Introduction to Materials Science and Engineering
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Lecture – 30
Buckminsterfullerene (C60)

A today's topic is C 60 that is a 60 atom carbon molecule named, a very long name buckminsterfullerene. So, we will look at the structure of buckminsterfullerene. So, we have already discussed allotropes of carbon, we are discussing that topic and we have discussed graphite, diamond, graphene and carbon nanotubes.

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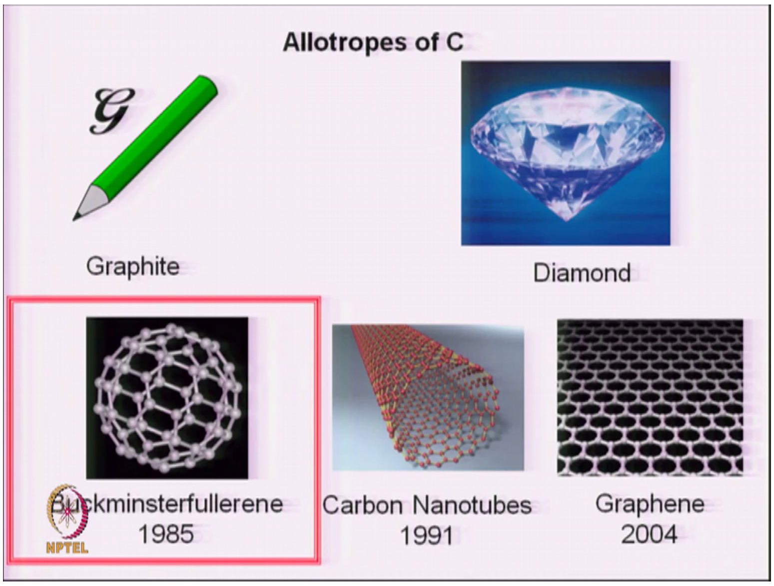

So, this is the last topic in the allotropes of carbon, which we will discuss now and that is buckminsterfullerene, discovered in 1985.

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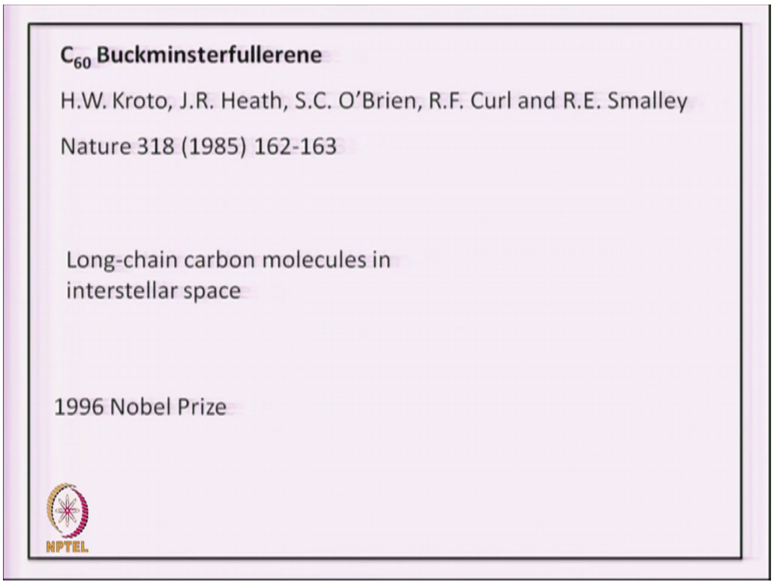

The discovery was reported by a article titled C 60 buckminsterfullerene. So, a new molecule was discovered by these authors Kroto, Heath, Brien, Curl and Smalley and they published their report in a very famous journal called nature, in 1985 a very short article you can see only two pages 162 to 163 and the title of the paper was C 60 buckminsterfullerene.

