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THERMAL-CVD SYSTEM DESIGNED FOR GROWTH OF CARBON NANOTUBES

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ABSTRACT

We report a study on a thermal chemical vapor deposition (CVD) system optimized for the growth of well packed and vertically aligned carbon nanotubes (CNTs) on uncoated silicon substrates. The process of synthesis involves the co-evaporation of a carbon precursor and a metal catalyst in a nitrogen atmosphere inside a high temperature furnace. Beside the formation of CNTs, depending in particular on the deposition temperature, other carbon structures can be deposited, such as nanographite.

We show the growth results analyzed by different characterization techniques (electron microscopy, porosity and thermal stability investigations, micro-Raman spectroscopy). In addition, we report an investigation on the development of secondary transversal vortex flows caused by the effects of distribution of temperatures inside the growth system, in order to correlate them with the growth results.

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 present a new and relatively simple thermal-CVD method for massive growth of vertically well-oriented multi-walled carbon nanotubes, and other nanostructured materials (such as nanographite, of elevated interest for tribological and biological applications), on uncoated silicon substrates. In particular we are able to grow CNTs at a high deposition rate (up to 500 nm/s) and yield (over 30% in weight).

We show also the experimental observation of vortex flow development in mixed convection of precursor vapor carried by a low Reynolds number nitrogen gas flow through our deposition system, composed by a horizontal circular quartz tube (which is bottom heated) housed in a cylindrical furnace. This investigation intends to experimentally visualize the development of secondary vortex flows of the precursor vapor phase in order to explain the growth of vertically aligned carbon nanotubes.

Usually, reactors for thermal CVD process are operated with a combination of a large Grashof number (Gr) and a small Reynolds number (Re), so that the value of Gr/Re^2 ranges from 10 to 1000 [6]. Hence, the various complex secondary flow structures like longitudinal vortices, transverse waves and reversal flow may appear beside the main forced flow due to the nitrogen gas carrier. Even if the governing parameters affecting the process are not well understood, the study of the superposition of transverse and longitudinal vortices can help in clarifying the growth of well oriented carbon nanotubes layers, whose thicknesses result rather not uniform.

Furthermore, we report the analysis of the samples grown in this thermal-CVD system under different conditions. The morphology and nanostructure was studied by electron