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The Role of the Nickel Catalyst and Its Chemical and Structural Evolution During Carbon Nanopearl Growth

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The role of the nickel catalyst size and its chemical and structural evolution during the early stages of carbon nanopearl nucleation and growth, by chemical vapor deposition from acetylene/argon mixture, were investigated and correlated with the resulting nanopearls' morphological and structural properties. Carbon nanopearls were grown using Ni nanoparticles that were 20 nm and 100 nm in size, at a growth temperature of 850°C, for the following growth times: 10 s, 30 s, 60 s, 90 s, 120 s, and 300 s. x-Ray diffraction, x-ray photoelectron spectroscopy, Raman spectroscopy, and transmission electron microscopy were performed on the carbon nanopearl samples. The x-ray diffraction and x-ray photoelectron spectra showed that the following chemical constituents were present during the growth of carbon nanopearls: NiO, Ni_2O_3, Ni_3C, Ni, CO, and C (both amorphous and graphite). Transmission electron microscopy showed an increase in carbon nanopearl size with larger Ni nanoparticles. Raman results concluded that the smaller catalyst resulted in a more crystalline graphitic structure. Finally, the results showed that the 20 nm Ni nanoparticles chemically reacted sooner than the 100 nm Ni nanoparticles.

Key words: Carbon nanopearls, nickel, catalyst, chemical vapor deposition

INTRODUCTION

Carbon nanopearls (CNPs), also known as carbon spheres and carbon nanospheres, have been of interest to the nanoscience community since Smalley and Iijima introduced buckyballs and carbon nanotubes.[1,2] These spheres of graphene flakes are reported to have diameters ranging from 60 nm to 2000 nm.[1–11] They exhibit field-emission properties that would be ideal for cathode materials, and potentially tribological coatings and lubricant additives.[7–9] Carbon spheres have also been reported to be potential transporters of proteins, nucleic acids, and drug molecules in the nuclear membrane and across the cell membrane.[11] Although work has been published on the characterization and properties of carbon nanopearls, there has been a lack of studies focused on understanding the mechanisms underlying the synthesis process.

Carbon nanopearls are defined as monodisperse nanospheres of nanocrystalline carbon that form a three-dimensional (3D) arrangement similar to a string of pearls.[7] These sp^2-hybridized carbon spheres are made up of concentrically oriented nanosized graphitic flakes that are two-dimensional (2D). The most common growth method used for carbon nanopearl growth is chemical vapor deposition (CVD). This growth method consists of using a metal catalyst (typically Ni) to break down a carbon precursor (acetylene) for synthesis of carbon nanopearls at 850°C.[7] According to Levesque et al.,[7] carbon nanopearls grow by the following process: the acetylene gas decomposes into atomic carbon, a wavy 2D structure of graphene flakes is formed, and

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