AMAZING CARBON

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Carbon does not stop amazing us – again and again. For many years, elemental carbon, found in *sp*^{2} bonded graphite or *sp*^{3} bonded diamond, was believed to be well understood. The complexity and importance of Organic Chemistry reflects the fact that chemically functionalized carbon, often forming *sp* bonded chains, dominates our world, disguised as clothing, medication, or gasoline. Without carbon, the key player in molecular biology, our life would be different, or not exist in its complexity. The picture emerging from findings across different disciplines suggests that *form determines function*. In this context, carbon is a real champion, with its layered *sp*^{2} allotrope being as stable as the *sp*^{3} bonded crystalline diamond and, even without functional groups, almost as stable in *sp* bonded chains.

Even though other pure-carbon allotropes, such as C_{60} with a significantly different structure from graphite and diamond, have been speculated about for a long time [Eiji Osawa, *Kagaku* (Kyoto) **25**, 854 (1970)], the synthesis of this and other fullerenes fifteen years later [H. W. Kroto, J. R. Heath, S. C. O'Brien, R. F. Curl, R. E. Smalley, *Nature* **318**, 162 (1985)] was considered significant enough to warrant the 1996 Chemistry Nobel prize for Smalley, Kroto and Curl. The amazing world of sub-nanometer fullerenes, which have eluded significant applications so far, was soon to be expanded by the discovery of nanotubes in the deposit formed during the carbon arc synthesis of fullerenes [Sumio Iijima, *Nature* **354**, 56 (1991)]. Nanotubes can be thought of as graphitic sheets rolled up into seamless cylinders, which are only nanometers in diameter, but up to millimeters long. They may have one or multiple walls, arranged as coaxial cylinders, or can be bundled. Depending on how exactly a graphene sheet is rolled-up and reconnected in terms of diameter and chiral angle, they can be metallic or semiconducting. Nanotubes are already improving the performance of Li-ion batteries and field electron emitters in displays. Next likely applications are in fuel cells, supercapacitors, advanced nanocomposites, and in molecular electronics. The role of nanotubes in hydrogen storage is a matter of continuing controversy. It comes as no surprise that the number of commercial nanotube suppliers is growing fast, with producing countries ranging from the U.S. to China, Japan, and even Cyprus in the Mediterranean.

Nanotubes are not the last word in the apparently inexhaustible structural arsenal that carbon seems to offer. Nanometer-sized diamond crystallites, intriguing on their own, may also convert into multi-wall nanocapsules. The latter are close relatives of spherical carbon onions, which can be thought of as nested fullerenes. Even more amazing are the so-called 'peapods', ordered arrays of fullerenes inside a nanotube [B.W. Smith, M. Monthioux, and D.E. Luzzi, *Nature* **396**, 323 (1998)], which form spontaneously when nanotubes are exposed to fullerenes [S. Berber, Y.-K. Kwon, and D. Tománek, *Phys. Rev. Lett.* **88**, 185502 (2002)]. Nanohorns, conical graphitic structures with a fullerene-like dome at the apex [S. Iijima, M. Yudasaka, R. Yamada, S. Bandow, K. Suenaga, F. Kokai, and K. Takahashi, *Chem.. Phys. Lett.* **309**, 165 (1999)], bear promise for energy storage due to their large accessible surface area. Recent observations suggest that foam-like carbon, related to 'schwarzite', may even become ferromagnetic and remain so well above 800ºK [A.V. Rode, E.G.. Gamaly, A.G.. Christy, S.T. Hyde, R.G.. Elliman, B. Luther-Davies, A.I. Veinger, J. Giapintzakis, J. Androulakis, N. Park, M. Yoon, S. Berber, J. Ihm, E. Osawa, and D. Tománek (submitted)].

Does form always determine function? With carbon, we do not know yet. In any case, it appears that elemental carbon will not cease amazing us with an ever growing variety of stable allotropes and an even faster growing range of physical properties.

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