INFLUENCE OF ASPECT RATIO AND SKIN EFFECT ON EMI SHIELDING OF COATING MATERIALS FABRICATED WITH CARBON NANOFIBER/PVDF

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Introduction

Carbon nanofibers are noble materials which can be produced by the decomposition of carbon containing gas over certain metal particles [1]. Carbon nanofibers with high aspect ratio have advantages in both electrical conductivity and specific surface area, so their SE is superior to general carbon fiber and carbon black.

The principle factor influencing the performance of conductive component-filled plastic composites is the aspect ratio of the conductive fillers [2]. The frequency permeability of composite materials has been studied theoretically and experimentally on a variety of materials [3]. In particular, it was deduced that, for composites made of a dispersion of carbon nanofibers particles in a matrix, the skin effect could drastically affect the measured permeability. When the coating layer thickness is not deep compared to the skin depth at a given frequency, the measured permeability is affected by the skin effect [14-16]. The objective of this study is to investigate the influence of aspect ratio and skin effect on the EMI shielding effectiveness with carbon nanofiber filled PVDF composites.

Experimental

Carbon nonofibers with the diameters ranging 50 200 nm were prepared from the decomposition of propane, ethylene and acetylene gas over nickel-copper and pure nickel catalysts. The crushed fillers (40 wt% of PVDF) were introduced into the PVDF solution, and the mixture was stirred at 600 rpm for 30 min by a mechanical stirrer and at 20,000~40,000 rpm for 3 min by a homogenizer continuously. The electrical conductivity of coating materials was measured using a digital multi-meter (Keithley 236). The SE of the coating materials was measured using a HP-8720C apparatus according to the method described in ASTM D 4935. BET surface area measurements were carried out using nitrogen adsorption at -196 .

Results and discussion

In order to compare the effectiveness of EMI shielding with different structure of carbon fillers, various carbon nanofibers were prepared from the decomposition of propane, ethylene and acetylene gas over nickel:copper 7:3 bimetallic (NC73) and pure nickel (N) catalysts. The carbon nanofibers obtained and a commercial carbon black were used as the fillers to fabricate PVDF composite coatings. Fig. 1 represents the variation of the electrical conductivity for a carbon nanofibers filled PVDF coating materials as a function of thickness. When the thickness of carbon nanofibers filled PVDF coating materials varied from 25 to 50 μm, the electrical conductivity of coating materials increased sharply from 1.34 to 1.91 S/cm. However, the electrical conductivity approached a certain value with further raise of the thickness. This phenomenon denotes that a critical thickness of coating materials exists around 50 μm.

The electrical conductivity of carbon nanofibers crushed with ball mill and their PVDF coating materials are presented in Table 1. With the heat treatment of carbon nanofibers at 1100 for 1hr, the electrical conductivity of carbon nanofibers increased by 2.6 times and that of their composite coatings increased by 5.3 times. Although the electrical conductivity of carbon nanofibers was not much changed with ball milling, the electrical conductivity of their composite coatings decreased dramatically. The electrical conductivity of composite coatings decreased to one eighth after 24 hr's ball milling and this phenomenon could be explained by the decreased aspect ratio after ball milling.

Fig. 2 represents the SE of carbon nanofibers filled PVDF coating materials with the different milling conditions. The SE of composite coatings decreased at a similar fashion with the electrical conductivity of them when the carbon nanofibers were crushed by ball mill. From the results, it was concluded that concerning the SE of carbon nanofiber filled composite, the discontinuities developed within the carbon nanofiber network was caused by the decrease of the filler's aspect ratio after ball milling.

Conclusions

Carbon nanofibers were dispersed as conductive fillers in a PVDF matrix and the influence of aspect ratio and skin effect on the SE of resulting composites was investigated. When the thickness of carbon nanofibers filled PVDF coating materials increased from 25 to 50 μm, the electrical conductivity of coating materials increased from 1.34 to 1.91 S/cm, but the electrical conductivity approached a certain value with further raise of the thickness. The electrical conductivity and shielding effectiveness (SE) of coating materials decreased dramatically as the carbon nanofiber fillers were milled. It could be concluded that the decrease of the shielding effectiveness of carbon nanofiber filled composite was due to the decrease of the filler's aspect ratio by ball milling.

References

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Acknowledgments

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Table 1. Electrical conductivities of carbon nanofibers and their PVDF composite coatings with different ball mill treatment of carbon nanofibers

Ball mill treatment of Carbon nanofibers	Electrical conductivity of filler at 10000 psi (S/cm)		Electrical conductivity of composite coatings (S/cm)	
	As grown (A)	With heat treatment 1hr(B)	Filled with (A)	Filled with (B)
None	5.5	14.4	0.6	3.2
Ball mill 1hr		12.6		1.7
Ball mill 24hr		13.4		0.4

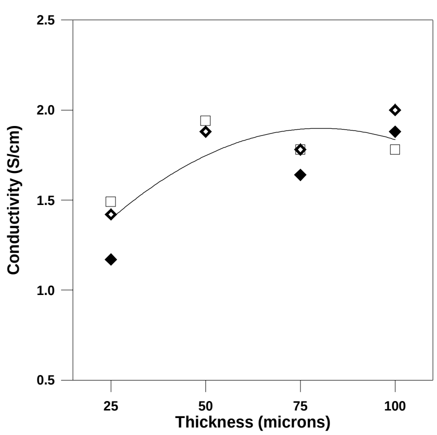

Fig. 1. Electrical conductivity of carbon nanofibers filled PVDF coating materials with different thickness.

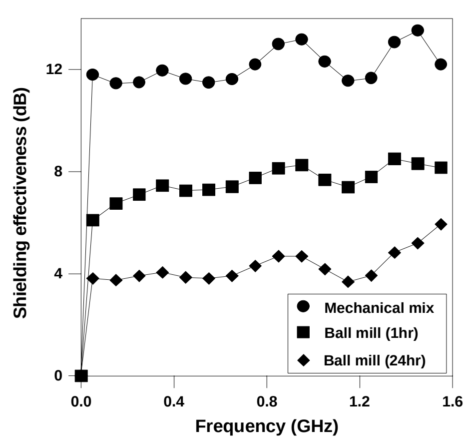

Fig. 2. Shielding effectiveness of carbon nanofibers filled PVDF coating materials with different ball mill treatment of carbon nanofibers.