Introduction to Materials Science and Engineering
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Lecture - 25
Ordered and disordered solid solutions

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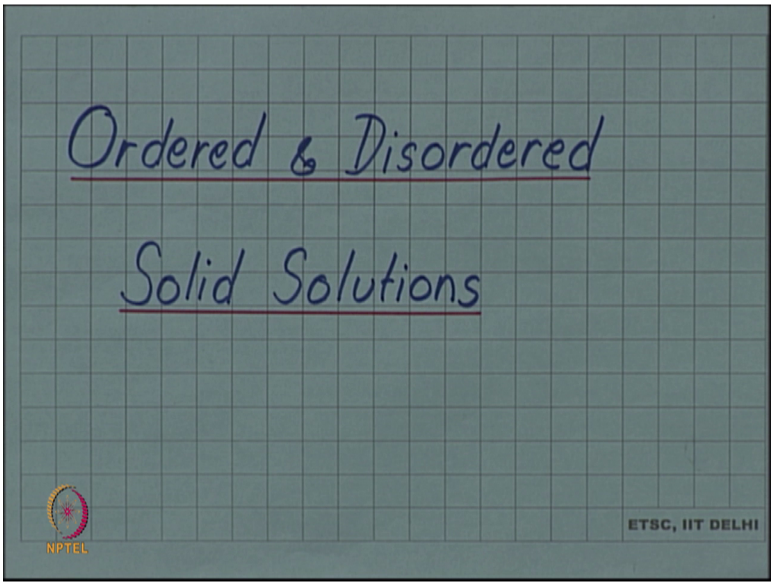

Hello, we will discuss today a topic in solid solutions ordered and disordered solid solutions, we have already seen that and classified the solid solutions and substitutional and interstitial, but another way of looking at solid solutions is the ordering of locations of atoms inside location of solute and solvent atoms inside the solution, on this basis we have 2 types ordered and disordered. So, let us begin with a 2-dimensional example.

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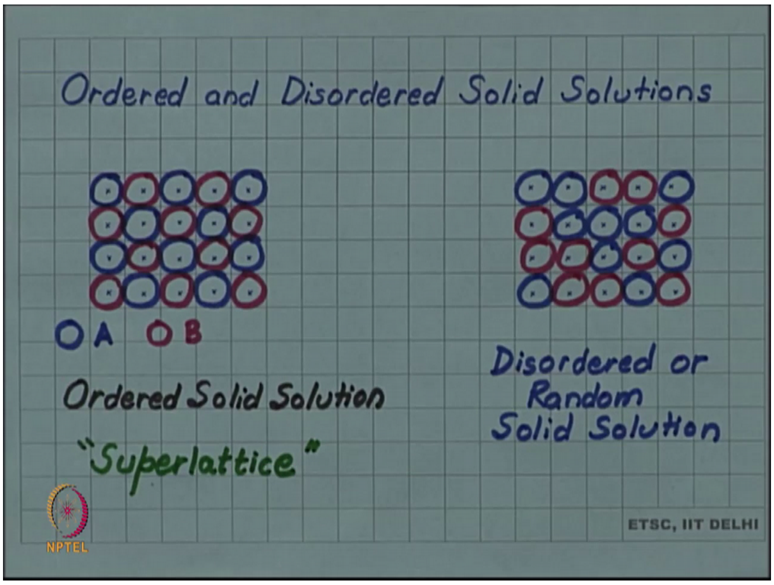

And let us consider in this 2-d lattice site of 4 into 5, 20 sides and I wish to populate these 20 sides by a 10 A atoms and 10 B atoms to form a substitutional solid solution.

So, let me for an I wish to do it in a nice orderly fashion. So, what I will do I will put A and B atoms at alternate locations. So, let me put A atoms first. So, the blue atoms are my A atoms and I am putting them at alternate locations on these atomic sites. So, I have populated 10 sites by A atoms. So, the blue let us call this blue is my A atoms, and on the remaining sites I am putting the red B atoms to complete my solid solution. So, you can see that A and B are occurring in a nice systematic fashion, and every A atom the blue atom is surrounded by 4 B atoms, and every B atom is surrounded by 4 A atom. So, that is a nice regular arrangement of A and b, if solid solution shows this kind of behavior we will call such solid solution an ordered solid solution.

in the second example let us again put 10 A atoms and 10 B atoms, but now we do that randomly. So, I randomly select 10 sites as a. So, these are 10 A atoms, and then I place on the remaining 10 sites the B atoms. So, you can see that in this example, now we do not have the systematic ordering of A and B atoms like in the first example. So, this is called a disordered solid solution. So, we will call this disordered or sometimes also called random solid solution, ordered solid solution sometimes are given a special name they are also known as super lattices, another name for ordered solid solution.

