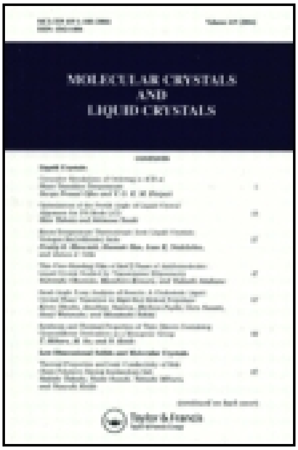

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Enhancement of Electromagnetic Interference Shielding Efficiency of Polyaniline through Mixture and Chemical Doping

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Enhancement of Electromagnetic Interference Shielding Efficiency of Polyaniline through Mixture and Chemical Doping

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Electromagnetic interference (EMI) shielding efficiency (SE) of undoped and doped polyanilines and their mixtures with silver (Ag), graphite, and carbon black powder are measured in the frequency range from 10 MHz to 1 GHz by using ASTM (D 4935-89) technique. The measured SEs of the systems are from 20 dB to 50 dB, which agrees with theoretical values obtained from a good-conductor approximation. The SE of the system increases with increasing dc conductivity. This implies that the SE can be controlled by the intrinsic properties such as conductivity and dielectric constant. For the mixture of emeraldine base (EB) form of polyaniline and Ag powder doped with hydrochloric acid (ES/Ag), the SE is ~46 dB with 70 μm thickness, indicating the capability of commercial applications to EMI shielding. Chemical doping in polyaniline mixture samples induces the increase of the SE. The model accounting for the increase of the SE in the mixture system is discussed.

Keywords: polyaniline; electromagnetic interference shielding; conductivity

INTRODUCTION

Polyaniline (PAN) is the best promising material for commercial applications in conducting polymers, because of environmental stability, easy processing, and economical efficiency[1]. PAN has been used for electrode of light emitting diode and Li ion secondary battery, corrosion protection, RF and microwave absorber, and anti-static material[1]. Conductivity (σ) and dielectric constant (ε) of PAN system are controllable through dopant, solvent, molecular weight, doping level, or stretching[2]. The sphere of applications using PAN broadens with the increase of conductivity.

There is an increased interest in electromagnetic interference (EMI) shielding as the rapid increase of the use of commercial, military, and scientific electrical and electronic devices[3]. The EMI shielding has been intensively studied for reducing noise and for increasing the efficiency and the life-time of electrical products[4]. The requirement of EMI shielding efficiency (SE) for commercial and military applications is ≥ 40 dB and ≥ 80 dB, respectively[3]. Typical metals such as Cu or Al have disadvantages for the practical use of EMI shielding because of heavy weight, rigidity, corrosion, and lack of flexibility. PAN systems and their composites with metal powders are promising materials to supplement the disadvantages of typical metals for EMI shielding.

EXPERIMENTAL RESULTS AND DISCUSSIONS

The chemical processing of polyanilines has been reported earlier[2,5]. A four-probe method was used for measuring dc conductitity. The SE of the sample was measured in the frequency range from 10 MHz to 1 GHz by using ASTM (D 4935-89) technique.

The EMI SE can be described as[3] SE = 10 log(P_{in}/P_{out}), where P_{in} and P_{out} are incident and transmitted power, respectively. The absorption, reflection, and multiple reflection inside shielding barrier contribute to the SE. With a good conductor approximation ($\sigma >> \varepsilon$) and a negligible magnetic interaction, the SE can be approximated as[6]

$$SE \approx 10 \log \left[1/4\{(\sigma/2\omega\varepsilon_0)[\cosh(2d/\delta) - \cos(2d/\delta)] + 2(\sigma/2\omega\varepsilon_0)^{1/2}[\sinh(2d/\delta) + \sin(2d/\delta)] + 2[\cosh(2d/\delta) + \cos(2d/\delta)]\} \right] . \quad (1)$$

Here, ω is the angular frequency, d is the thickness of shielding material, and δ is the skin depth. The intrinsic parameters for determining the SE are conductivity and dielectric constant. Based upon Eq. (1), the SE increases as σ increases.

Figure 1 presents the experimental SEs of PAN and its mixtures with metal powders as a function of dc conductivity (σ_{dc}). As σ_{dc} increases, the EMI SE increases, which implies that the SE is controllable by intrinsic conductivity. Based on the results, it is expected that the SEs of ES/Ag (the mixture of emeraldine base (EB) form of PAN and Ag powder doped with HCl) and PAN doped with camphor sulfonic acid in *m*-cresol solvent (PAN-CSA (*m*-cresol)) samples are ≥ 50 dB with 100 μm thickness, indicating the capability of commercial applications to EMI shielding.

