TOBY HOWARD LOOKS AT THE EXCITING POSSIBILITIES OF A NEW FORM OF CARBON.

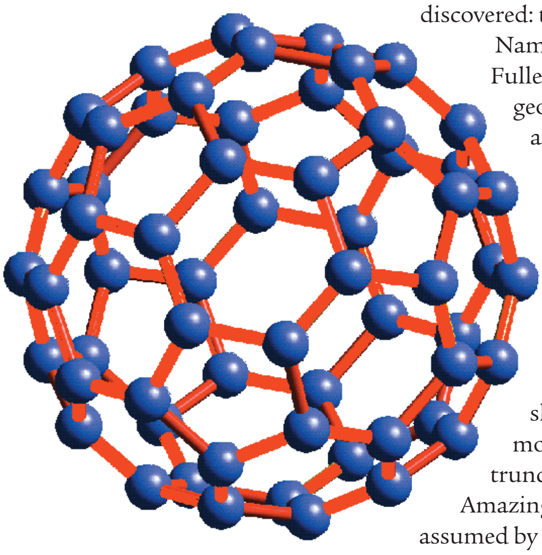
Carbon updating

A NEWLY-DISCOVERED FORM of carbon is sending waves through the research community. As well as the prospect of cheap, super-thin, high-quality display screens, this new kind of carbon – the nanotube – has unusual properties, which may lead to huge advances in computer memory technology and chip design.

Carbon is certainly strange stuff. In its graphite form it is soft and smudgy, but as diamond it is the hardest substance known on earth. Its peculiar chemical properties make it the basis for life. If this weren't enough of a repertoire for a single element, in the early 1990s a new class of carbon molecules was discovered: the fullerenes.

Named after Buckminster Fuller, inventor of the geodesic dome, fullerenes are complexes of carbon atoms arranged into regular geometric shapes.

Perhaps the best-known fullerene is the 'buckyball', comprising 60 carbon atoms arranged in the shape of a football (or more accurately, a regular truncated icosahedron). Amazingly, this is the shape assumed by some carbon atoms in an ordinary candle flame.



The Buckyball is the best-known fullerene and is made up of 60 carbon atoms. Its shape can often be found in ordinary carbon atoms in a candle's flame

A related fullerene is the nanotube, first discovered in soot deposits in 1991 by Sumio Iijima of Japan's NEC Corporation. A nanotube is made of millions of carbon atoms, arranged into a long thin hollow cylinder, just a few atoms in circumference. Effectively, a nanotube is a sheet of graphite one atom thick, rolled up into a cylinder. And nanotubes have some very interesting properties.

Their electrical conductivity, for example, enables them to be used as wires on the quantum scale. Such wires would be almost unimaginably small, even by the standards of silicon chips. Sufficiently long nanotubes could be used to effectively connect the quantum world to our macroscopic world, enabling, for example, the control of machines made from molecules.

And it's the electrical behaviour of nanotubes that makes them suitable for building a new kind of flat-screen display called the 'field-emission display' or FED. Conventional liquid-crystal displays are certainly flat, but they also have a number of drawbacks – such as poor image quality, a restricted field of view and high cost. FED technology addresses all of these problems.

In principle, FEDs work in the same way as conventional cathode-ray tubes (CRTs). A grid of coloured phosphor dots emit light when stimulated by an electron beam. In the conventional CRT, there's a single source of electrons – the electron gun – whose aim is scanned across the screen. But in order for the gun to have enough room to 'see' the whole area of the screen, it needs to be mounted far enough away – hence the very obvious non-flatness of CRTs.

An FED, however, doesn't have a single electron gun. Instead, every pixel in the display has its own private gun, mounted just behind it. An electric field applied to the screen pulls electrons out of the guns. The design calls for the tiny guns to have sharply-pointed tips, so they emit coherent, focused streams of electrons. It turns out that nanotubes are perfect for this.

The main difficulty of fabrication is to grow an array of nanotubes on a glass substrate, making sure they're all perfectly aligned in the array, and all pointing perfectly forwards. Recently, researchers at Samsung's Korean labs demonstrated a working prototype, and several other Japanese companies are known to be working on the technology – in secret.

Another application of nanotubes is to make computer memory. Place a buckyball inside a nanotube whose ends have been sealed, apply an external electric field and – hey presto – you have a memory cell. The polarity of the field can be used to push the buckyball to either end of the nanotube, and the two positions can be used to represent a 1 and a 0 (www.pa.msu.edu/cmp/csc/memory.html).

Researchers at Delft University of Technology have also used nanotubes to create single-molecule transistors, which could be used for building logic gates (vortex.tn.tudelft.nl).

Nanotubes may only be visible through an electron microscope, but we're sure to be seeing a lot of them in the future.