Actually, their interest was in long chain carbon molecules in interstellar space and they were trying to replicate some of these in their laboratory experiments by evaporating graphite by laser and in this kind of experiment they came across this new molecule 60 atom molecules, the structure of which they solved and gave a name buckminsterfullerene. For this achievement they were awarded, 1996 Nobel Prize.

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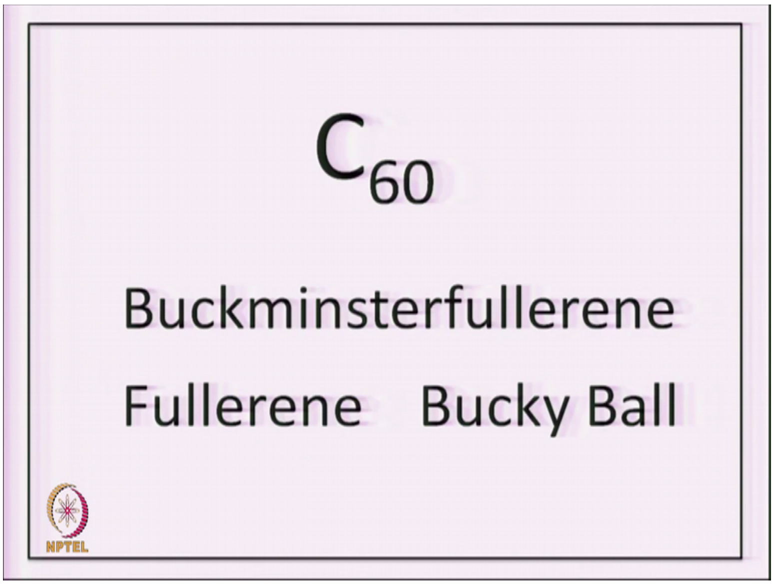

Buckminsterfullerene of course, a very long name, so shorter names like fullerene or bucky ball is also common for this molecule. So, let us now look at the structure of this fullerene or bucky ball, to get this structure we have to be familiar with a solid called truncated icosahedron.

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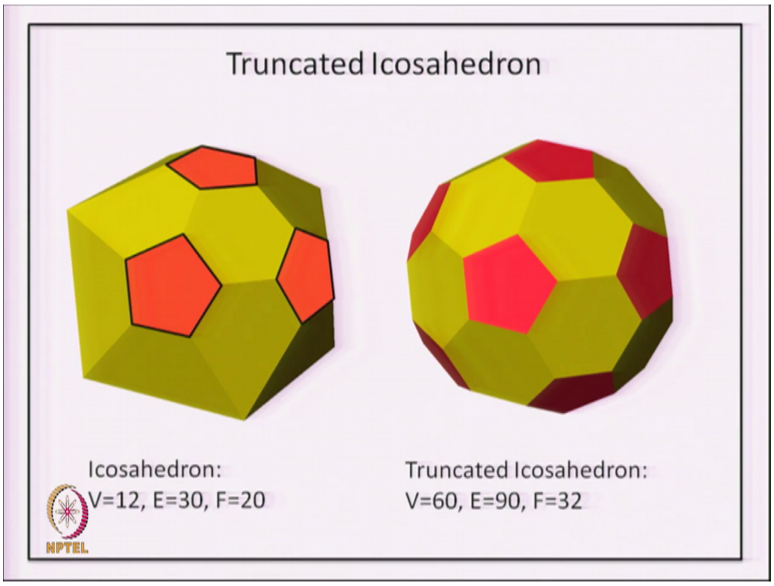

To understand truncated icosahedron, let us look at icosahedron. Icosahedron shown here is 1 of the platonic solids or regular solids. I will have a separate discussion on platonic solids for you, for the moment; let us just look at this icosahedron. It has 12 vertices or

12 corners, 30 edges; 30 such edges and 20 equilateral triangles. So, all edges are equal, all vertices are identical that 5 equilateral triangles meet there and all faces are identical equilateral triangles. This is a beautiful solid and is known as an icosahedron.

