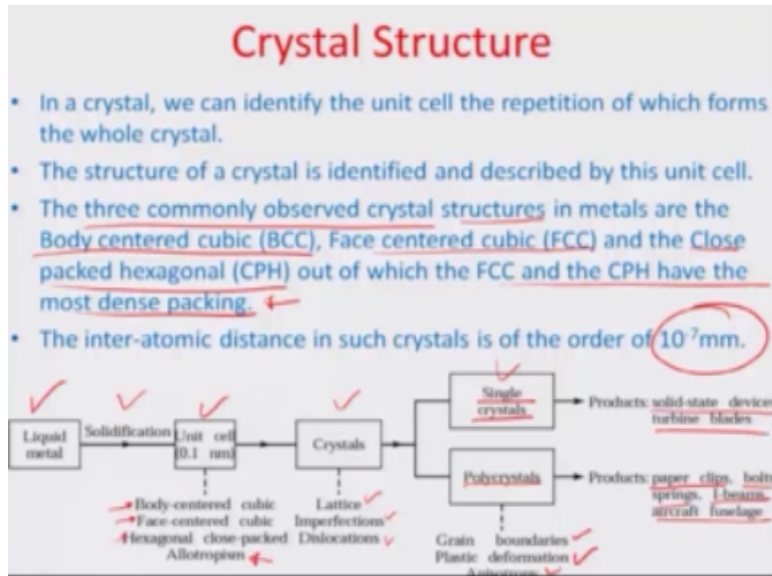
So there is some kind of repetition of the arrangement of that one unit as for as the whole solid system is concerned which is being composed of this small, small unit cells. So these systems are known as crystals. And the property of the material very heavily depends obviously on the bond strength, but also on the arrangements of atoms in such crystal lattice and if you have an arrangements which is very well ordered, well structured, then obviously the strength of that system would much higher in comparison to materials where such arrangements does not exists.

So such solids are commonly called as crystalline solids and large number of situations the whole solid is now composed of one single crystal instead it has large number of small randomly oriented crystalline grains from the whole solid you can see such composition here that, this one grain or for example, this one grain they are having a long range order for arrangement because this structure is repeating as you can see here or as you can see here.

But then the structure does not repeat beyond these boundaries which are also known as grain boundaries. And such systems are typically known as polycrystalline systems of arrangements. So the learning experience is so far that we have learnt how, what kind of bonding systems work between different atoms, so that they can be strengthen corporate about the arrangement systems which would be there over a longer range or a shorter range which would enable structure to be called crystalline as supposed to noncrystalline or polycrystalline. And so the topic could be that, what are those small blocks which actually composed of this crystalline structure.

(Refer Slide Time: 11:34)

Crystal Structure

- In a crystal, we can identify the unit cell the repetition of which forms the whole crystal.
- The structure of a crystal is identified and described by this unit cell.
- The three commonly observed crystal structures in metals are the Body centered cubic (BCC), Face centered cubic (FCC) and the Close packed hexagonal (CPH) out of which the FCC and the CPH have the most dense packing.
- The inter-atomic distance in such crystals is of the order of 10^{-7}mm.

And so the three commonly absorbed crystal structures in terms of those small units also called unit cells or blocks the body centered, cubic structure, the face centered cubic structure, and the closed packed hexagonal (CPH) structure out of which the FCC and the CPH have the most dense amount of packing that is imaginable.

So the inter atomic distance of such crystals is of the order of 10^{-7}mm for an Armstrong unit. And typically when the material solidifies particularly in case of metals where there is a possibility of the crystal grow, the round that is taken as we start with the liquid metal, and then after solidification, the solidification centers are well arranged centers in terms of unit cells which have dimension of Bowdon Armstrong i.e. 0.1nm.

And there can be several such arrangements body centered cubic, face centered cubic, hexagonal closed packed, or then there are crystal structures which can change as the function of temperature allotropes so on so forth. You then formulate the repetition of these unit cells which leads to the long range order of the arrangements of materials called crystals. So you have, now in these crystals lattice imperfections, dislocations so on so forth, and these crystals either would be formulating single crystals or poly crystals.

Single crystals of course, are used for very specific applications where you really need a defect free predictable behavior of the material one aspect that is very, very different which are differently in case of some materials is that the predictability of the material behavior may not be that certain. So poly crystalline materials are suppose to not be completely predictable in terms of their mechanical behavior.

