Mechanism to shield the electromagnetic wave interference in the carbon coils composites

Gi-Hwan Kang[a], Sung-Hoon Kim[a*], Saehyun Kim[b]
[a]Department of Engineering in Energy & Applied Chemistry, Silla University, Busan 617-736, Republic of Korea
(E-mail: shkim@silla.ac.kr)
[b]Onnuri International Christian Academy, Yangsan, Kyungnam, 626-813, Republic of Korea

Abstract: The electromagnetic wave shielding properties of the carbon coils with polyurethane composites were investigated in the frequency range of 0.25 ~ 1.5 GHz. The shielding effectiveness of the composite having the various-shaped carbon coils were measured and discussed according to the weight percent of the carbon coils in the composites with the thickness of the composites layers. We confirmed that the absorption was the main mechanism to shield the electromagnetic wave interference in the carbon coils composites.

1. Introduction

Carbon coils are understood to play a good electromagnetic wave absorbers because the coil geometry had an effective form for inducing current through an inductive electromotive force [1, 2]. Furthermore, the demand of lightweight and moldable materials for the portable electronic devices, the desiring of polymer-matrix composites for the electomagnetic wave interference (EMI) shielding materials are more and more increased [3]. In this respect, carbon coils have been regarded as promising candidates for EMI shielding materials [2].

Meanwhile, reflection, absorption, and multiple reflections are thought as the major three mechanisms to shield EMI [4]. In the conducting materials like metals, the shielding is usually enhanced by the electrical conductivity of the materials [4]. So, reflection is understood to work as the main shielding mechanism to protect EMI [4]. For the materials having the high electric constants or the magnetic permeability, absorption was known as the major shielding mechanism [4]. For the multiple reflections, the small-sized fillers having the high surface area in the composite usually gave rise to the better shielding performance. These three mechanisms can complementary and/or supplementary operate to shield the EMI.

In this work, we investigated the main shielding mechanism of the various type carbon coils in polyurethane (PU) composites. The electromagnetic wave shielding properties of the carbon coils composites were measured according to the weight percent of the various-shaped carbon coils in PU and the thickness of the carbon coils with PU composites layers. Based on these results, we discussed and suggested the main shielding mechanism of the carbon coils with PU composites.

2. Results and Discussion

We made two different sample categories. Category I has three kinds of the samples (samples A, B, and C) having the mixture of double helix type and single helix type carbon coils. Category II has three kinds of the samples (samples D, E, and F) having the dominant formation of the double helix type carbon coils. After manufacturing six kinds of paste-type samples, each sample was coated onto the circular-shaped glass plate. As expectation, the highest composition ratios of the carbon coils in the composites gave rise to the highest thickness of the coated layers among the samples of each sample category.

After measuring the thickness of the coated layer of the sample, we examined the variation tendency of shielding effectiveness (SE) according to the different composition ratios of carbon coils in the composites and the different thickness of the composites.

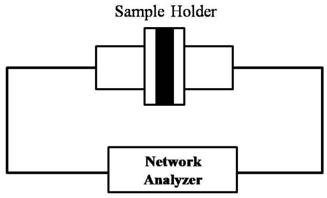

Fig. 1 Instrumental setup for measuring the shielding effectiveness.

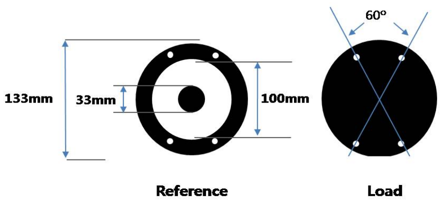

Fig. 2 (a) The coaxial transmission test specimen according to the method of ASTM D4935-99 and (b) the coaxial sample holder.

The SE of the composites was analyzed using a network analyzer (SynthNV2_3b, Windfreak Tech.) in accordance with the method of ASTM D4935-99. The set-up consisted of a sample holder with its outside connecting to the network analyzer as shown in Fig. 1. The coaxial sample holder (Electro Matrix EM-2107A) and the coaxial transmission test specimen were set according to the method of ASTM D4935-99 as shown in Fig. 2. The performance measurement range of the SE for the composites was from 250 MHz to 1.5 GHz.