Now, in fact, the icosahedron word comes from it is 20 faces, 20 is icosa and hedron is faces. So, it is a 20 face solid, it is a 20 faced regular or platonic solid. Now, to get to the structure of C 60 we have to truncate this icosahedron. By truncation, we mean cutting off or chopping off the vertices, let us see how we do that. So, I make a small pentagon here, so, this around this vertex I have now a small pentagonal pyramid and I just chop off this pyramid to get a pentagonal face.

So, the pyramid has been chopped off and instead of the vertex of icosahedron I now have 5 new vertices and the corners of this pentagon and a pentagonal face. I do this operation for all other vertices, so if I chop off the second vertex there I again get a pentagon and if I chop off this top vertex, I again get a pentagon there. The chopping is done in a way that what remains of the original triangular face is now a regular hexagon. So, you can see that if I chop off all the 12 vertices of icosahedron I will get 12 pentagonal faces and they will also be hexagonal faces corresponding to the original at 20 triangular faces.

So, I then get a truncated icosahedron which is shown here. So, you can have these, you can see these 12 pentagonal faces, total face now is 32, out of which 12 is pentagonal and 20 is hexagonal. So, it is the structure is not that difficult, once you come from icosahedron and then truncated icosahedron. If you are still facing difficulty, all you have to do is to just look at a football. So, the makers of football have already solved this problem.

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The football is nothing but a structure made of hexagons; the yellow hexagons in my football here and the black pentagons and you can see that there are 12 such pentagons and 20 hexagons in a football. So, if you examine a football carefully, so you will get these numbers directly from the football. So, a football is nothing but a truncated icosahedron. So, if you look at a football you get the structure of C 60 molecule, that in the truncated icosahedron I have probably not yet mentioned, that in the truncated icosahedron now, you should imagine a carbon atom sitting at each of these vertices.

So, that is how, there are 60 vertices and you get 60 carbon atoms sitting at each of the vertices of a truncated icosahedron. So, that is the structure of the molecule, a very solid molecule, carbon valences are all satisfied, because you have for every carbon atom you can see their 3 edges that corresponds to 3 bonds, but two of them a single bond and 1 of them is the double bond. So, the 4 valency of carbon is satisfied in the molecule, it is a very nice solid molecule, very strong, but still this is just a molecule.

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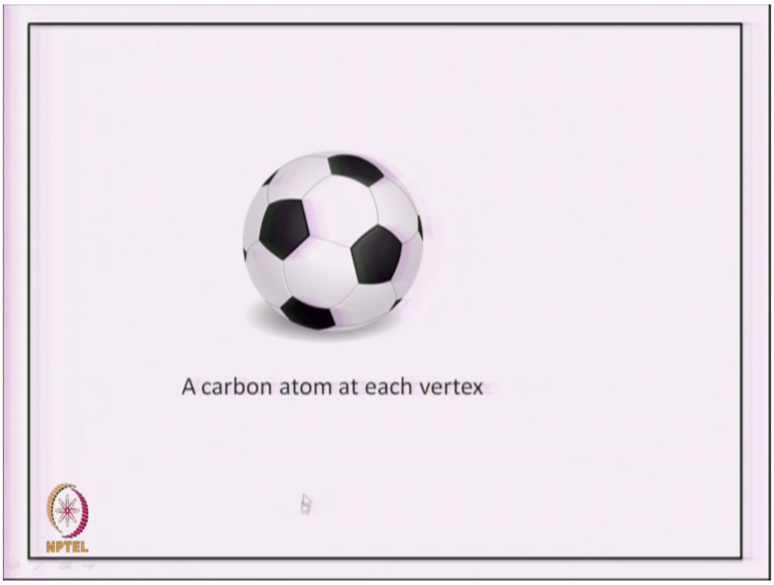

So, this word, this is the football picture and I have already shown you the real football, you imagine a carbon atom sitting at each of these vertices and you get a nice C 60 molecule.

