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Thermal CVD Growth of Carbon Nanotubes Thick Layers

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Abstract. Since their discovery, carbon nanotubes received a great deal of attention because of unique physical and chemical properties. However, in order to become of interest in the field of super resistant fibers for nanocomposite materials or in the production of textile material, very long carbon nanotubes are needed. Massive samples of well packed, vertically aligned and very long self-standing multi wall carbon nanotubes (MWNT) were synthesized on uncoated silicon by a very efficient thermal CVD process, which involved the co-evaporation of camphor and ferrocene in a nitrogen atmosphere. We obtained structures with diameter between 20 and 80 nm with an average growth rate of about 400 nm/s, organized in thick carpets of entangled nanotubes. By the weight of the deposited carpet of MWNTs (density circa 0.8 g/cm^3) the conversion of about 30% of the total hydrocarbon feedstock was calculated.
Morphology and physical properties were characterized by electron microscopy techniques, Micro-Raman spectroscopy and thermogravimetric analysis. The analyses performed showed the absence of secondary carbonaceous products, whereas only 6% in weight of ferromagnetic iron clusters are present. BET analysis was used to calculate the porosity and the specific surface area density of the as grown samples, which resulted approximately 70 m^2/g. Hydrophobicity of the CNT carpet was also investigated.

Introduction

Carbon nanotubes and other nanostructures have received a great deal of attention in many research fields because of their unique physical and chemical properties. They were first reported in 1991 [1], but currently the gap towards application is closing in many fields such as chemical and biological catalysis or separation, energy storage, composites for coating or filling [2, 3], devices for molecular imaging or sensing [4], nanoelectronic devices, field emission devices [5] and so on.
Nowadays, the bottleneck in the carbon nanotechnology is represented by the growth process, in order to achieve worthwhile quantities of a material which should be of high purity and well defined orientation. So far, mainly three techniques have been implemented for the growth of CNTs, but only chemical vapor deposition (CVD) seems able to satisfy the requirements of a high purity material and a reasonable growth rate, compared to arc-discharge and laser ablation methods.
In this work, we report the characterization of the material grown by a new and relatively simple thermal-CVD method which does not require pretreated substrates, it does not involve elevated working pressures and in principle it is simple and inexpensive. This method allowed the massive production of vertically well-oriented multi-walled carbon nanotubes, on uncoated substrates. In particular we were able to grow CNTs at a high deposition rate (up to 400 nm/s) and yield (over 30% in weight).

Experimental

The growth of CNTs was obtained by a chemical vapor deposition (CVD) technique in which an inert gas flow carries a reactive gas evaporated from a solid mixture of catalyst and carbon source,