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Approach for synthesizing individual, controlled diameter SWNTs for electronics

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Abstract

Single wall carbon nanotubes (SWNTs) are still regarded as excellent candidates for applications in nanoelectronic devices due to their unique structure and their remarkable electrical properties [1]. They have been investigated for various applications ranging from single electron transistors [2] and field-effect transistors to memories, chemical and mechanical sensors, and measurement probes [3]. However, the electronic performances of such devices still strongly depend upon the SWNT diameter and chirality as well as their crystalline quality [4]. The development of new methods enabling precise control over the structural properties (and consequently the electronic properties) of SWNT is of paramount importance for future progress in CNTs-based electronic applications. Here we report, a robust and versatile approach for reproducible and controllable growth of single walled carbon nanotubes (SWNTs) using self-assembled monolayer (SAM) technique coupled with atomic hydrogen (H_{at}) pretreatment to control the catalytic metallic nanoparticles morphology and density. This new approach represents a first step towards a general route to control the yield, the diameter distribution and possibly the chirality of nanotubes. The nanoparticles are obtained from a self-assembled pre-catalyst monolayer using a two-step strategy. Initial oxide-type growth substrate is functionalized by silanisation with a coordinating organic compound, forming a first SAM of ligand. Then, a SAM of metallic complexes such as ruthenium porphyrin (RuTTP) or salts ($FeCl_3$, $RuCl_3$) is grafted onto the first SAM. Precise morphology and chemical composition as well as density control of the metallic nanoparticles are achieved by a subsequent pyrolysis step under radical hydrogen atmosphere. Using the as-formed nanoparticles as catalysts, SWNTs are grown by hot filament chemical vapour deposition (HFCVD).They exhibit remarkably high crystalline quality, with well controlled yield and diameter strongly dependent on the initial catalyst species. Field effect transistors (FETs) with excellent performance characteristics were obtained using such in-place grown SWNTs as channel. The electronic properties of SWNTs can also be tuned using this approach. Indeed, the transistors obtained from RuTTP and $FeCl_3$ as catalysts precursors exhibit ON/OFF current ratio up to ~ 10^8, indicative of the direct growth of mostly semi-conducting SWNTs. By contrast, devices obtained from $RuCl_3$ salts display ON/OFF current ratio well bellow 10^2, indicating the direct growth of highly metallic specimens enriched SWNTs.

[1] See e.g.: “Physical Properties of Carbon Nanotubes”, R. Saito, G. Dresselhaus, M.S. Dresselhaus, Imperial College Press, 1998, ISBN 1-86094-093-5.

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[3] McEuen, P.L.; Fuhrer, M.S.; Park, H.; IEEE Trans. Nanotechnol. 2002,1, 78.

[4] Saito, R.; Fujita, M.; Dresselhaus, G.; Dresselhaus, M. S. Appl. Phys. Lett. 1992, *60*, 2204-2206.