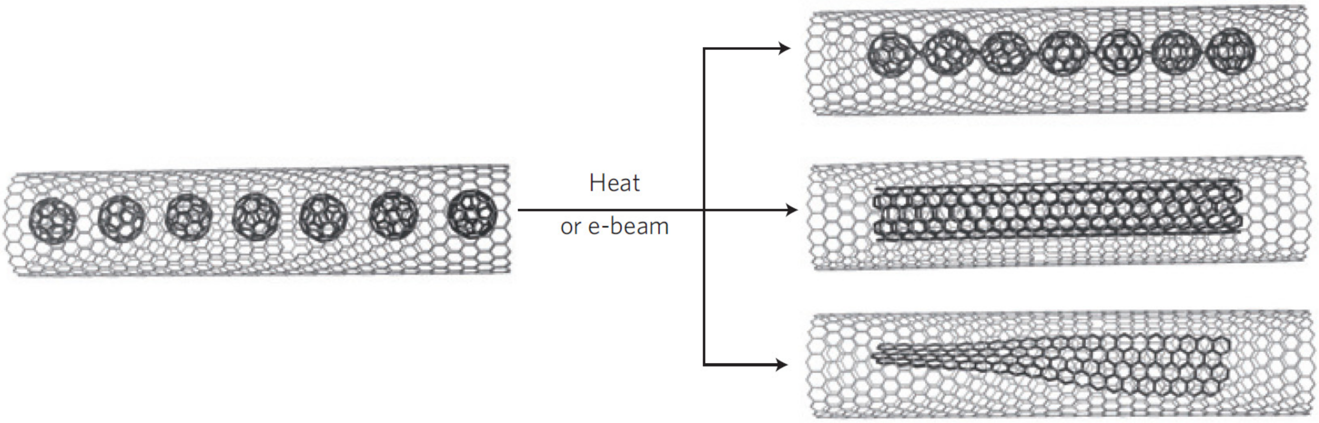

Fig. 1 Guest-molecules encapsulated within a CNT can be transformed into a 1D structure under the influence of heat or an electron beam. The host-SWNT acts as a template that allows the growth only in one direction. Depending on the conditions, the molecules of fullerene can either be transformed into a polymer(polymer@SWNT) or into a narrow internal nanotube (SWNT@SWNT); although the formation of a nanoribbon within a SWNT is also possible in theory, GNR@ SWNT have never been previously observed.

Carbon materials with unique properties

Self-assembly of a sulphur-terminated graphene nanoribbon within a single-walled carbon nanotube

August 17, 2011 - Although the unique ability of nanotubes to act not only as containers, but also as efficient templates for the synthesis of structures was already known, the growth of GNRs had never been observed in nanotubes. The assembly of carbon atoms inside a SWNT had been shown to create a system containing a guest polymer or SWNT inside the host SWNT (Polymer@SWNT or SWNT@SWNT). This preferences were related to the energy over-cost related with the unsaturated valences of the carbon atoms at the edge of the nanoribbon. However, theoretical studies had shown that, in the presence of heteroatoms that could saturate those valences, the resultant edge-terminated GNR became more stable than the other structures.

In the experiment reported in the article, a complex molecule containing a selection of heteroelements (H, O, N, and S) is linked to C80 fullerenes that are introduced inside a SWNT. The fragmentation of both the fullerenes and the linked molecules can be triggered using the electron beam of a TEM or simply by heating the sample. The subsequent self-assembly of the atoms inside the nanotube produces a GNR with sulphur atoms saturating the edge valences (S-GNR).

The observed S-GNRs are 7 – 28 nm in length, but there is not fundamental reason why they cannot be formed throughout the entire length of the host-nanotube, resulting in nanoribbons up to several micrometres long. Furthermore, the S-GNRs show a helical twist that could give rise to interesting piezoelectric effects at the nanoscale, as compression of the nanotube would result in changes in the electric properties of the S-GNR and viceversa. This, together with the fact that the S-GNRs are expected to show semiconducting properties, may pave the way for future applications of these materials in electronic and mechanical nanodevices.

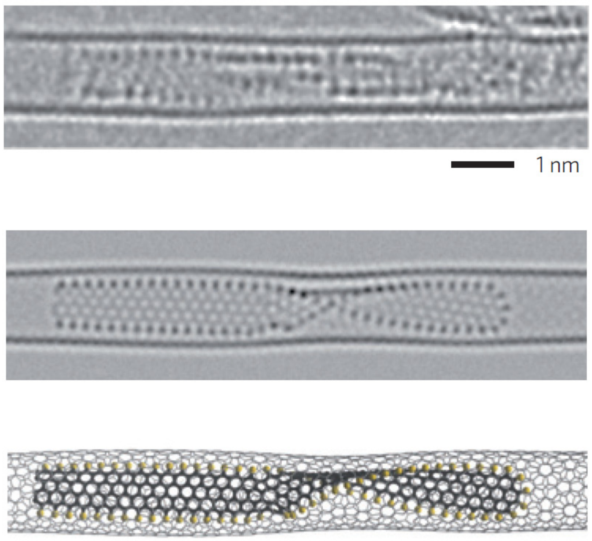

Fig. 2 Top: An experimental AC-HRTEM image, Middle: A model of S-GNR@SWNT, Bottom: An image simulated from the model

“With the results of our work, we explore new avenues in the production of nanostructures. Ultimately, GNR with well-defined properties are required for nanotechnological applications”, said Ute Kaiser (University of Ulm). With the words „carbon materials for specific applications“ the scientists describe the formation of graphene nanoribbons in well-defined shapes and sizes.

The nanotubes that are formed from carbon serve the scientists as a material component and „test tube". In their experiments with electron beams, the researchers have discovered two key principles: (1) if the GNR grow inside the carbon nanotube, the tubes determine the size and thickness of the tiny ribbons and (2) protect them from damage by the electron beam. In addition, by binding sulfur to the graphene edges, the formation of a second carbon nanotube is prevented and the GNR can grow in a desired shape.

This work was made in cooperation with researchers from the Ulm University and chemists from the Nottingham University, as well as Dr. Andrey Chuvilin from the spanish research institute CIC nanoGUNE Consolider (formerly Ulm University).

More information: Self-assembly of a sulphur-terminated graphene nanoribbon within a single-walled carbon nanotube, Nature Materials (2011), doi:10.1038/NMAT3082.

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