CARBON NANO COIL SYNTHESIZED ON ZERO-DIMENSIONAL SILICA

Huy-Zu Cheng, **Chang-Cheng Su, Tin-You Chen, Guo-Ju Chen and Kuo-Jung Lee**

Department of Materials Science and Engineering, I-Shou University, Kaohsiung, Taiwan R.O.C.

Introduction

Polymer-based composites are popular in electronic appliances'; however, most polymers are transparent to EM radiation and provide no shielding against electromagnetic interference (EMI). The EMI pickup by electronic components could cause serious problems such as malfunction of electronic instruments in electronic and communication industries.

The most often available technique for EMI shielding is to blend in the conductive fillers such as metal particles or flakes, graphitized carbon particles or fibers and metal coated glass. In comparison with these high aspect ratio fillers, the three-dimensional carbon coils with unique helical morphology are believed to be good chiral microwave absorbers. The microwave electromagnetic characteristics of carbon nanocoils was concluded to exhibit superior microwave absorption compared with the larger carbon microcoils by Zhao[1]

The carbon micro-(CMCs) or nano-coils (CNCs) are usually synthesized by the thermal decomposition of hydrocarbons either with single catalysts such as Ni, Co, and Fe [2] or mixed catalysts or alloys [3] such as Sn-Fe and Fe-Ni-ITO.[4]

Systematically understanding of the growth mechanism of either CMCs or CNCs is difficult, since the synthesis of either one is hardly reproducible and experimental parameters dependent. Motojima and co-workers [5] suggested that CMCs may grow from each crystalline face of metallic catalyst particles. However, Pan and co-workers [6] concluded that the CNCs grow mainly from the interface of Fe and ITO films.

In this study, a high population of CNCs gown by the pyrolysis of acetylene using Fe catalysts coated on the surface of silica spheres with diameter of 250 nm is obtained and the morphologies and microstructure are examined in detail and the growth mechanism is also proposed.

Experimental

The catalyst precursor was prepared by mixing the 0.1 M ferric nitrate aqueous solution ($Fe(NO_3)_3 \cdot 9H_2O$) with nan-sized silica particles of average diameter of 250 nm for 24 hours.

The prepared solution was then sprayed onto the 1.5 mm × 1.5 mm silicon substrate which was pre-cleaned with reagent grade acetone, isopropanol, and methanol. After drying at room temperature for a day, the spray coated substrate was then sent to a thermal chemical vapor deposition system to grow the carbon nanocoils.

The CVD system was first raised to 450 ^{o}C for 2 hours to remove the organic molecules release from the substrate, then was further raised to 550 ^{o}C for 2 hours under hydrogen environment to reduce the ferrite into iron. After then, the acetylene mixed with argon with flow rate ratio 50/50 was fed into the quartz tube furnace, as the carbon source to deposit carbon nanotubes/nanocoils.

The surface morphologies of the specimens were observed using the FE-SEM (Hitachi S-4700) and the equipped EDX (Horiba EMAX-7000) was used to confirm the composition. The XRD (PANalytical X'PERT Pro) was used to identify the structure of the nanoparticles on the silica.

Results and Discussion

The observation from the FE-SEM micrograph revealed that the silica nanoparticles tend to aggregate together on the silicon substrate, possibly due to the large total surface area of the nanoscale particles.

Investigation by the FE-SEM as shown in Fig. 1 found that catalytic nanoparticles were deposited on the surface of silica nanoparticles.

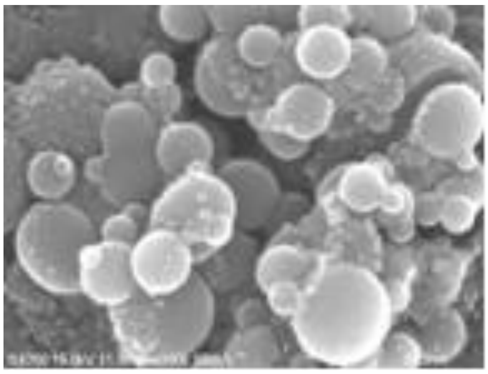

Fig. 1 FE-SEM micrograph of the silica nanoparticles coated with ferrites.

The averaged diameter the gown catalytic nanoparticles was calculated to be 15±5 nm based on the particle size distribution plot as shown in Fig. 2.

