Pattern formation on carbon nanotubes

Researchers at the Institute of Materials in Nantes have discovered a new and unexpected property of carbon nanotubes when exposed to fluorine gas. Over 10,000 times thinner than a human hair, carbon nanotubes are long tube shaped molecules made from carbon. Although roughly 100 times stronger than steel, they have only about 1/6 of the weight, and are at the forefront of the new field of “nanotechnology”, holding the promise of revolutionizing modern materials.

When exposed to fluorine gas, the fluorine atoms stick to the nanotube surface, changing the surface of the tubes to be more like that of Teflon. However in their latest study (in the journal ‘Physical Review Letters’), researchers from the IMN found that the fluorine gas is not arranged at random, but instead organizes itself into different patterns on the nanotube surface depending on the temperature.

Like children in a playground, the fluorine atoms mill around on the nanotube surface, always avoiding getting too close to one another. But heat the tubes up, and remarkably, the fluorine atoms undergo a change of heart. Between 200 and 250°C, they overcome their natural reticence and form up into close packed soldierly ranks along the length of the nanotube, sitting shoulder to shoulder. Even more surprising, each row has the same length, resulting in “stripy” nanotubes with bands of fluorine and bands with none.

The result is a sharp change in the physical, electrical and chemical properties of fluorinated nanotubes as they are heated (for example they become electrically resistive). The team hopes that it may be possible to exploit this “self-organising” effect of the fluorine to better control the surface chemistry of nanotubes, tailoring their surface properties by controlling the arrangement of species attached to their surfaces.

“Although each fluorine atom is moving in response to the position of its neighbours, collectively this results into different patterns on the nanotube surface”, explains Dr Ewels from the IMN, “It’s a bit like flocking birds; each bird is only interested in flying close to its neighbours without colliding with them, but the collective result is the patterns that bird flocks form”.

Fluorinated nanotubes may find application in the future as electrodes in batteries, in supercapacitors for storing energy, and as highly efficient lubricants.

The research was the result of a collaboration between teams at the Institute of Materials (Nantes, France), Université Catholique de Louvain (Louvain-la-Neuve, Belgium), Sussex University Chemistry Department (Brighton, UK) and Newcastle University (Newcastle, UK).

“It’s a curious effect, but explains nicely the experimental observations”, Dr Chris Ewels (IMN). “The calculations suggest that putting fluorinated nanotubes in solution should change the temperature at which the patterns rearrange, depending on the choice of solvent”.

