Introduction to Materials Science and Engineering
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Lecture - 26
Graphene

Hello today we will discuss the structures of carbon and we take graphene as our first stop. So, let us look at the structure of graphene.

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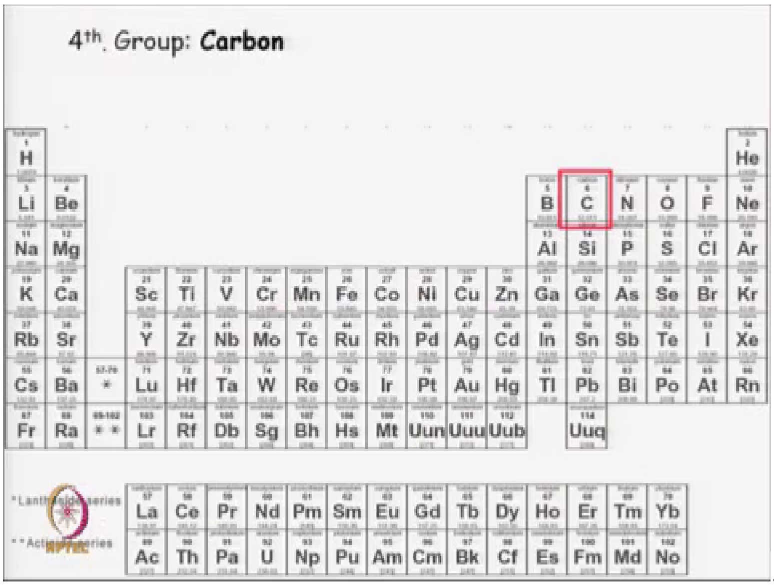

So, carbon is as you know a fourth group element located there in your periodic table, it has 4 bonds.

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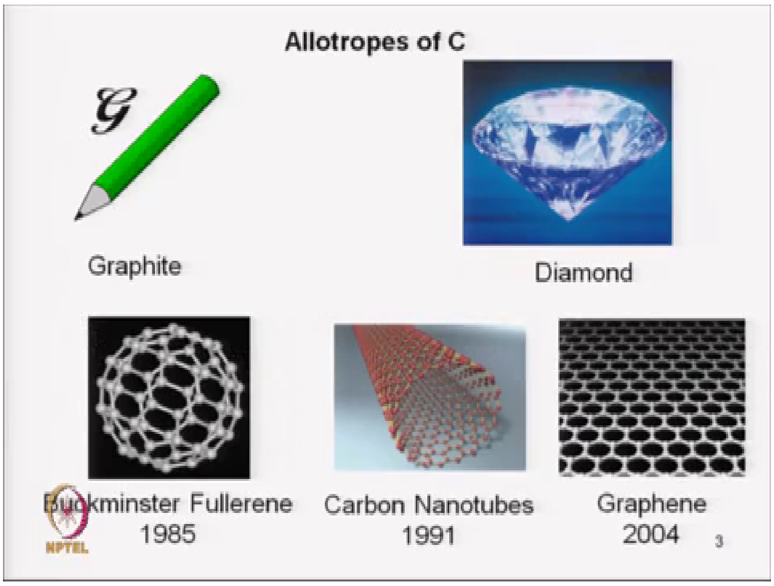

And these are the variety of allotropes of carbon which are known. So, graphite and diamond are the two classical examples which are very well known, but since 1980s newer forms of carbon have been discovered. So, Buckminster fullerene have was discovered in 1985, then carbon nanotube in 1991 and graphene in 2004. So, one of the latest forms of carbon which was discovered is graphene in 2004. And we will begin our journey with the structure of graphene.

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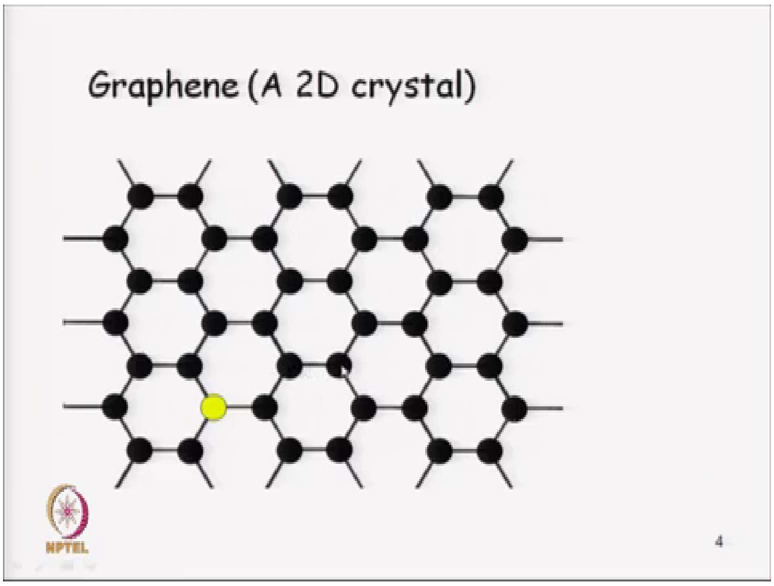

So, let us look at the structure of grapheme. Graphene is a two dimensional crystal structure based on a hexagonal network. So, you can see we have a hexagonal tile and hexagon style the space 2D space are in only one way if you want to have no overlaps or no gaps left and that is this way as shown. So, this is the hexagonal network or hexagonal tiling.

