Introduction to Materials Science and Engineering
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Lecture – 36
Amorphous solids

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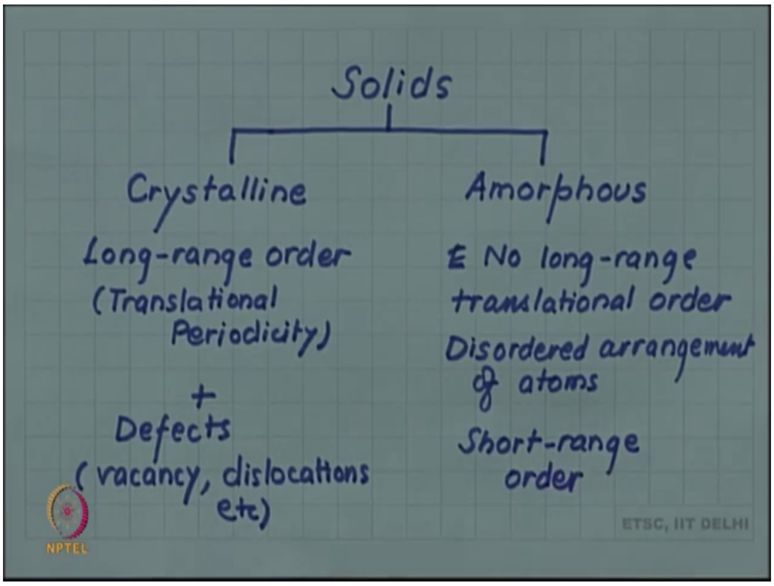

Solids can be crystalline or amorphous. We have been focusing on crystalline solid for quite a bit of time. Now, we have seen that the crystalline solid has periodic arrangement of atoms. Crystalline solids have long range long range order and the character of that order is translational periodicity. Translational periodicity, but amorphous phage or amorphous structures lack any such long range translational order. They lack they do not have no long range translational order.

But we saw that a crystal with perfect translational periodicity is an idealization real crystals will have various kinds of defects. The long-range periodicity is actually broken by the called defects. We have seen can be vacancy or dislocations etcetera. Similarly, a perfect disorder is also an idealization. When we say no long range translational order or sometimes we call disordered arrangement of atoms. Disordered arrangement of atoms this disorder also is not perfect and in fact, amorphous phage have what is called short range order.

They are not totally random they are having a short-range order what we mean by short range order will become clear when we consider the example of silica.

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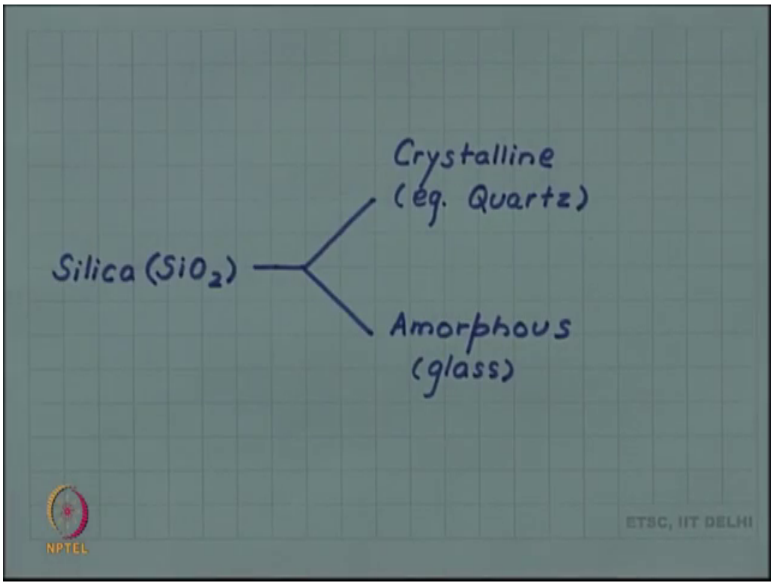

Which is one of the most common glass. Silica Sio2 is one of the most abundant phases or most abundant mineral in the earth crust, but it can come I either in a crystalline form or in amorphous form. When silica is crystalline it has various crystalline phases for example, one of them is quartz. But, if the silica units or the silicon and oxygen atoms in in in the phase are disorganized are not ordered then we have amorphous way or glass.