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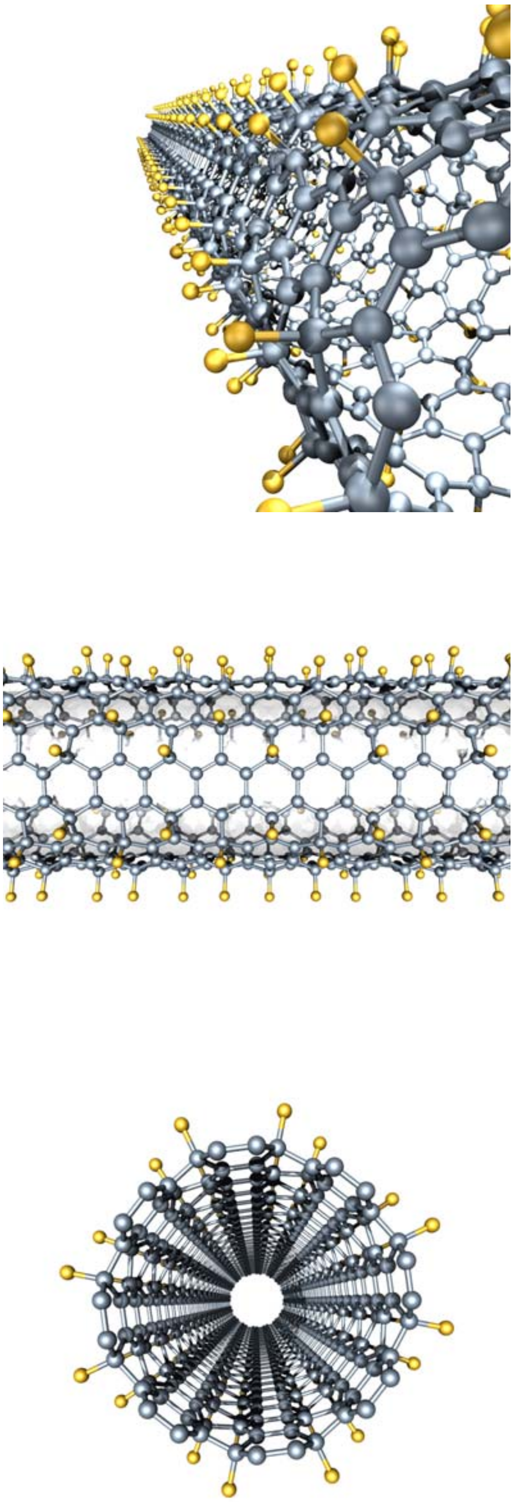
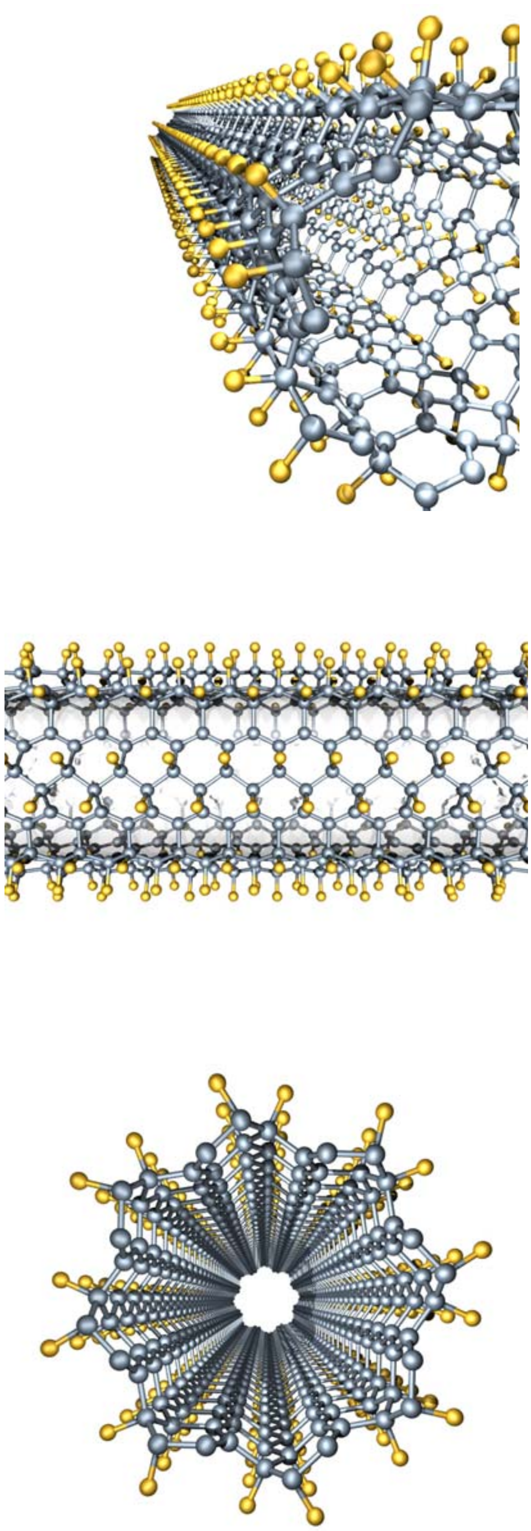
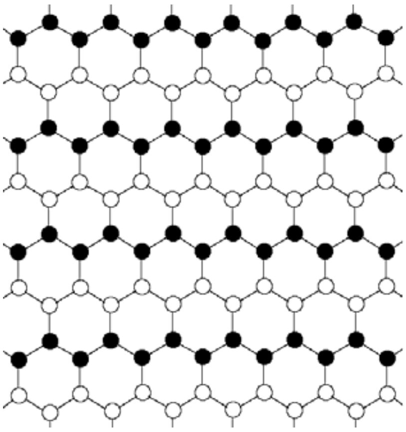


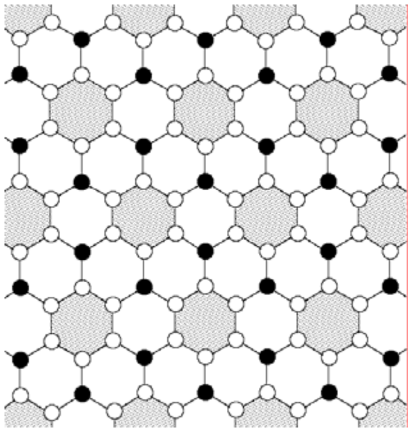


C_4F coverage (low temperature), different views along the nanotube.

C_2F coverage (high temperature), different views along the nanotube.



(a)



(b)

Schematic diagrams showing (a) C_2F and (b) lower coverage C_4F (filled circles denote fluorinated carbon atoms, empty circles unfluorinated). C_4F is the maximum coverage possible when limited by the exclusion of fluorinated carbon atoms at 2nd neighbour spacing. *(Figure taken from the article).*

<u>Reference</u>

'Pattern formation on carbon nanotubes'
C. P. Ewels, G. Van Lier, J. -C. Charlier, M. I. Heggie, P. R. Briddon,
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Contact Ref: Chris Ewels (ewels@yahoo.com / chris@ewels.info)

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Authors: Chris P. Ewels, Gregory Van Lier, Jean-Christophe Charlier,
Malcolm I. Heggie, Patrick R. Briddon

Chris Ewels address:
Institut des Matériaux Jean Rouxel, CNRS-Université de Nantes, UMR6502, 2 rue de la Houssinière, B.P. 32229, 44322 Nantes, France