Now, if I put a carbon atom at each of the corners of this tiling what I get is graphene. So, let me do that. So, I have now placed a circle which represents a carbon atom at each of these sides, at each of the corners or vertices of the hexagons. Now, let us look at let us analyze this two dimensional crystal structure in terms of lattice and motif. So, if we select one of the atoms let me show that in yellow and try to find that if this is one of my lattice locations it is one of my lattice points then where are the other lattice points, you think about that. So, my question is, are all carbon atoms equivalent in the lattice sense. Wonder about that, think about that maybe you can pause the video here and think about this that are all rest of the carbon atoms equivalent to this carbon atom which has now been highlighted in yellow.

If you do this analysis carefully you will find that all carbon atoms are not equivalent. For example if you look at the nearby carbon atom this carbon atom where I have now put the pointer. So, if I go from this yellow carbon atom to my right a certain distance I find this black carbon atom, but if I travel the same distance in the same direction that is on the right from this black carbon atom I do not find another atom there. So, in this sense this yellow carbon atom and the black atom to its right are not equivalent in the lattice sense. But instead of going to the nearest neighbor if I go to the next nearest neighbor I find that this carbon atom and this carbon yellow carbon atom are exactly identical. So, if I find the neighbor to the right from this yellow carbon atom I also find neighbor to the right from this next nearest carbon atom if I go in the same direction at by the same distance.

So, the nearest neighbors are not equivalent, but the next nearest neighbors are equivalent. So, if I now mark all the equivalent lattice points or atoms sitting on the lattice points then I get this set of yellow atoms the alternate atoms as my lattice points.

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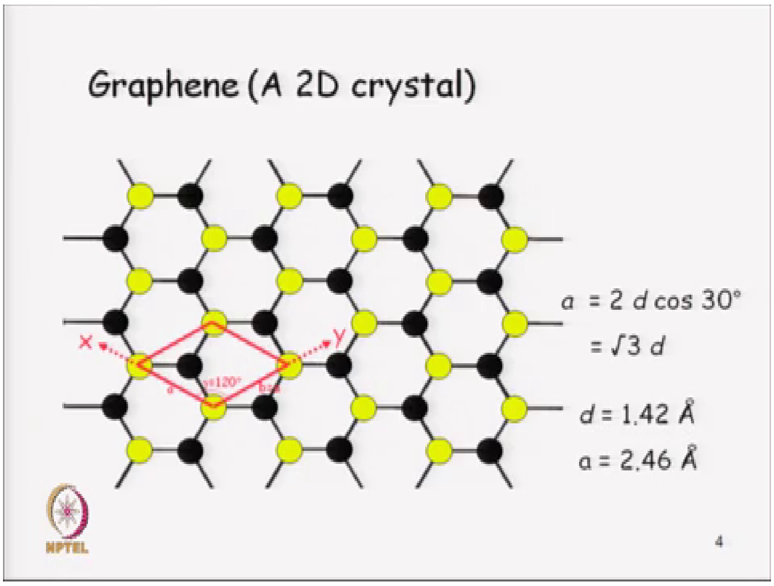

So, if I select one of these yellow atoms as my lattice point then the lattice will be formed by all these yellow atoms. The black atoms or the centers of the black atom will not be part of my lattice. So, the unit cell will be a rhombus unit cell with 120 degree included angle. So, I can call this as my X axis and this as my Y axis and the included angle is 120 degree. And of course, I have a and b lattice parameters where b is equal to a because this is a rhombus and this you can easily these details you can easily work out geometrically for a hexagonal packing.

In describing the structure of graphene many you and later on we will see in carbon nanotubes also many authors actually select their origin at the 60 degree angle. So, and we will take these two as their X and Y axis. So, in their case the angle between X and Y axis will be 60 degree. But the general crystallographic convention is to take the obtuse angle as the angle included between the axes. So, we have selected our unit cell axes like this, but while looking at other books or literature you should be careful in noting whether the authors have used 120 degree angle between X and Y axes or 60 degree angle between X and Y axis.

So, this is our unit cell of the 2D structure. The motif of course, will now be one atom from the corner, but that will not include all the atoms we are leaving out the black atom. So, black atom also has to be associated to the lattice point to create the motif. So, you have and we can write the lattice parameters in terms of the carbon carbon distance and also see that the carbon carbon distance d is not the lattice parameter. So, lattice parameter is related to the carbon carbon bond distance a through this relationship again easily derived geometrically that the lattice parameter is root 3 times the carbon carbon distance and carbon carbon distance in graphene usually is about 1.42 angstrom. So, the lattice parameter will be 2.46 angstrom.

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This graphene was discovered quite late all the carbon is so well known, but it was discovered quite late in 2004 and was awarded a Nobel Prize in 2010. These are the two Nobel Prize winners, the discoverers of graphene Konstantin Novoselov and Andrei Geim. These were the two the scientists who discovered this, rather accidentally a single layer of grapheme. They were playing with graphite and what they did was to put a cellotape on the graphite and pulled out the cellotape and along with the cellotape came a single layer of graphite sheet which is what we call graphene. So, graphite is nothing but a stacking of layers of graphene or graphene is nothing but a single layer of graphite

So, in our next video we will discuss the structure of graphite.