# ELECTROMAGNETIC PROPERTIES OF CARBON NANOTUBES REINFORCED CARBON COMPOSITES

*Yun-Soo Lim[1*], Tae Wan Kim[1], Sung-Soo Kim[2]*

*[1)] Dept. of Nano Sci. & Engineering: Myongji University, Yongin, Gyeonggi-do 449-728 Korea*
*[2)] Dept. of Materials Sci. & Engineering: Chungbuk National University, Chungju, Chungbuk Korea*

## Abstract

Carbon fiber composites exhibit many unique properties including high strength, high fracture toughness and good electromagnetic properties. High frequency electromagnetic properties of various fibers (glass, carbon) and fillers (carbon black and ferrite powder) were investigated as the major constituent materials of electromagnetic absorbing materials. In this study, carbon fibers reinforced phenol resin composites with carbon nanotubes as fillers were studied for the high frequency electromagnetic properties. Carbon nanotubes were prepared by xylene decomposition on a Fe catalyst in catalytic chemical vapor deposition method. The composites were carbonized at 1000℃. The electromagnetic properties were measured at green body and carbonized composites, respectively. The electromagnetic insulating properties were measured by micro strip line method in this study. Electromagnetic interference shielding properties of composites were investigated in the frequency region of 0.3-6 GHz. The experimental results indicated that the EMI shielding effectiveness of carbon composite is sensitive to the existence of CNT.

Keywords: Carbon fibers, Carbon nanotubes, Carbonization, Electromagnetic interference.

## Introduction

Electromagnetic interference (EMI) shielding and absorbing materials, which can effectively prevent the leakage of harmful electromagnetic wave, have attracted attention with the increasing application of electronic devices that emit electromagnetic energy resulting in electromagnetic wave pollution. Typically metals like copper or aluminum and their composites are considered to be the best conventional electromagnetic shielding materials with high electromagnetic shielding effectiveness because of high dielectric constant and electric conductivity. However, heavy weight and easy corrosion restrict their wide use for shielding materials. Compared to metal-based EMI shielding materials, electrically conducting polymer composites were used in recently because of their light weight, resistance to corrosion, flexibility and processing advantages. The EMI shielding efficiency of a composite material depends on many factors, including the filler's intrinsic conductivity, dielectric constant, and aspect ratio. The high electrical conductivity, high aspect ratio, and high mechanical strength of carbon nanotubes (CNTs) make them an excellent option to fabricate conductive composites for high-performance EMI shielding materials at low filling concentration. Multi-walled carbon nanotubes (MWCNS) have been studied with various polymer matrix, including polystyrene (PS), epoxy, poly(methyl methaacrylate) (PMMA), polyaniline (PANI), polypyrrole (PPY), etc., for the possible applications as effective and light weight EMI shielding materials and the EMI shielding has been attributed mainly due to the reflection contribution.

## Experimental

*Fabrication of carbon nanotubes on the carbon fibers surface and characterization*

CNTs were synthesized on 8-harness satin carbon fibers fabric by catalytic chemical vapor deposition (CCVD) method. The commercialized 8-harness satin PAN-based carbon fibers fabrics were placed in the middle of the furnace. One end of the quartz tube in the furnace is used to introduce $H_2/N_2$ gases and catalyst and the other end is connected to a water vessel. The ferrocene ($C_{10}H_{10}Fe$, $M_W$=186, Aldrich Co. U.S.A.) that was used as catalyst dissolved with toluene. The dissolved ferrocene/toluene mixture solution is pumped into the furnace by syringe pump. The feeding rate of 5 ml/h was used in the formation of CNTs. The end of syringe injector was located around 250°C in the furnace for the pyrolysis of mixture of ferrocene/toluene. The furnace temperature is increased with a ramp rate of 10 °C /min. The CNTs growth temperature was 800°C and kept for 0.5 to 2 h. Morphology of grown CNTs is analyzed using scanning electron microscopy (SEM, Hitachi S-3500N).

*Manufacturing of composites and measurements*

The as-prepared CNT growth carbon fiber fabrics are impregnated with phenolic resin and dried at room temperature for 24 h to make B-stage prepreg. The prepregs were stacked at the metal die and then hot pressed at 230˚C under 1000 psi in air for 30 min to obtain composites(CNT-CF-phenolic composites: CCP). In order to compare the EMI shielding properties, carbon fiber fabrics composites (CF-phenolic composites: CP) were prepared by the same method. The composites were made with the size of 30 mm x 30 mm x 1.8 mm.

The ac electrical conductivity of the CCP and CP composites was determined using the standard four-point contact method on rectangular composites in order to eliminate contact-resistance effects at room temperature. The EMI shielding effectiveness and relative permittivity data of CCP and CP composites were measured by micro strip method using a HP network analyzer (HP 8020) in 0.3-6 GHz.

## Results and Discussion

*Growth of carbon nanotubes on the surface of carbon fibers*

CNTs are synthesized on the surface of the PAN-based carbon fiber fabrics by catalytic CVD. The multi-wall CNTs can be grown on the surface of carbon fibers at the 800°C. The optimum CNTs growth condition was in ferrocene/toluene mixture of 6.5 mol % in the surface of carbon fiber fabrics. Fig. 1 showed the fabricated CNTs in this study.

