The Effect of Hydrogen Dilution on the Morphology of Carbon Nanowalls Decorated Carbon Nanotubes Deposited by Hot-Wire r.f. Plasma Enhanced Chemical Vapour Deposition

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Abstract. An investigation on the effects of hydrogen (H2) gas dilution on the morphology and growth of carbon nanowalls (CNWs) decorated carbon nanotubes (CNTs) by hot-wire r.f. plasma enhanced chemical vapour deposition technique is presented. With the assistance of nickel nanoparticle catalyst, CNWs decorated CNTs formed only under the presence of 25% of H2 gas, relative to the methane (CH4) gas precursor. By varying the amount of H2 incorporated with CH4, the role of H2 dilution in the development of CNWs decorated CNTs was studied. Based on the FESEM and HRTEM results, it is hypothesized that H2 density and relative carbon radical concentration are the important parameters for the deposition of CNWs decorated CNTs. The effect of H2 dilution on the formation of CNWs decorated CNTs is presented.

Introduction

CNTs are built from 1-D folded graphene sheets [1-3] with high aspect ratio and can be considered as semiconducting or metallic, depend on their diameter and helicity [1,4]. Single or multi-layered of rolled graphene sheet defines the unique properties and potential applications of single and multi-walls CNTs, respectively. Meanwhile, 2-D carbon nanostructures such as carbon nanowalls, carbon nanofibers, carbon nanotubes and carbon nanohorns owning a similar wall-like morphological structure that consisted of several layers of graphene sheets which is analogous to graphene [5]. Some researchers refer these wall-like carbon materials as graphene nanowalls, based on the amount of graphene sheets and the exceptional graphene properties observed from the CNWs structure [6]. Free standing CNWs typically have a good contact and stand perpendicularly to the substrate surface without auxiliary lateral support [7]. Although lots of works have been devoted to investigate the CNTs and CNWs characteristics, there are still limited works reported on CNWs decorated CNTs by HW r.f. PECVD technique. For instance, Meng et al. had deposited graphene sheets on graphene fiber using wet chemistry method, whereas Malasevic et al. and Hsu et al. reported few layer graphene sheets on CNTs using MW PECVD [6,8-9].

In this work, CNWs decorated CNTs was prepared using home-built HW r.f. PECVD technique. This technique combines both the advantages of HW CVD and r.f. PECVD such as convenient, low cost apparatus, large area deposition, large density of H2 radicals [10-11] as well as large decomposition rate of source gases [11]. By applying both of the techniques in reactor, coexisting of plasma and thermal decomposition may contribute to the growth of CNWs supported CNTs [12].

Experimental Section

CNWs decorated CNTs, catalyzed by Ni nanoparticles were deposited by means of home-built HW r.f. PECVD system. The 20nm Ni catalysts were sputtered on SiO2 substrate from Ni foil (Sigma Aldrich, 99.9% purity, 0.25 mm thickness) in a home-built r.f. PECVD sputtering hybrid system for 3 min at r.f. power, electrode distance and substrate temperature of 80 W, 6.5 cm and 150 °C, respectively. The substrate was cleaned using piranha solution (30% H2SO4 and 30% H2O2) before being put into the reactor. The graphite crucible was also cleaned using piranha solution before being put into the reactor. The CH4 flow rate was fixed at 40 sccm. The gas flow was fixed at 40 sccm, the pressure of the reactor was 5 mTorr, the chamber temperature was 350 °C and the substrate temperature was 100 °C. The deposition time was 60 min. The characterization analysis conducted for the preparation of the CNWs decorated CNTs. The SEM images were used to analyze the morphology and size of the CNWs decorated CNTs. The EDX was used to analyze the composition of the CNWs decorated CNTs.