Iron Catalyzed Carbon Nanotube-Alumina Nanocomposites with Enhanced Magnetic Properties

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ABSTRACT

Carbon nanotubes (CNTs) have been successfully synthesized on alumina powder using chemical vapor deposition (CVD) with an iron catalyst. Electron microscopy observations reveal the structural morphology of CNT-alumina nanocomposites. Thermogravimetric analysis was performed to determine the proportion of CNTs on the composite. Vibrating sample magnetometry measurement revealed an improved hysteresis loop with higher saturation magnetization. Fe-catalyzed CNTs have the potential to exhibit higher than expected coercivity as suggested by magnetic measurements. Future studies may seek to exploit the positive characteristics of Fe-catalyzed CNTs in electronics and manufacturing.

INTRODUCTION

Carbon nanotubes (CNTs) continue to excite researchers with their potential in the development of nanostructures with their wide-ranging applications in materials science, medicine, and electronics. These one-dimensional nanostructures exhibit exceptionally high mechanical strength but are extremely light-weight. The incorporation of CNTs with metals, ceramics, and other insulators is expected to greatly enhance the mechanical, thermal, electrical, and magnetic properties of the composite. Many efforts have been devoted to adding CNTs homogeneously in the matrix of these functional materials for advanced functionalities. Currently, low yield, prohibitively high costs, and randomness of dispersion in media are challenges being sought to overcome so the benefits of CNTs can be realized in industry and manufacturing.

OBJECTIVES

- To synthesize CNT/Alumina nanocomposites using iron as catalyst
- To study the structural and morphological characteristic of nanocomposites
- To measure the magnetic properties of nanocomposites
- The understand the valence state of catalysts by Mössbauer spectroscopy

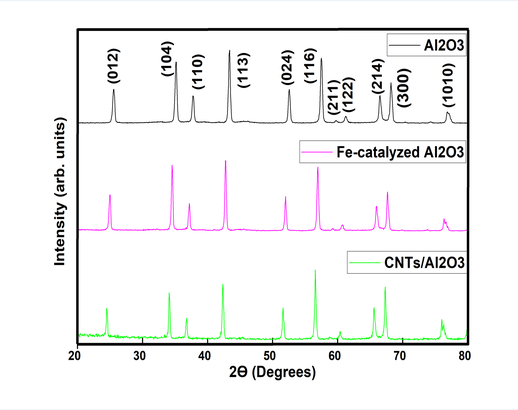
EXPERIMENTAL METHODS

Aluminum oxide nanoparticles are impregnated with iron catalysts by mixing the nanoparticles with iron acetate salt dissolved in isopropyl alcohol. CNTs were synthesized by chemical vapor deposition of Fe-catalyzed alumina. The alumina powder was first reduced by flowing hydrogen gas in an inert atmosphere created by following argon gas. Acetylene was used as the carbon precursor and the temperature of synthesis was 800 °C.

X-ray diffraction (XRD) studies were carried out using Rigaku MiniFlex equipped with Cu-K_a radiation source. Surface morphology of the CNT/Al_2O_3 nanocomposites was analyzed by scanning (SEM) and transmission electron (TEM) microscopes. The thermal degradation profile of the CNT/Al_2O_3 nanocomposites was investigated by thermogravimetric analysis (TGA). The magnetic properties of samples were investigated using a vibrating sample magnetometer. Field-cooled (FC) and zero-field-cooled (ZFC) measurements performed in a magnetic measurement property system (MPMS, Quantum Design) down to 5K and with a magnetic field up to 2T. Mössbauer spectroscopy were performed using a MS4 spectrometer, connected to a Janis cryostat, operating in the constant acceleration mode in transmission geometry.

RESULTS and DISCUSSIONS

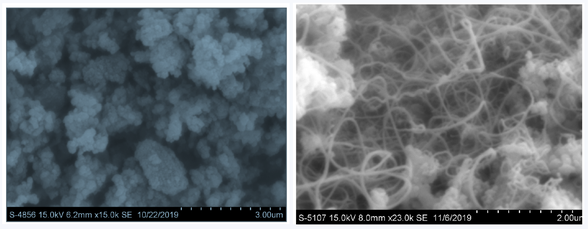
X-Ray Diffraction Studies



The sharp peaks in the XRD pattern shows the crystallinity of as-prepared nanocomposites.