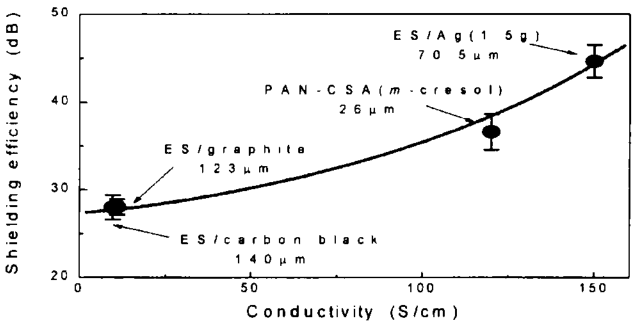

FIGURE 1 Shielding efficiency (SE) of PAN and its mixtures as a function of conductivity.

Figure 2 shows the frequency dependence of the experimental and theoretical SEs. The theoretical SEs based on Eq. (1) agree with the experimental values in the measured frequency range. The results show that the SE is independent of frequency from 10 MHz to 1 GHz, and the systems are applicable for the EMI shielding or absorber in RF and microwave frequency ranges.

The frequency dependent SEs of ES/Ag samples are compared to those of EB/Ag sample in Figure 3. The SE of ES/Ag sample is ~46 dB in the measured frequency range, while the theoretical SE of undoped EB/Ag sample is 3.5 dB, which indicates that the SE of the system increases more than 10 times through chemical doping. The inset of Figure 3 shows temperature dependence of σ_{dc} of ES/Ag sample. As temperature decreases, σ_{dc} increases, indicating that the system is intrinsic metallic state.

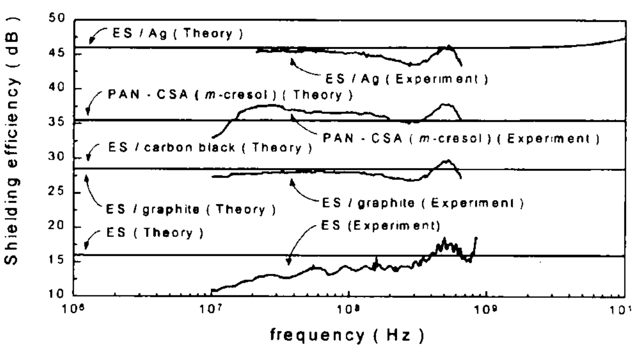

FIGURE 2 Frequency dependence of the SE of PAN and its mixtures.

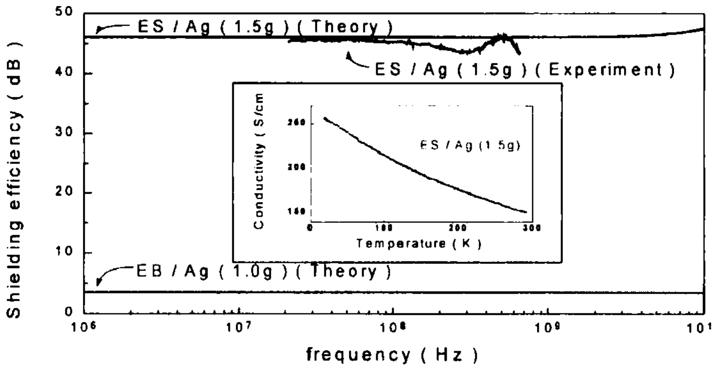

FIGURE 3 Frequency dependence of the SE of EB/Ag and ES/Ag samples.

For EB/Ag sample, EB surrounds Ag particle, and charges can not be easily delocalized because of the insulating barrier of EB. However, in ES/Ag system, the insulating outer shell (EB) becomes conducting state (ES). The electron wavefunctions are overlapped with the next Ag particle through ES. Therefore, σ_{dc} and the SE increase.

SUMMARY

The EMI shielding efficiencies of PAN-CSA (*m*-cresol) and ES/Ag samples are ~40 dB (d ~ 26 μm) and ~46 dB (d ~ 70 μm), respectively, from 10 MHz to 1 GHz. The SE of the systems increases as σ increases, indicating the control of the SE. We obtain that the mixture and chemical doping in PAN systems induces the increase of the SE.

Acknowledgments

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