Electric Double Layer Capacitors Using Ionic Liquids and Carbon Nanotubes

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INTRODUCTION

Fukushima and co-workers reported that carbon nanotubes (CNTs) and ionic liquids form a gel by mixing[1)]. This gel has two characteristic properties as electron conductor and ion conductor, so this gel is an ideal material in order to constitute electrochemical systems. We have studied the application of this gel to electric double layer capacitors (EDLCs). The CNTs structure is cylindrical tube composed of two dimensional graphite sheet, so the ions are easy to adsorb on the CNTs surface because of their large external surface area[2)]. Also, the ionic liquids are very interesting in multidisplinary areas for their unique physicochemical properties such as high thermal stability, negligible vapor pressure, relatively high ionic conductivity, electrochemical stability, and high electric double layer capacitance. Because of the electrochemical stability and high electric double layer capacitance, we expect that high-performance EDLCs are assembled by using the CNT gels as electrodes. Owing to the high thermal stability and negligible vapor pressure, we hope that long-time-stable and safe EDLCs are realized. The performance of EDLCs based on this gel was examined. Further, we studied how the capacitance changes with gelation.

EXPERIMENTAL

Cell assembly:

Single-walled carbon nanotubes (SWNTs) were used as an electrode-material for the EDLCs. The specific surface area of SWNTs is 654 m^2g^{-1}; it is estimated by N_2-BET adsorption. 1-Ethyl-3-methyl imidazolium bis(trifluoromethane sulfone)imide (EMITFSI) was used as an ionic liquid. The SWNTs and EMITFSI at various mixing ratios were mixed to form gels. They are thoroughly grounded with a pestle for a few minutes. Sample cells were fabricated with two gel electrodes having apparent areas of 0.55 cm^2 with thickness of 3 mm, separated by a viscose rayon separator, which is soaked with EMITFSI. Stainless steel was used as the current collector.

Charge-discharge measurements:

Charge-discharge experiments were carried out to determine the capacitance of the EDLCs. The assembled cells were charged and discharged by constant current (CC) mode from 0.0 V to 2.3 V at a constant current I =0.157, 0.314, and 0.628 $mAmg^{-1}$, at a constant temperature of 25℃.

RESULTS AND DISCUSSION

Figure 1 shows the cell capacitance of the EDLCs as a function of composition of the gels. At 0.628 $mAmg^{-1}$, the measurement was partially possible, because of the limitation of the equipments. Referring to Figure. 1, the cell capacitance increases as weight of the SWNTs in the electrode increases. It is found that the gels comprised of the SWNTs and ionic liquids function as electrode materials in the EDLC in the various compositions. Continuous electron and ion conduction paths are formed in the gels over the entire electrodes (3mm : the cell thickness).

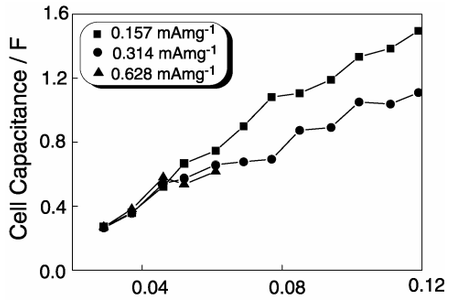

Figure. 1 Cell capacitance of EDLCs as a function of composition of electrode. (Voltage range 0.0 V-2.3 V)

Changes in the capacitance with the gelation are investigated to know the effect of the gelation. Figure 2 shows the changes in the capacitance of the EDLCs consisting of the SWNT electrodes with the gelation and without the gelation as a function of current density. For the EDLCs using the electrodes without the gelation, the SWNTs and EMITFSI were simply put into a cell without forming a gel. From Figure 2, it is evident that the gelation contributes to increasing the capacitance. This result reflects that the EMITFSI and SWNTs are molecularly mixed during the gel formation. To increase the capacitance of the EDLCs, the gelation turns out to be essential. The gelation does not occur when water or organic solvents are mixed with the SWNTs, which indicates the excistance of specific interaction between the SWNTs and the ionic liquid..

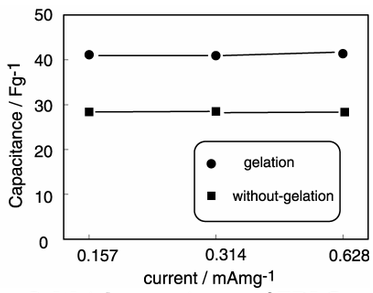

Figure. 2 Weight capacitance of EDLCs with gelation and without gelation as a function of the current density. (Voltage range : 0.0 V-2.3 V)

REFERENCES

1) T. Fukushima. et al., *Science* **2003**, *300*, 2072-2074
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