Conducting Polypyrrole-ITO Particles Toward Display Elements for Electronic Paper

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ABSTRACT

We have prepared conducting nanocomposite particles which consist of polypyrrole and ITO. The conductivity of the polypyrrole-ITO nanocomposite particles was the same as that of polypyrrole. We confirmed that the nanocomposites have potential to be utilized as particles for electronic paper due to their high conductivities and colloid stabilities.

1 Introduction

Conducting polymers are usually insoluble and infusible due to their stiff structure and conjugated backbones. This poor processability must be a major problem which has prevented these materials from actual usage. A useful approach to overcome the lack of processability of conducting polymers is to prepare colloidal dispersions of conducting polymers [1].

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. But it generally takes long time and high cost to find such surfactants.

In our previous works, we use polypyrrole as conducting polymer because it is one of non-toxic organic materials. We reported the application of nanocomposite particles of polypyrrole and silica in the field of electronic papers [2]. In this approach, the silica particles act as dispersant due to the high surface area for the precipitating polypyrrole. However, their solid-state pressed pellet conductivities are consistently lower by 1-3 orders of magnitude relative to bulk polypyrrole powders prepared under the same conditions.

In the present work, we report the result that indium tin oxide (ITO) is used instead of silica because ITO exhibits much higher conductivity relative to silica. It is well-known that ITO is electrical conductor while silica is insulator.

2 Experiment

2.1 Preparation of polypyrrole-ITO nanocomposite particles

Typical polypyrrole-ITO nanocomposite particles were prepared as follows. 0.5 ml of ITO dispersion (20 wt% in water) was added to the solutions of $FeCl_3 \cdot 6H_2O$ (4.55 g) in de-ionized water mixtures at 25 °C with constant stirring. The total solution volume was 50 ml. Pyrrole (0.5 ml) was then injected via syringe into these stirred solutions and the solutions turned black within 3 minutes. The polymerization was allowed to proceed for 20 hours. The resulting black dispersions were centrifuged at 16,000 rpm for 10 minutes using a KURABO FB-8000 instrument. The supernatants were carefully decanted and discarded. The resulting black sediments were redispersed in water. This centrifugation−redispersion cycle was repeated three times until the color of the supernatant solution became clear, in order to ensure removal of the excess, non-aggregated ITO particles and soluble by-products (unreacted monomer, excess oxidants, etc.).

The analogous polypyrrole-silica nanocomposite particles were prepared in the presence of silica particles instead of ITO particles using the same protocol described above. In addition, the analogous polypyrrole bulk powders were prepared in the absence of inorganic oxide particles using the same protocol described above.

2.2 Characterization of the polypyrrole-ITO nanocomposite particles

Transmission electron microscopy (TEM) studies were made on dilute polypyrrole-ITO nanocomposite particles dried down on carbon-coated copper grids (Bio-Rad; 3 mm diameter) using a JEOL-100C instrument at an operating voltage of 5 kV.

The particle size of polypyrrole-ITO and polypyrrole-silica nanocomposite particles were determined by dynamic light scattering (DLS) with a LB-550 (HORIBA Instrument).

The zeta potentials of polypyrrole-ITO and polypyrrole-silica nanocomposite particles were measured using zeta potential & particle analyzer (ELSZ-2000, Otsuka Electronics Co., Ltd.).

The conductivities of polypyrrole-ITO and polypyrrole-silica nanocomposites, and polypyrrole bulk powders were carried out at 25 °C on compressed pellets of the powder using conventional four-point probe techniques using a four-in-line probe configuration.

3 Results and Discussion

3.1 Colloid stability and morphology

Our TEM studies confirmed that the polypyrrole-ITO nanocomposite particles are made up of micro-aggregates of the original small inorganic oxide particles (see Fig.1). On the other hand, the polypyrrole bulk powders have fused, globular morphology (not shown here). Thus, there is no doubt that the polypyrrole morphology within the polypyrrole-ITO nanocomposite particles must be substantially different to that usually observed for conventional chemically synthesized polypyrrole bulk powder.

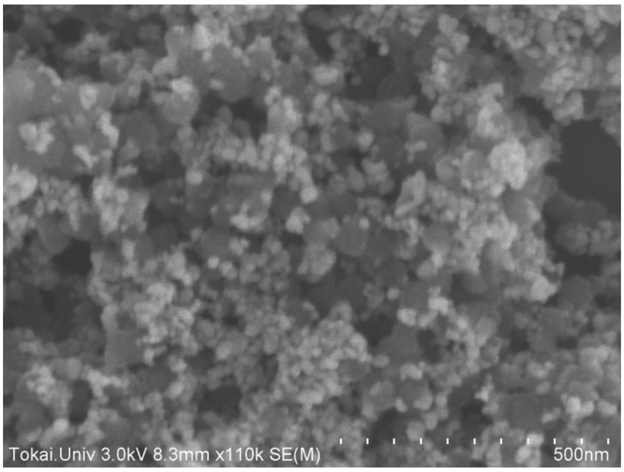

Fig. 1 SEM images of polypyrrole-ITO nanocomposite particles

The long-term colloid stability of polypyrrole-ITO and polypyrrole-silica nanocomposite particles relative to the bulk polypyrrole were confirmed in the visual observation.

A summary of the experimental data on the particle size Zeta potential and conductivity of samples is presented in Table 1. The particle size distribution of the polypyrrole-ITO nanocomposite particles is almost the same as that of polypyrrole-silica nanocomposite particles. The zeta potential value of polypyrrole-ITO nanocomposite particles was confirmed to be -24 mV. In general, zeta potential value below -25 mV and above 25 mV is considered to be stable.

3.2 Conductivity

The polypyrrole-ITO nanocomposites show the same conductivity of the bulk polypyrrole and the conductivity of two orders of magnitude higher than the polypyrrole-silica nanocomposites.

Table 1 Comparison of the particle size and the electrical conductivity of polypyrrole-ITO nanocomposite, polypyrrole- silica nanocomposite, and bulk polypyrrole

Sample	Particle size (nm)	Zeta potential (mV)	Conduct-ivity (S/cm)
polypyrrole-ITO	300±90	-24	15
polypyrrole-silica	250±50	-28	0.2
bulk polypyrrole	—	—	15

3.3 Application Toward Display Elements for Electronic Paper

We have already reported that the polypyrrole-silica nanocomposite particles can be utilized as display elements for electrophoretic display due to their high colloid stabilities [2]. The potential of the polypyrrole-ITO nanocomposite particles as display elements for electronic paper seems to be higher than that of the polypyrrole-silica nanocomposite particles. This is because the higher conductivity of polypyrrole-ITO nanocomposite particles relative to polypyrrole-silica nanocomposite particles enables to enlarge the conductivity range that affects to the movement of display elements of electronic paper systems. In addition, the zeta potential of polypyrrole-ITO nanocomposite particles is higher than that of polypyrrole-silica nanocomposite particles. This means that polypyrrole-ITO nanocomposite particles can move faster than polypyrrole-silica nanocomposite particles.

4 Conclusions

We have succeeded in synthesizing polypyrrole-ITO nanocomposite particles. The polypyrrole-ITO nanocomposite particles represent a potentially useful processable form of polypyrrole, a normally intractable conducting polymer. In addition, the polypyrrole-ITO nanocomposites show the same conductivity of the bulk polypyrrole. The polypyrrole-ITO nanocomposites could be utilized as display elements for electronic paper due to their high conductivities and colloid stabilities.

References

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