Conducting Sheet Made of Polypyrrole-Cellulose Fibers Toward Electrodes for Electronic Paper

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ABSTRACT

We have prepared conducting sheets made of polypyrrole-cellulose fibers that utilize polypyrrole as conducting parts and cellulose fiber as flexible part. The sheets have a potential that can be utilized as back electrodes for electronic paper.

1 INTRODUCTION

Conducting polymers are usually insoluble and infusible due to their stiff structure and conjugated backbones. These poor processability must be a major problem which has prevented these materials from acting as processable forms. A useful approach to overcome the lack of processability of conducting polymers is to prepare colloidal dispersions of conducting polymers. Polypyrrole is one of most attractive conducting polymers because of its environmental stability and biocompatibility. We have studied nanocomposite inks of polypyrrole using small silica particles as a particulate dispersant [1]-[2]. In this approach, the silica particles act as a high surface area substrate for the precipitating polypyrrole. We found that the particle distribution of the polypyrrole-silica nanocomposite particles is almost the same as that of a commercially available inkjet inks. Therefore, there is a possibility that the polypyrrole-silica nanocomposite particles act as conducting inks for inkjet devices [3]. Very recently, we have succeeded in printing some images with polypyrrole-silica nanocomposite particles using a thermal inkjet printer . The image qualities with polypyrrole-silica nanocomposite ink are almost the same as that with the conventional ink. Therefore, we conclude that our polypyrrole-silica nanocomposite particles could be used as inks for printed electronics.

On the other hand, in the field of electronic paper, microcapsule electrophoretic display is most preferable system because it has good readability which is close to conventional paper. Particles as display elements of an electrophoretic display are usually covered with polymer surfactants which prevent these particles from co-aggregation. However, it generally takes long time and high cost to prepare such surfactants. In the previous work [4], we have shown the results that the polypyrrole-silica nanocomposite particles can be utilized as display elements for electrophoretic display due to their high colloidal stabilities.

In the present work, we have prepared polypyrrole-cellulose fiber composites using cellulose fibers instead of silica particle. In this approach, the cellulose fibers act as a high surface area substrate for the precipitating polypyrrole. We will show you how to prepare the polypyrrole-cellulose fibers. Then, we report the characterization of the sheets made of the polypyrrole-cellulose fibers to discuss the applications of these sheets in the field of electronic paper.

2 EXPERIMENT

2.1 Preparation of Polypyrrole-Cellulose Fibers

The polypyrrole-cellulose fibers were prepared as follows: 0.03 g (dry weight) cellulose fibers (Daio Paper Corporation; Elleair Toilet Tissue Compact Double) were added to a solution of $(NH_4)_2S_2O_8$ (1.92 g) in de-ionized water (total solvent volume=50 ml) at 25 °C with constant stirring. Pyrrole (0.5 ml) was then injected via syringe into this stirred solution turned black within 1 minute. The polymerization was allowed to proceed for 1 hour. This reaction mixture was then centrifuged at 3500 r.p.m. for 10 hours. using a KOKUSAN Co.Ltd.; H-103n instrument and the resulting black sediment was redispersed in de-ionized water using an ultrasonic bath. This centrifugation-redispersion cycle was repeated three times in order to completely remove the by-products from the polypyrrole-cellulose fibers.

2.2 Observation of Polypyrrole-Cellulose Fibers

Scanning electron microscopy (SEM) studies were made on dilute polypyrrole-cellulose fibers dried down on specimen holders using a (JEOL Ltd.; JCM-6000Plus NeoScope) instrument at an operating voltage of 10 kV.

2.3 Preparation of Conducting Sheets made of Polypyrrole-Cellulose Fibers and Their Characterizations

Conducting sheets were made by mixing and then drying the polypyrrole-cellulose fibers at 25°C, 48 hours.

The polypyrrole-cellulose sheets were put in between circular metal plates (2.0 cm in diameter) and measured by a digital multimeter (Sanwa Electric Instrument Co., Ltd.; CD770) (Fig. 1). The chromaticity studies of these sheets were carried out using a spectrophotometer (X-Rite; 962).