But at least single crystalline materials are used in solid state devices for example where you need to predictably a certain the electronic property of material or for turbine blades where things like mechanical strength and compressibility or load bearing nature of the materials are very important. So there typically tend to use the single crystalline material. So the poly crystalline materials on other hand can be used for regular applications where the predictability of the strength may not be of that way of concerned.

For example, you can use the paper clips, bolts, springs wherever you are deforming materials to be used post form state like I beams, aircraft so on so forth. The grain boundaries in such poly crystals are very important. The concepts of plastic deformation in isotropy are very important in recording such poly crystalline. And we are going to look into some of the aspects as we go long so let us look at the three different structures which we talked about.

(Refer Slide Time: 14:28)
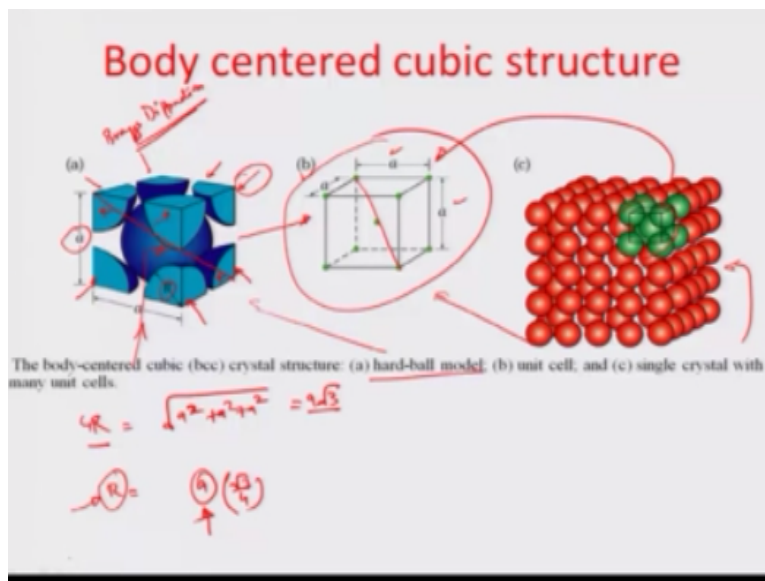
So let us look at the three different crystal structures which we have talked about. The first one is the body centered cubic structure, and what you can see here is that there is a central atom which is placed at the centre of the cube and there are contributions of $1/8^{th}$ of the atom coming from all different edges of the cube. So that is how you are able to make a unit cell something which can be more clearly illustrated by a wire diagram like this.

So obviously this particular section is an 8th of the total sphere. And so the 8 such small contributions together would formulate one atomic units. So there are three different structure in fact one is called as hard-ball model which is represented here this is the unit cell model, and single cell crystal with many such unit cells. So you can think of the packing of the arrangements.

So one of these cubes is what we are referring to here as the unit cell and you are repeating them in three dimensional space for being enable to envision how the system looks like. So obviously, geometrically, if you want to find out the diameter of radius of the atom we need to get this number in atomic spacing or the size of the unit cell which can come from fraction of some other experiments.

And you actually be able to now predict the atomic diameter based on the lattice distance which can be recorded by experiments like Bragg's diffraction. So let us look at what is the geometric relationship available between the radius and this lattice distance. So basically if I just look at diagonally what is going to happen here for example, you have radius r, radius 2r, and radius r combined together.

So you have a total 4r and this results in the diagonal distance in the unit cell which is actually equal to AQ is $\sqrt{a^2+a^2+a^2}$. So typically that is how you represent the diagonal distance of the cube of length A. And so you have $a\sqrt 3 =4R$ or in other words the radius R can be represented as $a\sqrt{\frac{3}{4}}$. So if you have this from an experimental evidence this is also a lattice constant which would come up in Bragg's diffraction plod or something.

You can easily calculate what is the radius of such a atomic system which formulates this body centered cubic structure. So we will also similarly discuss the face centered cubic can be closed packed hexagonal structures in the next module. So this module is closed here, thank you.

Ashish Singh
Badal Pradhan
Tapobrata Das
Ram Chandra
Dilip Tripathi
Manoj Shrivastava
Padam Shukla
Sanjay Mishra
Shubham Rawat
Shikha Gupta
K.K Mishra
Aradhana Singh
Sweta
Ashutosh Gairola
Dilip Katiyar
Sharwan
Hari Ram
Bhadra Rao
Puneet Kumar Bajpai
Lalty Dutta
Ajay Kanaujia
Shivendra Kumar Tiwari

an IIT Kanpur Production