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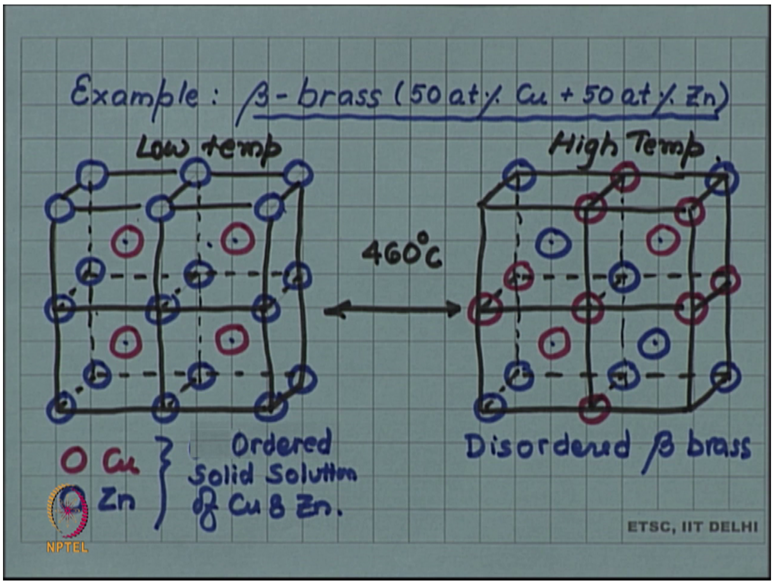

We will look up an example that was a 2 d cartoon example, let us look at a real example of ordered and disordered solid solution, we have already discussed brass and we discussed alpha brass, but now in the copper zinc system there is another brass occurring at 50 50 percent, 50 atomic percent copper and 50 atomic percent zinc which is known as beta brass, and beta brass is a good example of both ordered and disordered solid solution depending on the temperature. So, let me first make a ordered beta brass. So, again I have copper and zinc and the locations are like body centered cubic. So, I am drawing for you, 4-unit cells let me first draw the unit cell and then I will place the atoms.

So, you can see that I have 4 cubic unit cells, let me make 4 more here, here also I have 4 unit cells, and I decide and these unit cells and there are also locations of atoms in the center, in the body center also there are atoms in both the cases so, it is a kind of body centered cubic structure, and let me decide to place one kind of atom, let us say the zinc atoms all at the corners. So, I populate all the corners by a zinc atom whereas, I populate all the body centers by the red copper atoms.

So, it is a body centered like a structure, but all the corner atoms are zinc, and all the body centers are copper, and you know from your crystallographic calculations which we have done before, that corner atoms contribute only one 8h to the unit cell. So, in every unit cell there is 1 copper atom and 1 zinc atom. So, it is a 50 50 solid solution, 50 percent copper 50 percent zinc, and copper and zinc are on very specific sites. So, this is an ordered solid solution, of copper and zinc. So, it is an ordered beta brass, now if I in the second picture if I want to make a disordered beta brass, all I have to do is to randomly place in some unit cells copper may be at the center whereas, in some other unit cell zinc may be at the center, there is no systematic ordering and some sites I corner sites also, are competitively filled by both these atoms.

So, we do not have any such order, in this one this example which we had seen in the left example. So, here both atoms. So, this randomly select to be present at the corner or the body center. So, we have what we will call a disordered solid solution, or in this case disordered beta brass, and both are available and, what happens in nature? And that we will look at a little bit more detail when we discuss the topic of phase diagram, that these 2 structures interchange at a temperature of above 460 degrees celsius. So, at lower temperature below 400-degree celsius you will have the ordered structure, and above 460 degrees celsius, you will have the disordered structure of beta brass.

Now, I already called the ordered version ordered version as super lattice, this has a region because there is a subtle crystal structure change when ordering happens and let us look at that.