Considering only the reflection and the absorption effects as the main shielding mechanisms for EMI of this work, the SE of EMI for the polymer composites can be estimated by the empirical equation of Simon [5]:

$$SE = 50 + 10\log_{10}(rf)^{-1}+1.7t(f/r)^{1/2},$$

where SE is in dB, r is the volume resistivity (Wcm) at room temperature, t is the thickness of the sample (cm), f is the measurement frequency, respectively.

In this equation, the combined first and second terms, namely $50 + 10\log_{10}(rf)^{-1}$, shows the SE only by reflection mechanism. The third term, namely $1.7t(f/r)^{1/2}$indicates the SE only by absorption mechanism.

We first compared the SE for samples A ~ C in category I under the similar composite layer thickness. Then we compared the SE for samples D ~ F in category II under the similar composite layer thickness. The samples C, F have the highest SE among each sample category. As indicated by Simon's equation, the SE from reflection decreases with increasing the measurement frequency, while the SE from absorption increases with increasing the measurement frequency. For the measuring frequency dependence of the SE for the samples, sample C show the increase of SE with increasing the measurement frequency in the range of 0.5 ~ 1.5GHz (see sample C in Fig. 3). For the measuring frequency dependence of the SE for the samples in category II, we could not well confirm the variation tendency of the SE with the frequency (see Fig. 4). In this case, however, we are convinced that the SE didn't follow the decrease tendency with increasing the measuring frequency in the range of 1.0GHz to 1.5GHz. Accordingly, these results inform that the absorption may paly a critical role as the SE mechanism for the EMI of these composites.

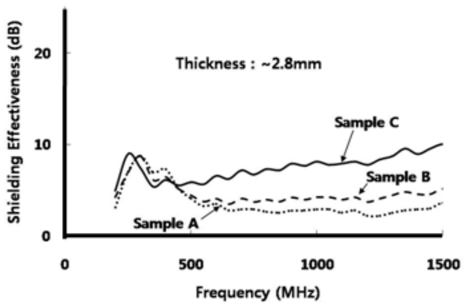

Fig. 3 Variation of the shielding effectiveness according to the different composition ratios of the carbon coils in category I

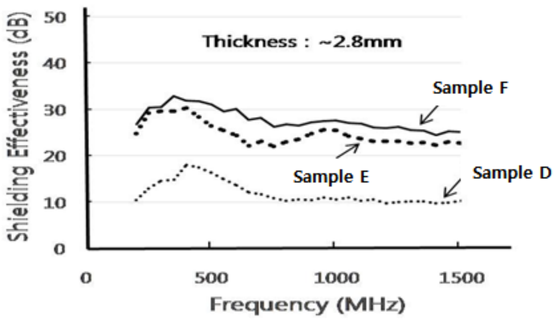

Fig. 4 Variation of the shielding effectiveness according to the different composition ratios of the carbon coils in category II

For the composite layer thickness dependence, the third term of Simon's equation, $1.7t(f/r)^{1/2}$), indicates that the SE by absorption mechanism increases with increasing the thickness (t). It is clearly observed that the SE of the samples in category I and II increases with increasing the coated layer thickness. For the samples in category I and II, therefore, we confirm that the absorption would play the critical role as the main shielding mechanism to protect EMI.

3. Conclusions

The samples which have the highest concentration of the carbon coils in category I shows the increase of SE with increasing the measurement frequency. In addition, the samples which have the highest concentration of the carbon coils in category II didn't follow the decrease tendency with increasing the measurement frequency in the range of 1.0 GHz to 1.5 GHz. Furthermore, the SE of the samples in category I and II increases with increasing the composite layer thickness. Therefore, we confirm that the main mechanism in the samples in category I and II to shield the EMI would be the absorption.

References

1. K. Akagi, R. Tamura, M. Tsukada, Phys. Rev. Lett. 74 (1995) 2307.
2. S. Motojima, S. Hoshiya, Y. Hishikawa, Carbon, 41 (2003) 2658.
3. X. Fu, D. D. L. Chung, Cement Concrete Res. .26 (1996) 1467.
4. D.D.L. Chung, Carbon 39 (2001) 279.
5. R.M. Simon, Polym. Plast. Technol. Eng., 17 (1981) 1.