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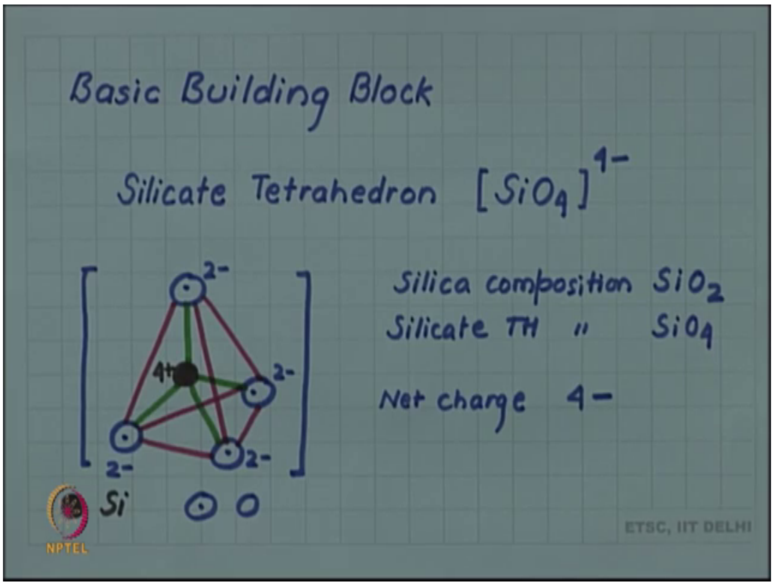

The basic building block of either the crystalline silica or amorphous silica is the so-called silicate tetrahedron. Let me draw it for you to show what we mean by silicate tetrahedron. Let me start with a silicon atom. This black circle is representing the silicon atom this is connected it has 4 valence of 4. It is connected to 4 it is connected to 4 oxygen atoms at the corners of a tetrahedron. These are oxygen atoms and these oxygen atoms are sitting at the corners of a tetrahedron.

If I outline the tetrahedron let me do it in the red. If I join these oxygen atoms in red we will get the outline of the tetrahedron from which it gets the mean. This is the tetrahedron the bonds themselves the silicon forms those 4 bonds are directed from the centroid of the tetrahedron to the oxygen atoms. The green lines are the 4-silicon oxygen bond which the central silicon is forming. This is the basic building block of all silicon structures. With a crystalline or amorphous and this is what is known as the silicate tetrahedron, but if you look at the composition of silica tetrahedron that is not of silica.

The silica composition silica composition is Sio2 whereas, the silicate tetrahedron composition silicate tetrahedron composition is Sio4. It is not satisfying the composition it is having more oxygen and if you look at it from the electrical charge point of view silicon has 4 plus charge whereas, the oxygens have 2 negative charges each of the oxygen have 2 negative charges.

The net charge there is a net charge balance imbalance also. Net charge will be 4 minus because you have 8 minus and 4 plus. The net charge becomes 4 minus. That is why it is called a silica tetrahedron with 4 minus as it is charge. The composition is not the right composition and the charge is not balanced both of these can be achieved if these.

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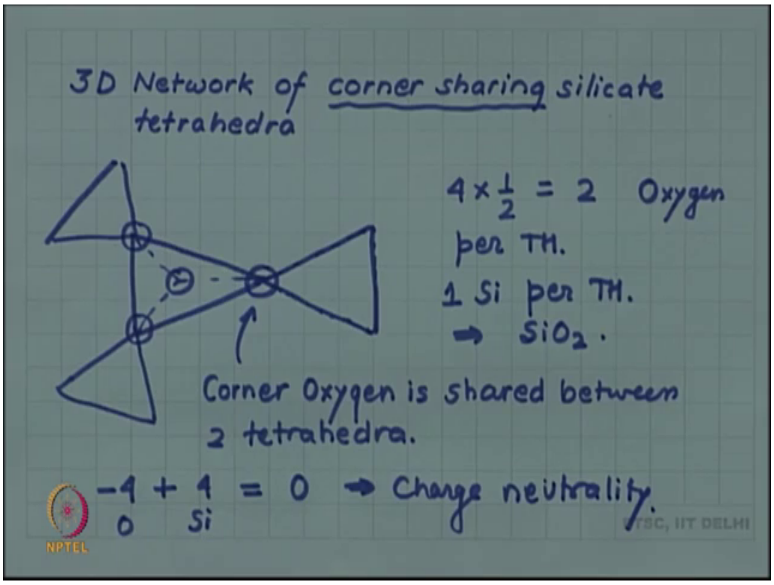

Silica tetrahedra form the so-called corner sharing network.

What we mean by this corner sharing network? Is that suppose I have suppose this is 1 tetrahedron with an oxygen at this corner and I have now another tetrahedron which is sharing that same oxygen. Now, that oxygen is common to both of these tetrahedra. The corner oxygen it is shared between 2 tetrahedra. Because of this sharing you can see the effective number this oxygen is now divided between 2 tetrahedra.