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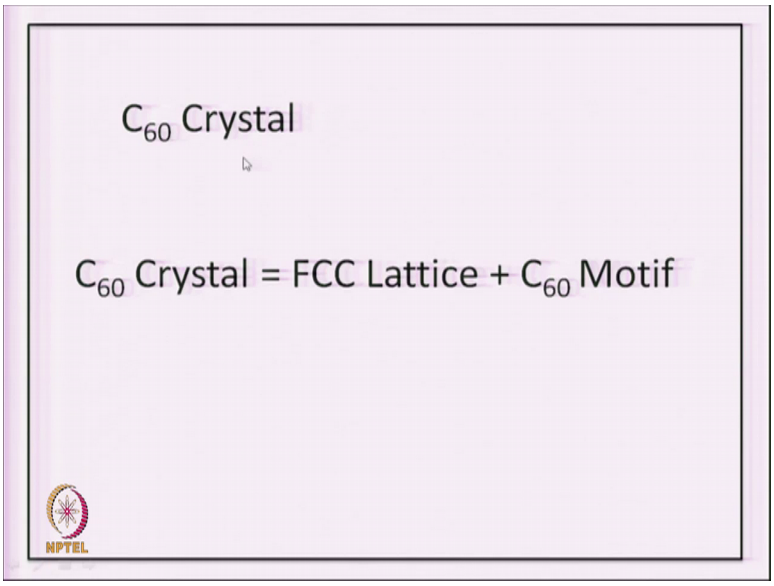

Now, this is just a molecule, if you crystallized it 1 of the forms of the crystal C 60 crystal is made up of these molecule and as we know that every crystal can be written in terms of a lattice and motive and it turns out that the lattice of C 60 is a face centered cubic lattice and the motive it is 60 atom fullerene molecule sitting at each lattice point. So, the centroid of the C 60 molecule coincides with the lattice.

So the carbon atom, do not actually sit on the lattice point, they are distributed around the lattice point, but they are associated with that lattice point. Let me draw that and show it to you.

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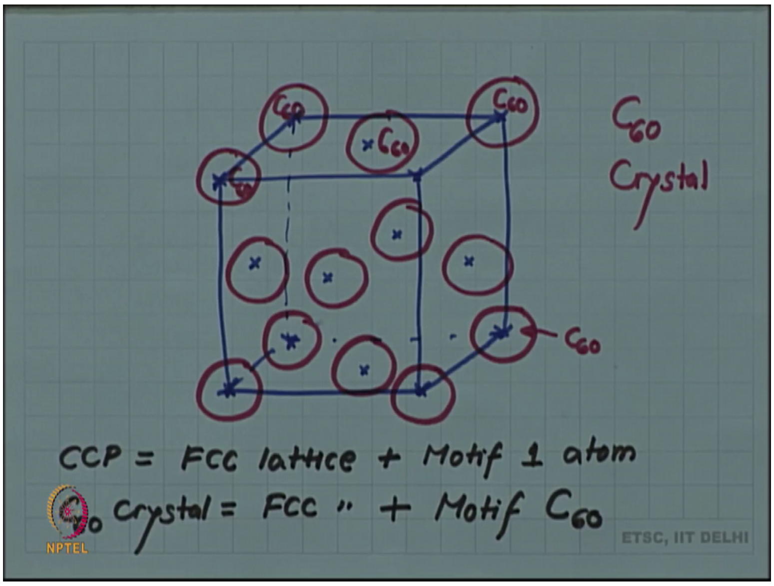

So, if I can now draw an FCC unit cell, you are familiar with FCC unit cell. So, we begin with a cube and we place lattice points at each of the corners and at the 6 face centers. So, all these little crosses are lattice points and if I now think in terms of the C 60 solid or a C 60 crystal. So, I place the C 60 molecule; the truncated icosahedron molecule at each of the lattice points.