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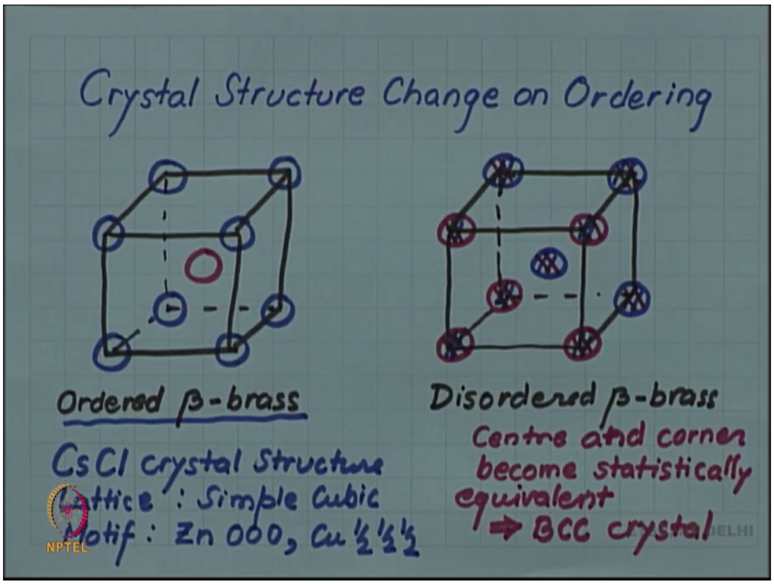

So, again I draw this time I draw only one-unit cell. So, let us have this unit cell, and let me draw the low temperature ordered structure. So, zinc takes all the corner sides, and copper takes to the body centered location, now a disordered unit cell will have no such preference. So, some locations some corners will be occupied by a zinc, maybe center is also occupied by a zinc whereas, some other corners are occupied by copper. So, this is ordered beta brass, this is disordered beta brass.

Now, if you look at the crystal structure of ordered beta brass, we have already discussed this case this will not qualify as a body centered cubic structure, because the corners and center atoms are different. So, there is a clear difference between the centered atom which is occupied by copper, and the corner atom which is occupied by a zinc or vice versa, because unit cell can be selected in a different way also we can make the copper atoms as corners, which will make the zinc atom in the center. So, in this ordered beta brass the unit cell and the crystal structure cannot be called body centered cubic, because body centered atom and the corner atom are not identical.

So, what and we have done this exercise before when we were discussing crystal structure. So, we will have to call this structure or the lattice of this structure as simple cubic, the structure name itself is a cesium chloride structure because cesium chloride shows this kind of a structure. So, cesium chloride crystal structure, the lattice in this case will be simple cubic and the motif will be the way I have drawn, zinc is at the corners. So, zinc at is ooo and copper is at body center. So, copper at half, half, half.

So, that is the structure of ordered beta brass, if you come to disordered beta brass, this presents an interesting problem. Now since the atoms are occurring randomly one can argue that, now none of the positions are equivalent, and they do not form a lattice because the periodicity really is lost, sometimes if I go from one atom to the another atom in any given direction, sometimes I find same kind of atom, sometimes I find other kind of atom, and this is happening totally randomly. So, in an a strict mathematical sense the lattice is lost, despite the positional periodicity due to the chemical identity varying randomly this is no more a mathematical crystal.

However, from all practical point of view this is still behaves like a crystal, and if we look at an x ray diffraction pattern from this crystal, it will show like a body centered cubic structure, why that happens is that there is because of the randomness thus corner atom and the center atom become statistically equivalent, because there is a 50 percent probability. So, let me try to draw 2 blue lines to. So, 50 percent probability at these locations of zinc atoms, but there is also 50 percent probability of these locations of copper atoms, and somehow whatever experiments you do for example, x ray experiment, it appears that the 2 atoms are equivalent. So, for practical purposes the center and corner become a statistically equivalent, and in experiments this will behave like a body centered cubic structure.

So, this becomes a BCC crystal, here center and corner do become identical. So, with this we end this topic. So, one more topic one last topic on solid solutions which we will discuss is primary and intermediate solid solutions.

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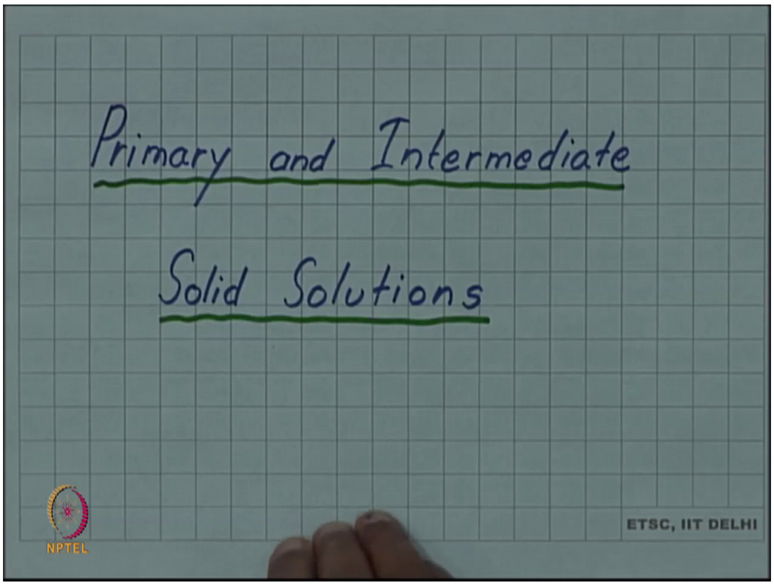

You have already seen these examples in the case of brass. So, I will just give those examples to complete this discussion.