The effective number of oxygen contribution from this corner is only half oxygen to any given tetrahedral and since a given tetrahedra has 4 corners. It will get half oxygen from each of these 4 corners because each of those corners are shared. Other corners are also shared by other tetrahedra in the network. You will get 4 into half to oxygen per tetrahedral unit. 2 oxygen per tetrahedron and since 2 oxygen and this there is only one silicon in the center of the tetrahedra. One silicon per tetrahedron. This kind of corner sharing then balances the composition.

The composition is balanced. This gives you Sio2 similarly for the charge since each oxygen is doubly charged, but it is being shared by 2 tetrahedron. Now, if every tetrahedron gets only a single charge from each oxygen. The charge also is minus 4 from oxygen and plus 4 from silicon. Now, you have 0 charge. You have charge neutrality or charge balance.

Corner sharing network is present in all silica structures. Now, this corner shared.

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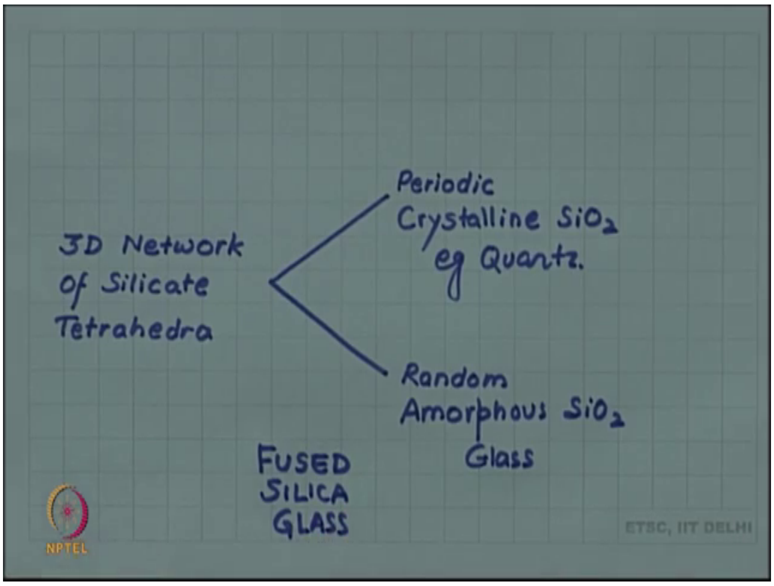

Silicate tetrahedra network if that network is a periodic network then we get crystalline silica quartz being an example crystalline silica example quartz and if this corner sharing network is a random network, then we will got we will get amorphous silica what we call glass. In fact, if it is pure silica glass without any other additive such glass is known as fused silica glass fused silica glass.

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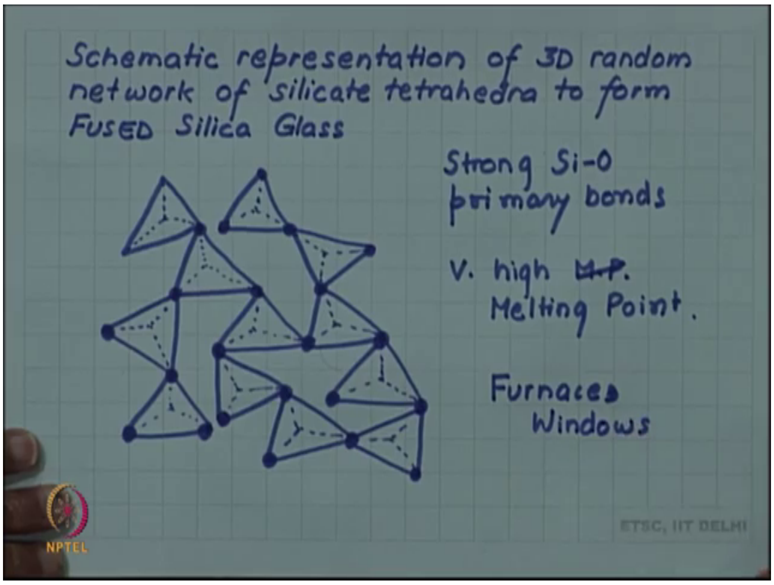

A schematic representation I am now showing you of a random network of tetrahedra in the fused silica glass. Each of these blocks each of the triangle with border lines is now representing a tetrahedra 3 corners of the tetrahedra the 4th corner is shown as intersection of these dashed lines and since it is for me it is difficult to draw in 3D. I am drawing a schematic 2D diagram and you can see that all corners which are locations of oxygen atoms are shared between 2 tetrahedra.

