Conducting Polypyrrole-Silica Nanocomposite Particles for Electrophoretic Display

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ABSTRACT

We have prepared organic conducting nanocomposite particles that utilize polypyrrole as conducting parts and small silica particles as dispersants. We found that the polypyrrole-silica nanocomposite particles can be utilized as display elements for electrophoretic display and black inks for printed electronics due to their high colloid stability.

1 INTRODUCTION

There has been increasing interest in conducting inks for the direct printing of conductive patterns using inkjet systems in the field of printed electronics. In general, these conducting inks are made from metal nanoparticles such as silver and copper. On the other hand, recently, there has been increasing expectation for utilizing conducting inks in the field of biological applications. When considering the application of conducting inks in biological fields, organic inks are preferable relative to metallic inks. Therefore, we have started to investigate the organic materials which play roles as conducting inks. One of the answers is to utilize conducting polymers.

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 dispersions. A useful approach to overcome the lack of processability of conducting polymers and to make them act as particles is to prepare colloidal dispersions of conducting polymers. Generally, such colloids are stabilized with polymeric surfactants in aqueous media. However, in our strategy, we focus on colloid forms of conducting polymers without polymeric surfactants utilizing charge stabilization instead of steric stabilization. In the previous works [1]-[2], we reported nanocomposite particles of polypyrrole which give a rise to "raspberry" morphology using small silica particles as a particulate dispersant. In this approach, the silica particles act as a high surface area substrate for the precipitating polypyrrole. It is concerned with a novel and easy method for obtaining processable inks of conducting polymers using small colloidal inorganic oxide particles as dispersants. The polypyrrole-silica nanocomposite particles as a ink side were carried out using electrostatic inkjet device.

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 present work, we report the results that we utilize polypyrrole-silica nanocomposite particles as display elements for electrophoretic display.

2 EXPERIMENT

2.1 Preparation of Polypyrrole-Silica Particles

The polypyrrole-silica nanocomposite particles which act as conducting polymer were prepared as follows: 0.5–2.0 g (dry weight) silica particles (Nissan Chemicals; Snowtex-XS, 4-6 nm particle diameter; provided as 20 w/v % aqueous dispersion) were added to a solution of $FeCl_3$ (4.55 g) in de-ionized water (total solvent volume = 50 ml) at 25 °C with constant stirring. Pyrrole (0.50 ml) was then injected via syringe into this stirred solution turned black within 1 minute. The polymerization was allowed to proceed for 2 hours. This reaction mixture was then centrifuged at 9,000 r.p.m. for 10 minutes. using a KUBABO FB-8000 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 excess small silica particles and (in)organic by-products from the larger polypyrrole-silica nanocomposite particles.

2.2 Colloid Stability of Polypyrrole-Silica Particles

The colloid stability of the polypyrrole-silica nanocomposite particles is compared with that of the bulk polypyrrole. We observed them two times immediately after the experiment and two weeks later.

2.3 Development as Display Elements for Electrophoretic Display

Procedures in order to use the polypyrrole-silica nanocomposite particles display elements of electrophoretic display were carried out using the model experiment system described in Fig. 1. The as polypyrrole-silica nanocomposite particles were dispersed between two electrodes and floated at the boundary between two dielectric liquids with different specific gravities (Exon Chemical; Isoper-G: specific gravity 0.75 and 3M Japan Limited; PF-5080 : specific gravity 1.70). A D.C. voltage was set between the pair of electrodes and the motion of the polypyrrole-silica nanocomposite particles were observed and recorded using digital microscope (KEYENCE VW-6000).

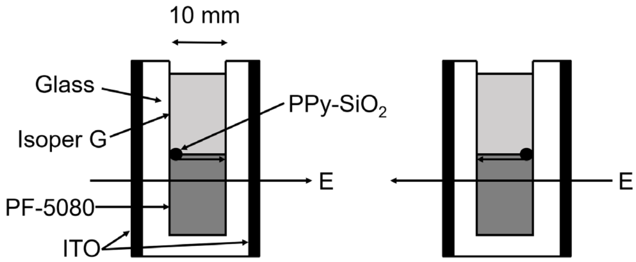


Fig. 1 Experimental apparatus for investigating the motion of the polypyrrole-silica nanocomposite particles as display elements for electrophoretic display

2.4 Application as Black Inks

We printed images on a paper with polypyrrole-silica nanocomposite particles as black inks using conventional thermal inkjet printer (CANON PIXUS MG6130BK) .

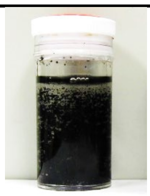
3 RESULTS AND DISCUSSION

3.1 Colloid Stability of Polypyrrole-Silica Nanocomposite Particles

The long-term colloid stability of polypyrrole-silica nanocomposite particles relative to the bulk polypyrrole was confirmed in the observation as shown in Table1.

The polarity of the surface charge potential of the polypyrrole-silica nanocomposite particles related to the surface charge potential of original colloidal silica. Generally, isoelectric point of colloidal silica is around pH 2.0, the silica colloid that we utilized is dispersed in pH 9.0~10.0 solution. Therefore, the polarity of the surface charge potential of silica colloid can be said to be negative. Thus, the polypyrrole-silica nanocomposite particles are also negatively charged.

Table 1 Colloid stability of polypyrrole-silica nanocomposite particles

	Polypyrrole	Polypyrrole-Silica
0 hour		
2 weeks		

3.2 As display elements for electrophoretic display

A summary of the experimental data of the motion of polypyrrole-silica nanocomposite particles are presented in Table 2. When applying the electric field of 600 V/mm and over, the polypyrrole-silica nanocomposite particles can be straightly moved from one of the electrodes to the other. Probably, there is a threshold between 500 V/mm and 600 V/mm. Converting polypyrrole-silica nanocomposite particles size to the typical display elements size (around 100 nm) for electrophoretic display, the response time is enough that people can be recognized.

Table 2 Motion and speed of polypyrrole-silica nanocomposite particles

Electric field (V/mm)	Velocity of polypyrrole-silica (mm/s)
100	Non-movement
300	Non-movement
500	Non-movement
600	415
700	623

3.3 Application as Black Inks

We succeeded in printing some images with polypyrrole-silica nanocomposite particles using thermal inkjet printer.

As shown in Fig.2, the print qualities with polypyrrole-silica nanocomposite ink are almost the same as that with conventional ink. Therefore, we consider that our polypyrrole-silica nanocomposite particles could be used as inks for printed electronics.

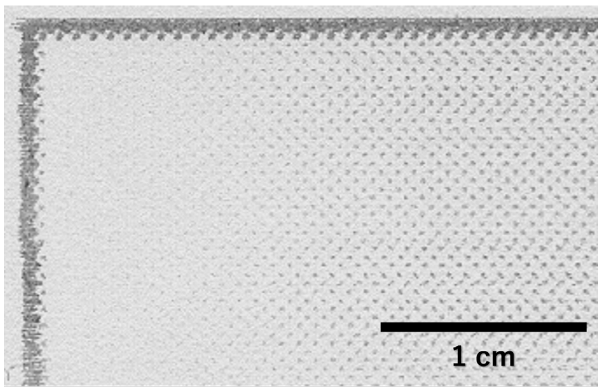


Fig. 2 Printed by using thermal inkjet

4 CONCLUSIONS

The polypyrrole-silica nanocomposite particles can be utilized as display elements for electrophoretic display due to their high colloidal stabilities. In addition, polypyrrole-silica nanocomposite particles have a potential as inkjet inks for printed electronics.

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