Structure, Morphology, and Magnetic Properties of Carbon Nanotube Alumina Nanocomposites

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Abstract

Magnetic carbon nanotube (CNT)-alumina (Al_2O_3) nanocomposites have been synthesized by the chemical vapor deposition (CVD) process. X-ray diffraction studies show that the crystalline structure of alumina nanoparticles after the CVD process. Electron microscopy studies were carried to study the distribution of CNTs within the alumina matrix. The proportion of CNTs in alumina composites was determined by using thermogravimetric analysis. CNT-reinforced alumina nanocomposites demonstrated significant improvement of the magnetic properties as compared to pristine alumina powder. We observed strong ferromagnetic response as-synthesized composites upon incorporation of CNTs. Hence, CNTs can be employed to engineer novel ceramic composites with interesting mechanical properties.

Introduction

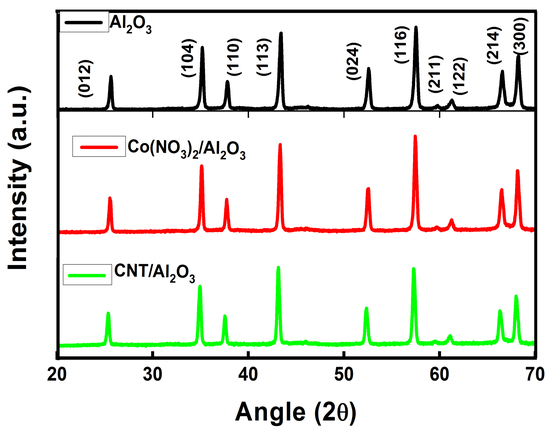
- Carbon nanotube (CNTs) can visualized as multiple graphene sheets rolled into cylindrical structure[1]. They exhibit outstanding mechanical, electrical, and thermal properties [2,3].
- Alumina (Al_2O_3) is a highly sought after ceramic due to its chemical stability, remarkable hardness, and refractory characteristics [4].
- The incorporation of thermally conductive CNTs with Al_2O_3 provides the thermal transport necessary to reduce material operating temperatures and improve thermal transport alongside enhanced magnetic properties.

Experimental Methods

- Carbon nanotube/ alumina nanocomposites were synthesized by chemical vapor deposition process in a tube furnace using cobalt as catalyst.
- As-synthesized nanocomposites were analyzed and their magnetic properties were measured at different temperatures.

Results and Discussions

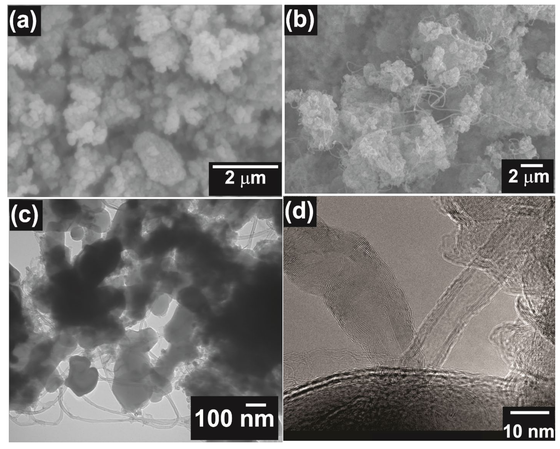
X-Ray Diffraction Studies



The sharp peaks on X-ray diffraction pattern confirms the crystallinity of as-prepared nanocomposites.

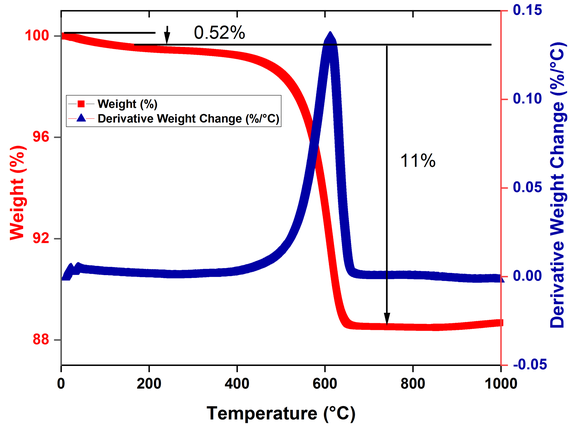
Results and Discussion

Electron Microscopy Images



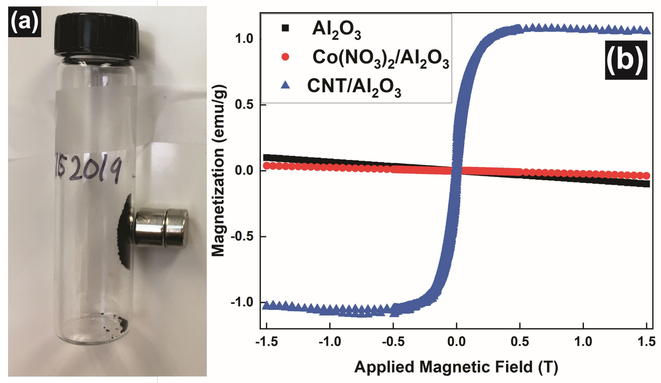
Electron microscopy images show that these CNTs are uniformly distributed around the alumina nanoparticle forming closely-connected network.

Thermogravimetric Analysis



Thermogravimetric analysis shows that the proportion of CNTs in the nanocomposites is around 11%.

Magnetization Measurement



	Al_2O_3	$Co(NO_3)_2/Al_2O_3$	CNT/Al_2O_3 nanocomposites
H_c (Oe)	0	0	68
M_s (emu/g)	0.10	0.04	1.06 (2500% increase)
M_r (emu/g)	~0.0	~0.0	0.10
Squareness ratio (M_r/M_s)	0.002	0.012	0.114

Vibrating sample magnetization measurements show that diamagnetic alumina nanopowder shows strongly enhanced ferromagnetic response upon the incorporation of CNTs with saturation magnetization of 1.06 emu/g. The $Co(NO_3)_2/Al_2O_3$ sample showed near zero coercivity, and the coercive field of nanocomposites increased significantly to 68 Oe when reinforced with CNTs. The saturation magnetization and remnant magnetization values also increased to 1.06 and 0.10 emu/g, respectively, for CNT/Al_2O_3 nanocomposites. This increase represents a 2500% improvement in the saturation magnetization of the CNT/Al_2O_3 nanocomposites.

Conclusions

We have successfully described the enhancement of the magnetic properties of alumina nanoparticles. The nanocomposite containing CNTs dispersed in the alumina matrix has been synthesized by chemical vapor deposition process. XRD analysis confirmed the crystallinity of as-synthesized nanocomposites, whereas, electron microscopy studies showed the presence of multiwalled CNTs facilitated by the catalyst particles. The composite contains ~10% CNTs, as confirmed by the thermogravimetric analysis. Magnetic measurements revealed the dramatic enhancement of magnetic properties of CNT/Al_2O_3 as compared to pristine Al_2O_3 powders. The saturation magnetization of alumina nanopowder increased by ~2500% upon incorporation of CNTs. We anticipate that our work can provide an alternative approach to prepare composites with enhanced magnetic properties. Moreover, the presence of conducting CNTs in alumina enables the fabrication of electrochemical sensors which can withstand harsh chemical conditions.

References

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