Of course, some of them at the surface is not shown to be sharing, but in a in a large network there will be very few such oxygen atoms at the surface which will not be shared all others will be part of a shared network. This is how you have and I have not again tried trying to draw this I have tried deliberately to draw it randomly that you have a random network of 3-dimensional silicate tetrahedra. This is what will be a representation of the structure of fused silica glass.

Now, all the bonds here are primary bonds their mixture of actually covalent and ionic bonds, but they are primary in nature. They are all very strong. Strong silicon oxygen primary bonds lead to a very strong glass a very stiff glass and this has this is a very high melting point because it is not easy to break these bonds. The thermal energy required to break this bond to make the make them mobile requires very high temperature very high very high melting point.

That is why these glasses. Because very high melting point the cost of processing is higher and that is why these will be fused silica glass will be expensive glass we will not like to use it for ordinary windows, but they can be used for let us say furnace window where temperatures are higher and we require a glass which can withstand such high temperatures.

For furnace windows we can use such glass, but for ordinary windows in our home we will not use fused silica glass mainly because of the cost. To reduce the cost and essentially to reduce the melting point because cost comes from the processing of glass at higher temperature. To reduce the cost or to reduce the melting point some additives are added and a glass commonly known glass is a soda lime glass.

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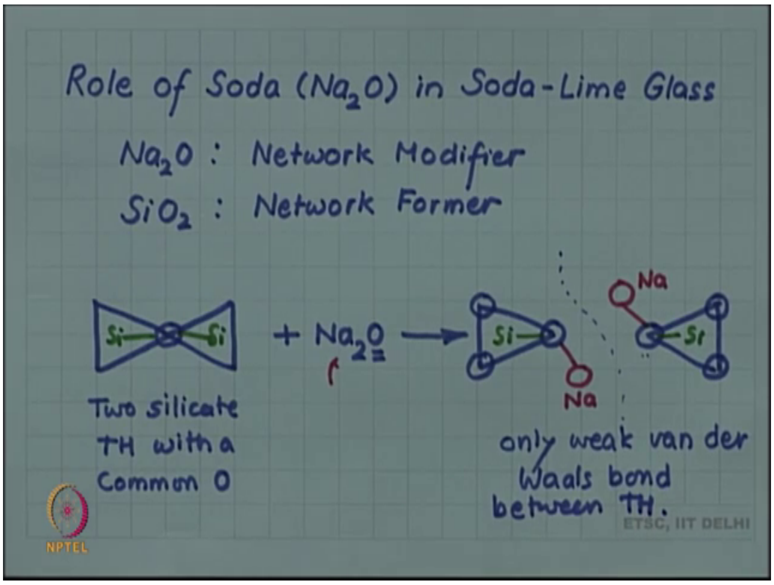

This soda lime glass has an additive soda and this soda Na2O has an important role in modifying the structure of the glass. That is why Na2O is called network modifier network modifier whereas, silica we have already seen silica was the one which was forming network. Silica is called network former. Let us see let me try to represent how the presence of Na 2 O how does Na 2 O modify the network.

Let me consider 2 silicate tetrahedra represented by these triangles sharing this common oxygen. These are 2 silicate tetrahedra with a common oxygen. Now, if I add soda to this and Na2O this then this Na2O provides an extra oxygen and this helps in breaking this corner bond. What happens then is the 2 tetrahedra can then get separated.

Now, since there was only one oxygen at the shared corner we will be having one oxygen less when we separate it into 2 tetrahedra, but that extra oxygen is already available force from Na 2 O. Na 2 O provides that extra oxygen, but then remember oxygen is divalent and is bonded and it satisfies it is valency by bonding it bonding to 2 silicon's it was bonded to a silicon in this tetrahedra and was bonded to silicon in this tetrahedra and that is why it is divalency was satisfied.

But now these oxygen atom are bonded to only one silicon. 1 valency is still unsatisfied, but then n a 2 o has is already providing 2 sodium which are both mono valent the sodium will now get connected and thus all balances are satisfied, but you can see that the net result of this is that a primary bonding previously there was a primary bonding between these 2 tetrahedra. It was not easy to move one tetrahedra with respect to the other this is what was giving high melting point for fused silica glass.

But now in this case you can see that this tetrahedra now has it is bonds independently satisfied independent of the other tetrahedra. There is no primary bond now between these 2 tetrahedra. Between the 2 tetrahedra only weak only weak secondary bonds van der Waal bonds between the 2 tetrahedra. Now, this tetrahedra can be independently moved with respect to this tetrahedra. The thermal energy required to break the bond the van der Waal bond is much smaller than to break the primary bond and that is why soda lime glass will melt or soften at much lower temperature making the processing cost lower and the glass cheaper. That is why the soda lime glass is what we will be using for windows.