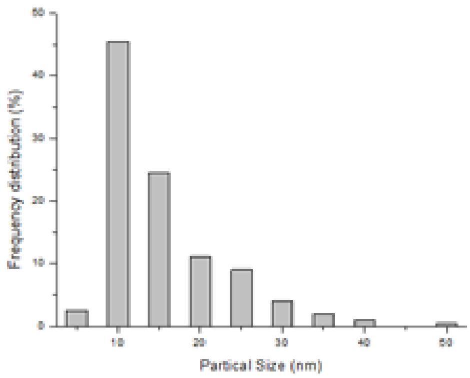

Fig. 2 The particle size distribution of ferrites formed on the silica surface.

Fig. 3(a) shows the SEM micrograph of carbon nanocoils grown at the reaction temperature 750^{o}C for 15-30 min with the C_2H_2/Ar flow rate of 100 sccm. A large population of nanocoils was found on the silicon substrate filled with silica nanoparticles coated with ferrites. The observation from the enlargement of Fig 3(a) as shown in Fig3(b) reveals that the average diameter is about 150 nm and the coil pitch is about the same.

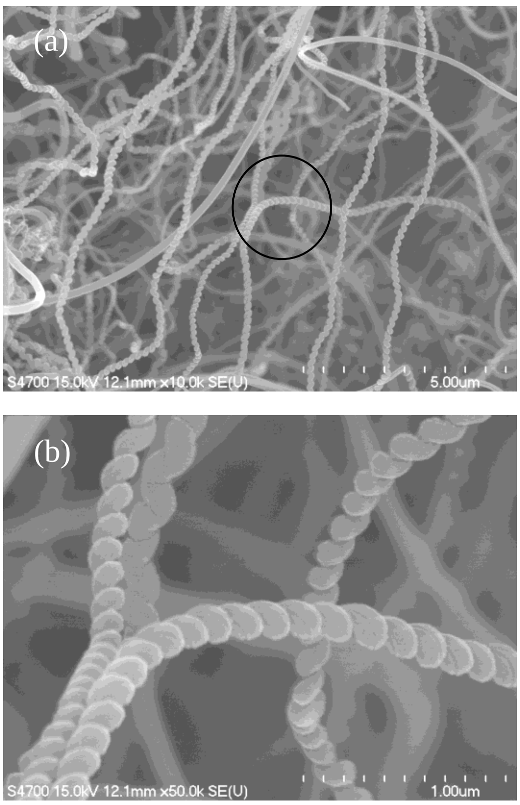

Fig. 3(a) The SEM micrograph of CNCs synthesized by catalytic thermal CVD. (b) The enlarged SEM micrograph as circled on (a).

The growth mechanism is carefully studied by observation the specimens at various growing time of CNTs from 3 min to 30 min. The authors found that at the very early stage, there has been some carbon nanotubes grown already on the reduced nanoparticles coated on the silica. Since the high curvature surface of silica, the carbon nanotubes grow perpendicular to the silica surface. One needs to notify that the average inter distance between catalytic nanoparticles is about 5-15 nm. Therefore as the CNT grows longer and encounter other CNTs grown on Fe nanoparticles in the neighborhood, CNTs may tangle together and lead the helical structure of the coils.

Conclusion

A high population of CNCs grown by thermal CVD using Fe catalysts coated on the surface of silica spheres is successfully synthesized. The average diameter of the grown CNCs is 150 nm and the coil pitch is about the same.

Acknologement

This work is partially supported by the National Science Council of the Republic of China under the contract number NSC99-2221-E-214-038 and by I-Shou University under the contract number ISU-99-02-19

Reference

1. Zho, D. and Shen, Z., Preparation and microwave absorption properties of carbon nanocoils, Chem. Mater.,62 (2008) 3704-3708
2. Yang, S., Chen, X., Motojima, S. and Ichihara, M., Morphology and microstructure of spring-like carbon micro-coils/nano-coils prepared by catalytic pyrolysis of acetylene using Fe-containing alloy catalysts, Carbon 43 (2005) 827-834
3. Yang, S., Ozeki, I., Chen, X., Katsuno, T., and Motojima, S., Preparation of single-helix carbon microcoils by catalytic CVD process, Thin Solid Films 516 (2008) 718-721
4. Zhang, M., Nakayama, Y., and Pan, L., Synthesis of carbon tubule nanocoils in high yield using Iron-coated Indium Tin Oxide as catalyst, Jpn. J. Appl. Phys. 39 (2000) L1242-1244
5. Kuzuya, C., Hwang, W.,Hirako, S. Hishikawa, Y. and Motojima, S., Preparation, morphology and growth mechanism of carbon nanocoils, Chem. Vap. Deposition 8(2) (2002) 57-62
6. Pan, L., Zhang, M., and Nakayama, Y., Growth mechanism of carbon nanocoils, J. Appl. Phys. 91(12) (2002) 10058-10061