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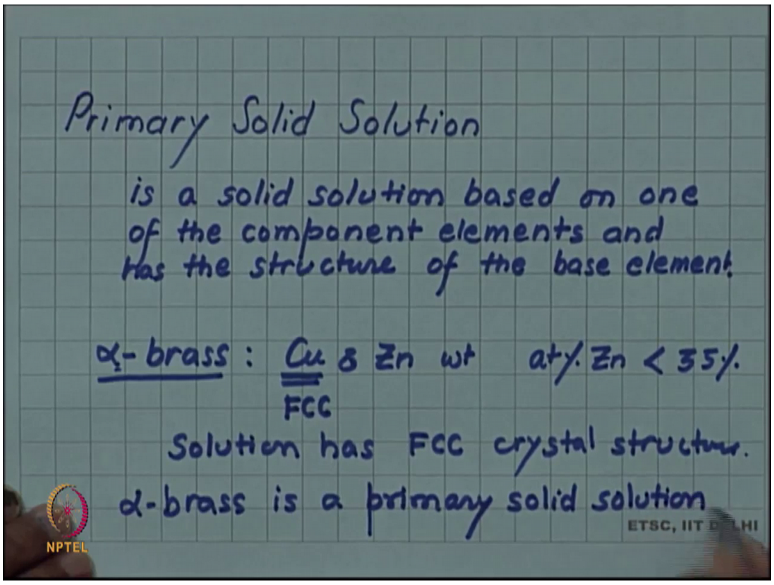

A primary solid solution is a solid solution based on one of the component elements, and it has the structure by structure, I mean the crystal structure has the structure of the base element.

So, as an example let us consider alpha brass, this is solution of zinc in copper, zinc with atom percent zinc, less than 35 percent. So, zinc is less so, it is based on copper, and copper is FCC the solution also has FCC structure, and from the discussion on our last video, this is a random solid solution. So, alpha brass is an example of a primary solid solution, the primary solid solution the next type is the intermediate solid solution.

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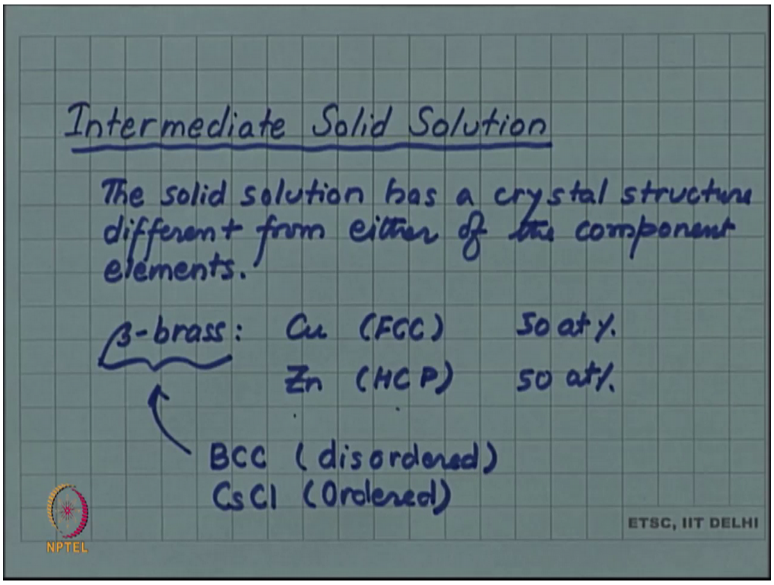

and brass again gives an example of this, and that is the beta brass. So, in intermediate solid solution in the solution or the solid solution, has a crystal structure different from either of the component elements.

So, again if you look at. So, we let us look at beta brass, it is made up of copper which is fcc, and zinc which is HCP and about 50 atomic percent of both, but the solution which you made out of this, the beta brass this does not have a structure either FCC or HCP we have seen in the last video that beta brass had a structure in disordered form is that of bcc, BCC when disordered and cesium chloride when ordered. So, beta brass is an example of an intermediate solid solution, this solid solution is neither based on copper, otherwise it would have had a structure FCC or zinc in which case it would have had a structure hcp. So, beta brass has a structure different from either of the component elements. So, this will be known as intermediate solid solution.

So, with this we have covered all the topics of solid solution, and we are now ready to go to look at crystal structures based on carbon.