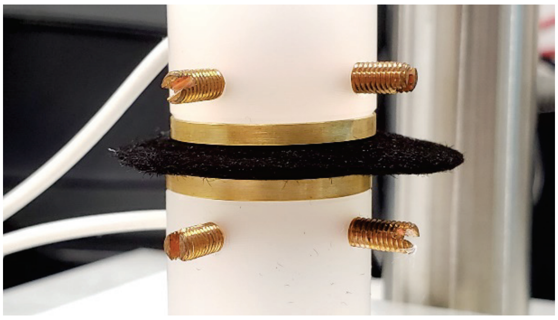

Fig. 1 Method of electrical resistance measurement

3 RESULTS AND DISCUSSION

3.1 Polypyrrole-Cellulose Fibers

The scanning electron micrograph depicted in Fig. 2(a) and (b) are cellulose fibers and polypyrrole-cellulose fibers respectively. Clearly these polypyrrole-cellulose fibers contain of polypyrrole particles in cellulose fibers. Thus, there is no doubt that the polypyrrole-cellulose fibers must be substantially different to that usually observed for conventional fibers.

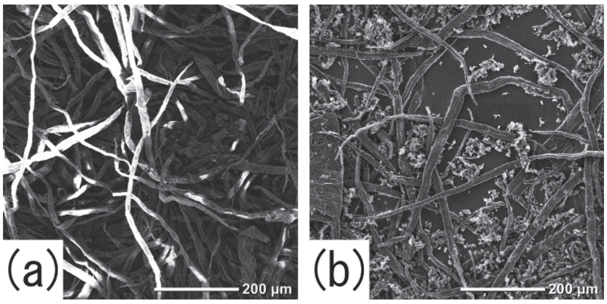

Fig. 2 SEM observations for (a)Cellulose and (b)Polypyrrole-Cellulose fibers

3.2 Characterization of Polypyrrole-Cellulose Fibers

A summary of the experimental date for the electrical conductivity of cellulose sheet and polypyrrole-cellulose sheet are shown Table 1. The polypyrrole-cellulose sheet shown high conductivity. We confirmed that there is electrical conductivity on polypyrrole-cellulose sheet.

Table 1 Electrical conductivities of cellulose sheet and polypyrrole-cellulose sheet

Sample	Electrical conductivities [Ω]
Cellulose	∞
Polypyrrole-Cellulose	18.2

The chromaticity diagram of cellulose sheet and polypyrrole-cellulose sheet is presented in Fig.2. Although the colors of cellulose sheet and polypyrrole-cellulose sheet are both achromatic, their brightness is opposite. The CIE Lab values of cellulose sheet and polypyrrole-cellulose sheet are shown in Table 2. Considering the L values in Table 2, The color of the polypyrrole-cellulose sheet is very black. These results indicate that the polypyrrole-cellulose sheet has potential to be utilized as a black flexible electrode.

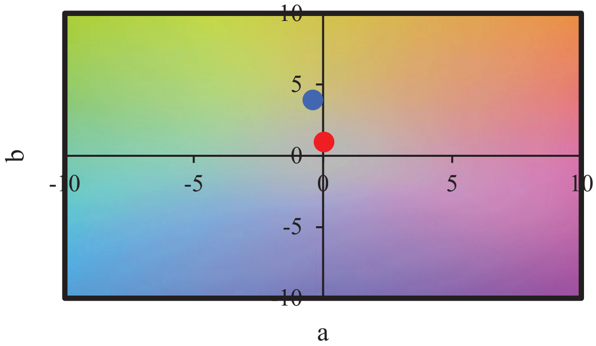

Fig. 3 Chromaticity diagram of cellulose sheet and polypyrrole-cellulose sheet

Table 2 CIELab value(D65/10) of Cellulose sheet and Polypyrrole-Cellulose sheet

	cellulose (bulk)	polypyrrole-cellulose
L	96.45	9.45
a	-0.39	0.04
b	3.94	0.95

3.3 Application Toward Electrodes for Electronic Paper

We are planning to use the polypyrrole-cellulose sheet as electrodes for electronic paper because it is flexible and electrically conductive. Especially the black color of the polypyrrole-cellulose sheet suggest that it is applicable for back electrode for electronic paper devices including cholesteric liquid crystal displays.

4 CONCLUSIONS

We have prepared polypyrrole-cellulose sheet that utilize polypyrrole as conducting parts and cellulose fiber as flexible part. The polypyrrole-cellulose sheet could be utilized as electrodes for electronic paper due to its flexibility and conductivity.

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