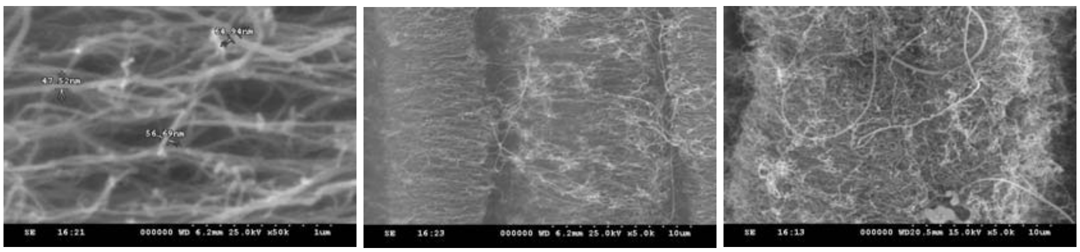

Figure 1. Fabricated CNTs

*Properties and characteristics of fabricated composites*

Electric resistance lowered with the increasing the number of carbonization. Carbonized composites showed the lower electric resistivity because the density of composites and carbon contents were increased with carbonization.

Figs 2 and 3 show the results of the S parameters (reflection coefficient $S_{11}$ and transmission coefficient $S_{21}$) and power absorption (defined by $P_{(loss)}/P_{(in)} = 1 - (S_{11}^2 + S_{21}^2)$) measured in the microstrip line with 50 ohm characteristic impedance. CP composites show a higher $S_{11}$ value rather than CCP composites in the high frequency region above 4 GHz. And also slightly lower value of $S_{21}$ is determined in CP composites. Due to the higher electrical conductivity of CP composites, higher value of $S_{11}$ (power reflection) and lower value of $S_{21}$ (power dissipation) is measured. Higher value of power absorption (as high as 0.5) is, therefore, predicted in CP composites especially in the frequency region above 4 GHz.

## Conclusion

Carbonization at 1000℃ of fabricated composites, the specific gravity of carbonized composites was increased. This is due to the increasing of carbon contents of the composites. Comparing the electric resistivity of both green composites and carbonized composites, the resistivity of carbonized composites was reduced. Composites with carbon nanotubes were shown the lower electrical resistivity rather than carbon/phenolic composites. Results of electromagnetic interference measurement, composites with carbon nanotubes were shown the higher reflection at 2~4 GHz and above 5 GHz rather than carbon/phenolic composites. This is due to reduce the electrical resistivity with carbon nanotubes.

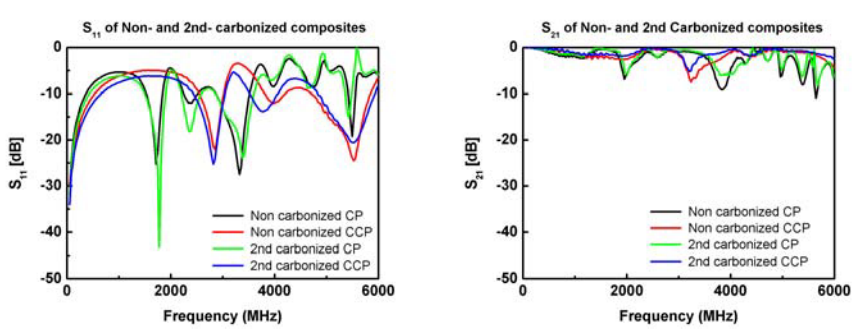


Figure 2. $S_{11}$ and $S_{21}$ of Non-carbonized composites and 2nd carbonized composites

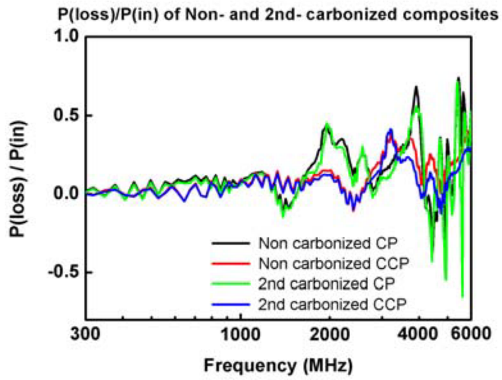


Figure 3. P (loss) / P (in) of Non-carbonized composites and $2^{nd}$ carbonized composites

## Acknowledgement

This work was supported by the Korea Science and Engineering Foundation (KOSEF) Grant funded by the Korea government (MOST) (No. R01-2006-000-10482-0(2006))

## References

Lee CY, Song HG, Jang KS, Oh EJ, Epstein AJ, Joo J. 1999. Electromagnetic interference shielding efficiency of polyaniline mixtures and multilayer films. Synth. Met. 102: 1346-9.

Han EG, Kim EA, Oh KW. 2001. Electromagnetic interference shielding effectiveness of electroless Cu-plated PET fabrics. Synth. Met. 123: 469-76.

Yang YL, Gupta MC, Dudley KL, Lawrence RW. 2005. Conductive carbon nanofibers-polymer foam structures. Adv. Mater. 17(16):1999-2003.

Joo J, Lee CY. 2000. High frequency electromagnetic interference shielding response of mixtures and multilayer films based on conducting polymers. J. Appl. Phys. 88(1):513-8.

Yang YL, Gupta MC. 2005. Novel carbon nanotubes-polystyrene foam composites for electromagnetic interference shielding. Nano Lett. 5(11):2134-4.

Liu Z, Bai G, Huang Y, Ma Y, Du F, Li F, Guo T, 2007. Chen Y. Reflection and absorption contributions to the electromagnetic interference shielding of single-walled carbon nanotubes/polyurethane composites. Carbon. 45:821-7.