The Next Big Thing: Nanotechnology

"Buckyballs": Triggering a Nano-Revolution

COLIN
Well it's certainly not then inconceivable that the world will be radically changed by nano technology, it already has been by microtechnology, by building components measured in millionths of a metre, hugely complex silicon chips have been developed. But by the end of the decade this silicon technology will start to run out of steam. The fundamental physical limits will be reached. Scientists will have to learn to build on the nano scale, a thousand times smaller than the micro engineering of the present day chip. It's been a long standing dream as far back as 1959 the physicist Richard Feynmann predicted a future where machines would be built atom by atom. His vision took a took a a step closer to reality in 1985 when new molecular building blocks were discovered. Christened Buckminster Fullerene or bucky balls for short, it was a previously unknown form of carbon. The incredibly strong football shaped molecule kick-started an atomic building boom. The Nobel Prize was awarded to the scientists who solved the problem of the bucky ball structure.

HARRY (Archive footage)
It's almost like you're looking at stars in the sky. It was just such a fantastic moment that as I took the plane back, I was on such a high that I don't think, I think the aeroplane would have actually flown without the engines running.

COLIN
Harry, are you still as excited about the discovery?

HARRY
Well yes I think every time I think about it and just focus on it, yes, it never never loses its charm.

COLIN
Tell us about the background to it, how did it develop.

HARRY
In fact I was interested in the chemistry in stars, and in 1985 with the group in Rice University,Texas, we tried to simulate the chemistry that was going on in a star, and this molecule popped out, totally unexpected. What this molecule did was change our understanding of sheet materials particular graphite, and also molybdenum sulphide and tungsten sulphide, because we now know that the sheet materials on a small scale are definitely unstable, they form round cages. They all do now, and it's so obvious now we see it but previous to that we didn't know that. Secondly if you elongate these molecules, what you get is the famous nano tube, here it is, and this is perhaps going to be the, the most likely form of these cages that's going to have an application.

COLIN
The these are the carbon atoms, the black….

HARRY
…..yeah, if you can imagine that it's a sheet of graphite that's rolled up in a tube, and then there's half of C60 30 atoms on the end, and 30 atoms on the other end.

COLIN
So the white things are the. are the bonds.

HARRY
The white things are the bonds, are the electrons and the black things are the carbon atoms. And the amazing thing about this material is that graphite's probably the strongest material that that can be made, certainly from atoms and electrons and if there's some other phase I'd like to know what it is. But if you could produce, bundles of these tubes, and make girders out of them, then you would have a material which is a hundred times stronger than steel, would be one sixth the weight, these are the emotive terms that people use. You can imagine building bridges that won't fall down in earthquakes, and you can imagine building aeroplanes which are so strong and so light that if the engines failed, they would just glide. Perhaps the most likely applications are in electronics because these are perfect molecular wires, it's actually a single molecule okay. And if we can construct these, with the right diameter and what we call the helicity because they have a helical pattern, or they can from non-helical to helical, to another type of non-helical structure, what we call a zigzag to an armchair structure, then we will have the wires that will be perfect for the next range of computers, the molecular computer. But we have major problems to solve, one of them being how do we solder this molecule to another element or an element, a molecular element that behaves like an element on a chip.

COLIN
Sure and when you use the word solder you mean that's just another a metaphor yeah.

HARRY
It's a metaphor yes.

COLIN
Sure I mean you've got, chemically binding somewhere.

HARRY
That's exactly it, we have to learn how to do the chemistry at the ends to link it chemically or through electrons or through bonds to the element.

JACKIE
When you find them though they're all different lengths.

HARRY
Yes.

JACKIE
So you, so you can't really predict at the moment how you're going to.

HARRY
No at this stage it's a case of, of producing them, and we do that just by a simple carbon arc process, and we sputter carbon from the rods, and we find these tubes, and then you have to pick them one at a time up, and put them there. Now then that could be done, but I don't think that's going to be the way forward, I think we've got to learn how to govern the growth of these materials, and that's still a major problem, there's no doubt in my mind that we've got a big barrier to cross.

JIM
But the long term potential of these Fullerene structures, these nano tube structures is is quite amazing that, because they are representing a very sophisticated, sophisticated form of self assembly. If we had to sit and make each bond here individually right, we would be a million years but these things self assemble and how one controls self assembly, he who can control self assembly sort of controls the future.

HARRY
But that's what biological systems do yeah.

JACKIE

Enzymes and things, exactly that yeah.

HARRY
And, I always think that what I would like to see is a sort of genetically modified spider, take the spider that spins a web, but if you can genetically modify it to spin carbon atoms, and build a helix, and just tell it, look I want a certain diameter, and a certain helicity, then we'll have these little spires and we'll be going around building our computers.

COLIN
Well of course the way biology does it is to read out the information from another molecule.

HARRY
Absolutely.

COLIN
From D.N.A. or R.N.A. that stores that information.

Peter you're interested in the biological applications. I mean do you see scope for that with this material?

PETER
Oh tremendous. I think that on the bio-molecule side there's many things we can do. We can for example, utilise some of those tubes to grow things inside them in a very controlled way. They might be purely inorganic crystals of a very low dimension, and these will have completely new properties, because they're just two or three atoms across, and they will probably follow the helical inside structure of the tube, hence giving it chirality, an optical behaviour that's not around at the moment. We can grow something I would think akin to nerve cells along some of these structures, opening up a whole realm of possibilities.

COLIN
Well bucky balls are clearly the building blocks of the nano world, to find out a bit more about what's involved when you work at this very small scale, we went to Cambridge.

MARK
I'm Mark Welland, Professor of Nano-technology at the University of Cambridge, and I engineer on a nanometre scale. A nanometre is about one ten thousandth of the diameter of a human hair. That's about the same as a string of five atoms. For comparison, if we take the distance between the earth and the sun to be one metre, then a football field would just one nanometre long.

If you really want to look at atoms and molecules, what you need is one of these, a scanning tunnelling microscope. This microscope was awarded the Nobel Prize in 1986. This particular one which is developed jointly with IBM Zurich, Jim Gimzewski, is incorporated inside a machine like this one. In this system, we're depositing fullarene molecules onto silicon surfaces to make a completely new type of device.