Preparation and applications of electrically conducting fabrics

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Abstract

Electrically conducting polymers such as polypyrrole(PPy) or poly(3,4-ethylene dioxythiophene)(PEDOT) were sequentially polymerized chemically and electrochemically on various kinds of woven fabrics, giving rise to the fabrics with high electrical conductivity. The specific volume resistivity of the fabric prepared in this study was extremely low as 0.2 Ω-cm. We figured out the electrically conducting fabrics were practically useful for many applications such as an EMI shielding material, a flexible surface heating element or a strain sensor for large deformation.

Introduction

Although synthetic fibers have been occupying a great part of textile and industrial materials, their undesirable hydrophobic and electrically insulating properties bring about inevitable disadvantages. Therefore, in order to provide the synthetic fibers with electrical conductivity, a number of researches have been carried out, which include spinning of electrically conducting fibers or coating fibers with electrically conducting materials such as metals or intrinsically conducting polymers.

In this presentation, we report a route to achieve the electrically conducting fabrics with extraordinarily high electrical conductivity. We investigated the effects of the chemical or the electrochemical polymerization conditions on the properties of the resulting fabrics such as surface morphology, environmental stability, electrical conductivity, and electromagnetic interference shielding effectiveness (EMI SE), heat generating property and mechanoelectrical property.

Experimental

Pyrrole was distilled under reduced pressure and stored at about −10 °C before use, while 3,4-ethylene dioxythiophene (EDOT) was used as received. Polyvinyl alcohol (PVA) with a degree of polymerization of 1,500 was used as a surfactant as well as a binder polymer without further purification. Ammonium peroxidisulfate (APS) and ferric p-toluene sulfonate (FTS) as the oxidants and 1-naphthalene sulfonic acid (NSA) as the dopant were used as received. Anthraquinone-2-sulfonic acid sodium salt (AQSA-Na) was used as received as a supporting electrolyte in the electrochemical polymerization.

Preparation of PET fabric/PPy composite

Electrically conducting fabrics were prepared by the chemical and electrochemical polymerization of PPy or PEDOT on the various kinds of fabrics in sequence. Chemical polymerizations of PPy and PEDOT were carried out following the procedures reported earlier[1,2]. Electrochemical polymerization was carried out at various temperatures under applying a constant current density by using KEITHLEY 2400 SourceMeter (KEITHLEY Instruments Inc.)[1].

Characterization

PPy or PEDOT content in the fabric was determined as the ratio of the weight of PPy or PEDOT in the fabric to that of the pristine fabric. Electrical conductivity of the fabric was measured by a two-probe method and expressed as the specific volume resistivity (Ω-cm) or the surface resistivity (Ω/sq).

EMI SE was obtained following ASTM D 4935-89 using a vector network analyzer (HP 8719 ES) equipped with an amplifier and a scattering parameter (S-parameter) test set over a frequency range of 50 MHz to 1.5 GHz [3]. We also measured the reflectance (R_e) and the transmittance (T_r) of the fabric and calculated the absorbance (A_b) using following equation.

$$A_b = 1 - T_r - R_e$$

We investigated the heat generating property of the PPy-coated fabric by measuring the temperature of the fabric upon applying an electrical power, where a commercial Li-ion battery (3.6 V, LGL1-AHM) for a mobile phone was used as the power supply. We also studied the mechanoelectrical properties of the electrically conducting fabric by monitoring the change of the electrical resistance with the mechanical strain at various the extension rates.

Results and discussion

The electrical conductivity of the fabric was as low as 0.2 Ω-cm. We observed the fabrics possessed practically useful EMI shielding, heat-generating and mechanoelectrical properties as shown in Figures 1-3.

Figure 1 shows the EMI SE, absorbance, and reflectance of the electrically conducting fabrics with various specific volume resistivities. EMI SE gradually increased from 10 to 20 dB with decrease of specific volume resistivity in the region from 7 to 2 Ω-cm and then more steeply increased to 36 dB below 0.75 Ω-cm, which must be due to increase of the conductivity toward a metallic conductivity. We noticed that the increase of EMI SE with the electrical conductivity results dominantly from shielding by reflection. The shielding by absorption decreased with increase of the specific volume resistivity, while shielding by reflection increased. As shown in Figure 1, it is interesting that EMI shielding behaviors of the fabrics prepared in this study follow the same trend, irrespective of the kind of the electrically conducting polymer.

Figure 2 displays the heat generating property of the PPy-coated fabric. The temperature of the PPy-coated fabric increased very quickly from room temperature to about 55 °C within 2 minutes and was sustained for about 80 minutes at the temperature as shown in Figure 2. The gradual decrease of the temperature after 90 minutes must be due to the discharge of the battery with the time. The heat generating property of fabric was so stable that exhibited the similar behaviors for at least 10 repeated cycles. We believe the heat generating period can be increased much longer when the temperature is controlled at a desired level such as 40 °C by applying an temperature controller.

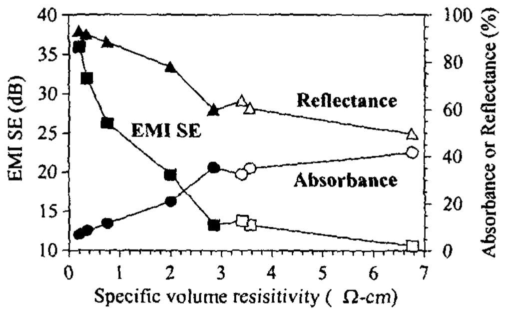

Figure 1. EMI SE, absorbance, and reflectance of PET textile/ICP composites with various specific volume resistivities. Black and white symbols represent PPy- and PEDOT-coated fabrics, respectively.

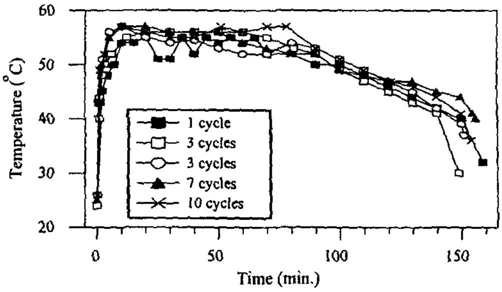

Figure 2. Temperature change of the PPy-coated fabric upon applying electrical power.

We also observed the change of electrical resistance depended only on the elongation. The fabric showed the identical change of electrical resistance with the elongation regardless of the elongation rate as shown in Figure 3.

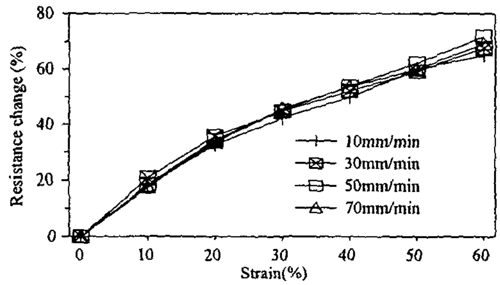

Figure 3. Resistance change of the PPy-coated fabric with the strain at various extension rates.

Conclusions

We prepared the electrically conducting fabrics by the chemical and electrochemical coating of PPy or PEDOT on the fabrics in sequence. The specific volume resistivity of the fabric was extremely low as 0.2 Ω-cm. We observed the electrically conducting fabrics could be used for many practically useful applications such as an EMI shielding material, a flexible surface heating element or a strain sensor for large deformation.

References

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