Synthesis of continuous macroscopic fibres with controlled type of CNTs

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Abstract

Carbon nanotubes (CNTs) have exceptional mechanical, thermal and electrical properties along the tube axis and which can be exploited on a macroscopic scale by assembling these nanocarbons into a continuous fiber preferentially oriented parallel to each other and to the fibre axis. One of the methods to produce such materials is by direct spinning of CNTs from the gas phase as they grow by chemical vapour deposition (CVD) [1]. In this work, we show significant progress in the challenge of controlling this process to tailor the building blocks that make the fibre in terms of the number of layers and chiral angle of the nanotubes.

The spinning process is based on the growth of CNTs by floating catalysts CVD using an alcohol as carbon source, iron as catalyst and sulphur as a "promoter". The carbon source decomposes at the nanoparticle catalysts which then supersaturate and extrude carbon to form very long nanotubes that entangle in the gas-phase forming an aerogel which can be withdrawn continuously to form a fibre of typically 20μm diameter. Clearly, the potential to make kilometers of a macroscopic fibre made up of specific type of CNTs (metallic single-walled nanotubes, multiwalled nanotubes, etc) is interesting both from a scientific and technical view point. Although the key role of the catalyst particle during CNT growth [2] is well-known and some sulphur assisted floating catalyst growth models have been proposed [3-4], numerous aspects of the growth mechanism remain poorly understood.

This work presents results showing that through the addition of sulphur it is possible to control the type of CNTs that make up the fibre, covering the range SWNTs (Figure 1), collapsed DWNTs (Figure 2, including Moiré pattern) and MWNTs. The CNT fibres are studied by Raman spectroscopy, HRTEM, EDX and XPS, which enables us to establish a correlation between S content in the fibre and type of CNTs, and to propose a growth mechanism that explain this selectivity as well as other aspects of the direct spinning process.

References

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[2] KKK. Koziol, C. Ducati and A. H. Windle, Chem. Mater., **22** (2010) 4904
[3] W. Ren, F. Li and HM. Cheng, J. Phys. Chem. B, **110** (2006) 16941
[4] M. S. Motta, A. Moisala, I. A. Kinloch and A. H. Windle, J. Nanosci. Nanotechnol., **8** (2008) 1

Figures

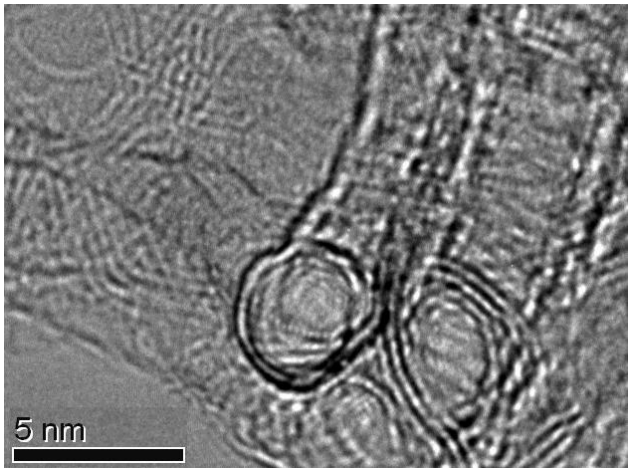

Figure 1: High-resolution TEM image of the cross section of CNTs

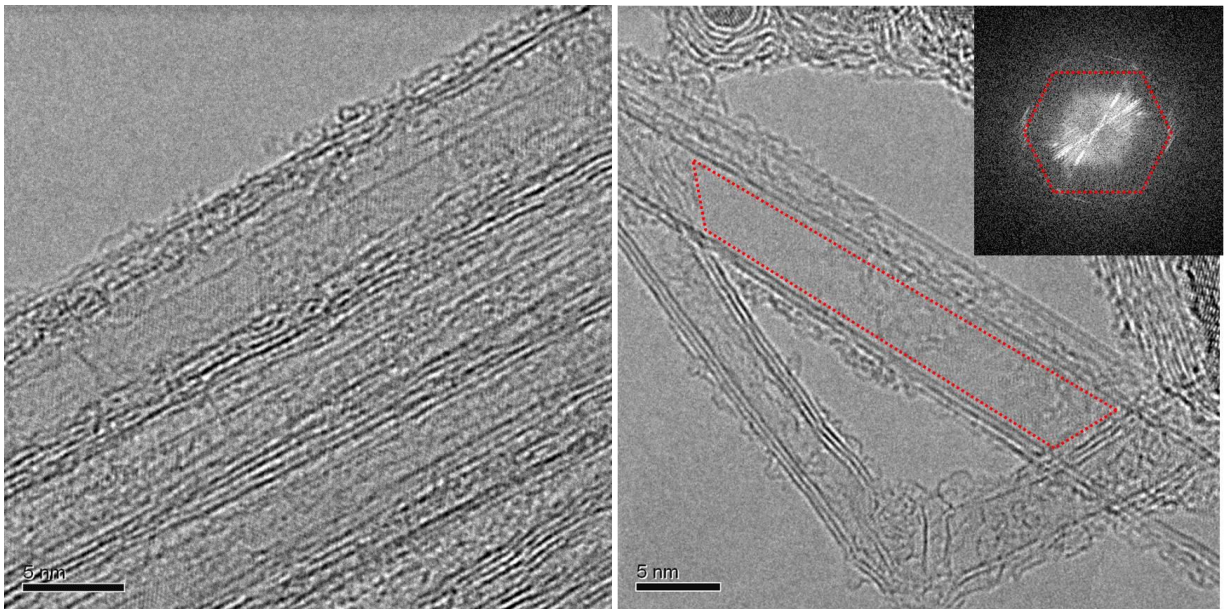

Figure 2: HRTEM images of bundles of collapsed few-layer CNTs and a Moiré pattern arising from the stack of collapsed graphitic layers.