Now, I will have difficulty drawing you can understand, the C 60 molecule exactly, so I just draw a sphere and write C 60 inside that to represent that it is not a single atom, but a 60 atom. So, I keep placing at each of these lattice points a 60 atom molecule, the centroid of the molecule coincides with the lattice point, but the carbon atoms do not coincide with the lattice point, they are distributed around that lattice point as truncated icosahedron, all of the a C 60.

So, you can see the structure is very different from the structure of the cubic close packed structure where each of these spheres would have been a single atom. So, the

CCP structure and the C 60 solid share the same lattice, but there is still a very different crystal structure because their motifs are very different, CCP has a single atom motif, so CCP, if I write that down for you CCP, also FCC lattice, but the motif is 1 atom at each lattice point; 1 atom at the lattice point and a C 60 solid you have the same lattice FCC lattice but, now, the motif is of 60 atoms.

So, motive, although lattice can be only 1 of those 14 Bravais lattices which we have discussed, motif can be quite complicated and this is 1 of the examples which we have, where 60 atom carbon molecules, the fullerene molecule is being used as motif on an FCC lattice.

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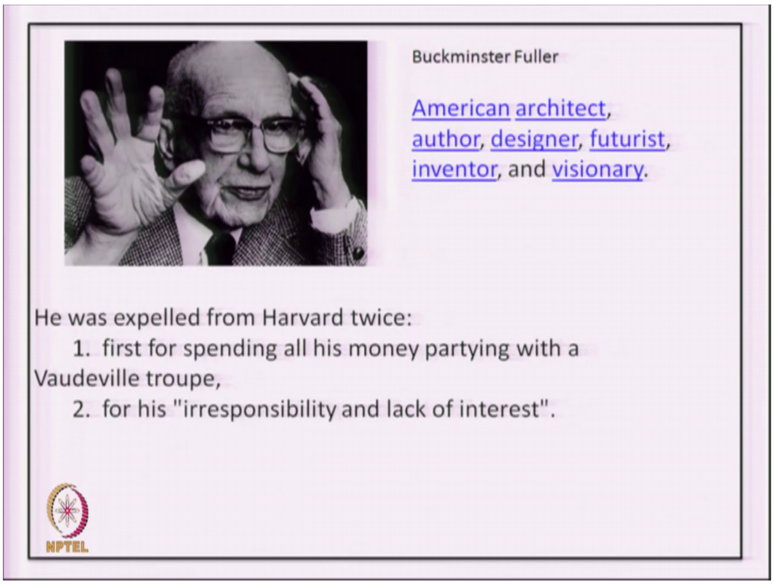

The name fullerene, it comes from an American polymath named Buckminster Fuller. So, I show him there a very famous American architect, author, designer, inventor he was a polymath, he excelled in many different fields. Although, he never graduated from Harvard University, where he went to study and was expelled twice during his stay here and you can see the regions once for spending all his money in partying and another for irresponsibility and lack of interest. So, if any such accusation is there by your university on you do not feel disheartened you are in good company, but why the molecule was named Buckminster Fuller, he was famous for designing, so called geodesic domes, show you here.

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Such 1 example the Montreal biosphere in Montreal, designed by Buckminster Fuller and you can see it is made, it is a huge dome made up of hexagons and possibly you will have to find pentagons also, because a lattice grid of only hexagons will always be flat, you requirement against to curve them. So, somewhere in this geodesic dome, I can see hexagons here, but somewhere in this geodesic dome you should be able to find pentagons also, otherwise the structure will not be curved.

So because, the earth authors; the original authors who got the Nobel Prize for discovering C 60 molecule, when they were trying to solve this structure they recalled the geodesic domes made by Buckminster Fuller and to honor him, they named the molecule Buckminster Fullerene.

So, with this thank you very much, we have finished the carbon structure. I will have 1 lecture on the structure of solids itself particularly the platonic solids or regular solids because you have seen a tetrahedron, cube an octahedron in while discussing crystallography and now in C 60 molecule you have met another 1 which is icosahedron. So, I think I will give a general discussion on this in another video.