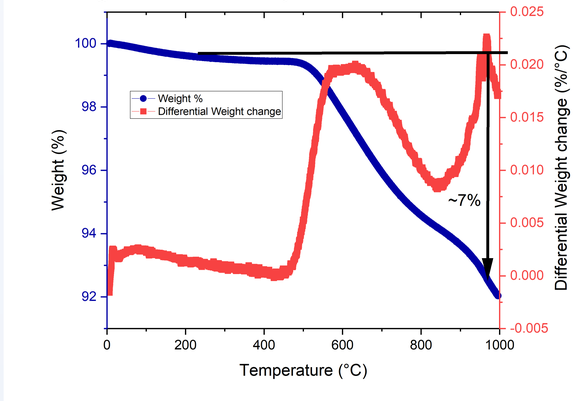
RESULTS

Electron Microscopy Studies



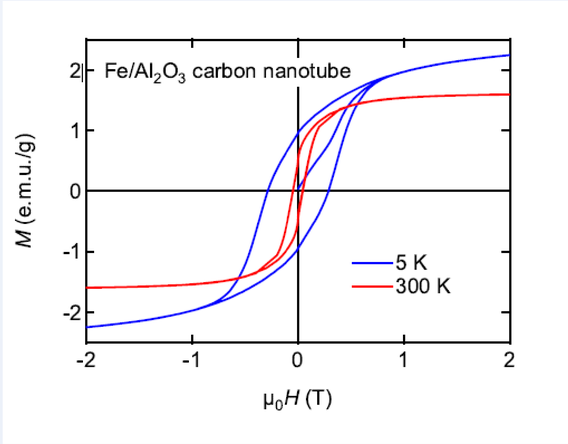
The average particle size of alumina nanopowder of (150± 20) nm (left) while the diameter of CNTs is (35 ± 15) nm (right).

Thermogravimetric Analysis



The yield of CNTs was around 7% after 30 min of growth.

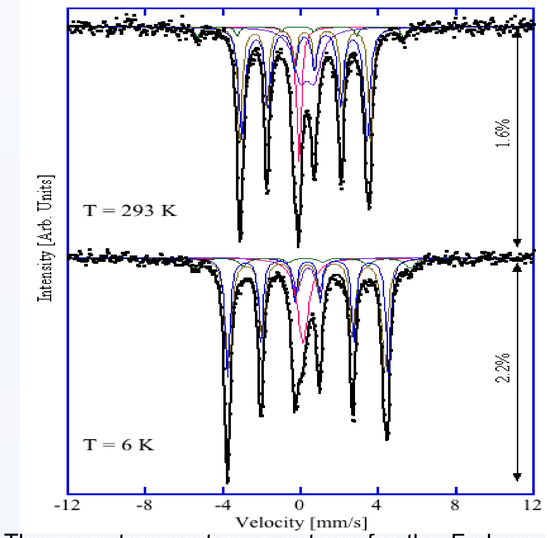
Magnetic Hysteresis



The Fe- catalyzed CNT/Alumina nanocomposites show a strongly pronounced hysteresis curve as compared to diamagnetic response from Al_2O_3.

RESULTS

Mössbauer Spectroscopy



The room-temperature spectrum for the Fe-based CNT is best fitted with a singlet, a doublet, and three sextets. The singlet has a d value of -0.105 mm/s. This negative d value may have its origin in face-centered cubic (FCC) Fe clusters in a superparamagnetic state. The doublet has a d value of 0.318 mm/s and a DE_Q value of 0.717 mm/s, which are characteristic values for small iron-oxide with high-spin Fe^{3+} in superparamagnetic state. The first magnetic sub-spectrum, Q_3, with -0.108 mm/s is probably from larger FCC Fe clusters in a magnetically blocked state. The other two sextets, Q_4 and Q_5, with d values of 205 mm/s respective 0.177 mm/s, and B_{hf} values of 20.8 T respective 20.0 T are signals from Fe_3C [4]. The 6 K spectrum for this sample is also fitted with the same number of the sub-spectra with slightly different intensities.

CONCLUSIONS

Fe-based CNT/alumina nanocomposites were prepared by direct chemical vapor deposition process and the different properties of these nanocomposites were studied.

ACKNOWLEDGMENTS

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