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DNA - shepherd dogs for nano-tubes

After the DNA scaffold come the DNA forceps, says S.Ananthanaryanan.

As the new science of nanotechnology prepares to transform our capability through complexity in miniaturization, the exciting developments are of ways to construct nano-objects at will and to pick out, from assorted nano-things that self assemble, the ones that we want!

Ming Zhen, of Delaware, USA, and colleagues report in ***Nature*** that they have harnessed DNA sequences to pick out specific carbon nano-tubes from a melé of nano components deposited by the most efficient production methods.

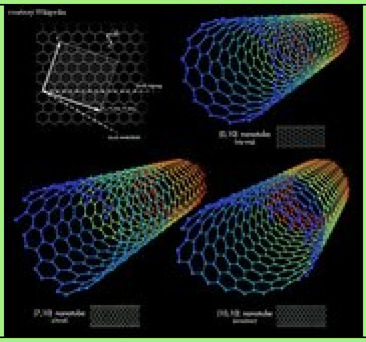
Versatile carbon

The element carbon, which dominates life and the whole range of ‘organic’ materials, owes is versatility to its atomic structure. Atoms of the elements consist of a core surrounded by ‘shells’ of electrons. The ‘outer shell’ electrons are ‘exposed and can participate in combining with the outer electrons of other atoms. But if the outer electron group consists of eight electrons (also two electrons), they mutually stabilize and such atoms have less affinity for other atoms. The whole activity of ‘pairing’of atoms is thus to simulate an ‘eight electron’ condition – through atoms with more than a few outer electrons ‘lending’ to atoms just short of 8, for instance.

Carbon, and also silicon, germanium, etc, have a ‘half-way’ surface, with 4 outer electrons. These materials can then simulate a ‘eight electron’ condition by ‘holding hands’ in twos, threes or fours, with most other atoms and even with each other! Carbon is best placed because it is light, gaseous or liquid at ordinary temperatures, abundant, etc. Carbon is able to participate in countless chemical combinations – and hence its central place in living things and also the world of synthetic materials like plastics, aromatic compounds, drugs, etc.

The nanotube

Apart from chemical combination with many elements, carbon is also able to connect with other carbon atoms in a variety of ways. Carbon thus exists in different forms, like diamond and graphite, where the atoms have formed into regular 3-D or 2-D formations. As we know, diamond is unmatched in hardness and sheets of graphite freely slide over each other, which happens when we write with a graphite pencil, for instance.



But apart from the regular form in graphite sheets, which is at the large scale, at the minute scale, the sheets of graphite can also fold over and join with themselves, to form tubes or balls, which have both remarkable strength as well as electrical properties. The 4-way connection that carbon atoms form among themselves helps them assemble like the geodesic dome of Buckminster Fuller and myriad other shapes and forms with economy and tremendous stability – all at the atomic scale.

The applications are limitless, from structural components, electronics to drug delivery conduits, paper batteries, solar cells, mechanical memory systems – it has been said that as we near the impasse with environment degradation and the end of sources of power, carbon may help find solutions, with the ability to manipulate nano-materials.

Nano-tube production

Unlike most nano-materials, carbon nano-tubes are easily assembled, because of the native tendency of carbon atoms to line up in sheets or tubes. Carbon nano-tubes can be readily created in good quantity by depositing carbon vapour, either through electrical arcing or using carbon vaporized by lasers or generated by chemical means. The electric arc method gives up to 30% yield, as a mixture of single-walled and multi-walled nanotubes, each as much as 50 microns long. The laser method has yield of 70%, primarily of single walled nano-tubes, but is expensive. But chemical deposition is the most promising method, and arrays of nano-tubes 18 mm long have been achieved with this method.

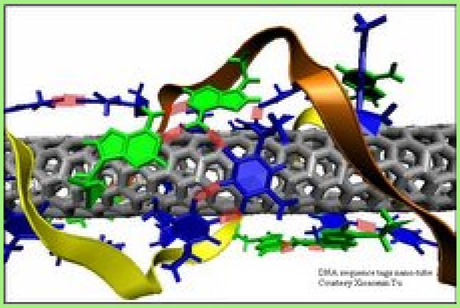
But the problem is that these efficient methods generate a highly mixed output of nano-structures, that is, of different sizes and shapes, all of which are too small to be easily sorted. The useful ones are hence lost in the 'haystack' and picking them out is a challenge. The usual purification methods used have depended on physical and electronic structure of the specimens. But these methods, borrowing from techniques to separate chemicals, like chromatography, are not effective with nano-tubes and many unsuitable forms often pass through the same filter.

DNA to rescue

DNA, the mega molecule that dwells in each cell of living things and encodes their genetic heritage, works its magic by the ability to define the exact construction of millions of complex proteins, to uniquely define every individual living thing. If the tools that the DNA uses were applied to identify specific nano-tube features, it could lead to a viable tool to separate specific nano-tube from others.

This potential, however, has not been tapped so far, mainly because the task of identifying DNA sequences that could bind to specific nano-tube structures is mind-boggling, to say the least. The custom made DNA sequences, as are available for use in such studies, are about 100 units long, in comparison to the DNA, which have millions of units. Even in these 100 unit sequences, each unit, called a base, can take four forms. Hence the possible forms of 1a hundred of such bases is 4^{100} (4 to the power of 100), which is a number like 1 followed by 60 zeroes. What Ming Zhen of Delaware and Mark Hersham of Northwestern University in Illinois, USA, have done is to work with simple units, first of only one base, and then of two bases, and so on, to generate a set of some 350 different DNA sequences.

These sequences were then tried out with nano-tube mixtures, to see if any of them attached exclusively to any specific nano-tube. It was found, by trial and error, that some sequences do attach to specific nano-tubes, very selectively – and 20 such have been identified. It is then possible to separate these selected nano-tubes with 99% purity. This is a remarkable achievement – a set of custom made molecules, of average complexity, which can go into a highly mixed population of nano-tubes, and identify specific ones to separate.



The development is viewed as the start of a powerful technique to generate carbon nano-tube component that can be used by themselves or used to generate other miniature components.