Proposal of a New Actuator Using Ion Gel Driven at Low Voltage under Atmospheric Condition

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INTRODUCTION

Electroactive polymers (EAPs) that respond to external electrical stimulation with a significant shape or size change have been of great interest for use in a variety of actuator applications, especilally in artificial muscles, because of their easiness of actuation, advantages in miniturization, mechanical peoperties similar to that of biological systems and so forth [1]. However most of the current EAP actuators [2] can be driven only at a high voltage or in aqueous media, therefore they have safety defects or long-term stability problems that impose some restrictions on the operating conditions.

In this study, aiming at solving the drawbacks, a new EAP actuator that can be driven at a low voltage under an atmospheric condition have been successfully made. We have proposed and realized the application of electric double layer capacitors (EDLCs) using ion gels as the polymer electrolyte, prepared by incorporating ionic liquids in network polymers [3], to the new EAP actuators. They have an advantage to be driven at a low voltage, and the presence of non-volatile ionic liquid in the ion gels allows them to be operated under an atmospheric condition for a long term.

From the specific bending displacement that the actuators show to the external applied voltage, we have investigated the principle of the applicability of the EDLCs to the new EAP actuators, and have approached to the elucidation of the operating mechanism.

EXPERIMENTAL

The ion gels were prepared by *in situ* radical polymerization of methyl methacrylate (MMA) in an hydrophobic ionic liquid, 1-ethyl-3-methylimidazolium bis(trifluoromethane sulfone)imide ([emim][$N(SO_2CF_3)_2$]; EMITFSI) at 60 ^oC for 20 h by addition of appropriate amount of a cross linking monomer, ethyleneglycol dimethacrylate (EGDMA) and 1 mol% 2,2'-azobisisobutyronitrile (AIBN).

Then, the EDLCs were made by adhering carbon powder as compliant electrodes to the both sides of the ion gels and cutting them into a ribbon. The EDLCs were supported by clamping the one end and displacement of the free end of them were measured by a laser displacement meter. The displacement responses under an atmospheric condition were stimulated by applying rectangular wave form voltage (±1.5 V) at a cycle of 20s or 120s, and triangular wave form voltage (±1.5 V) at a scan rate of 0.01V s^{-1} to 9 Vs^{-1}.

RESULTS AND DISCUSSION

The displacement responses of the EDLC to the applied voltage were always bends to the anodic side, and the applicability to a new actuator driven at ±1.5 V under an atmospheric condition could be found. Firstly, on applying rectangular wave form voltage (Fig. 1), the displacement increased with increasing the charging of the electric double layer. Secondly, on applying triangular wave form voltage, the displacement respose reversibly followed the forwarded and backwarded volatege change. In Fig. 2, displacement trends can be seen over a wide range of capacitance caluculated from cyclic voltammograms scanned at each rate. The same basic trend is a decrease in displacement with increasing capacitance.

According to these responses, it is considered that the actuator can convert a part of the electric energy stored at the electric double layer into the mechanical energy used for the deformation, and the charging and discharging was associated with the reversible deformation.

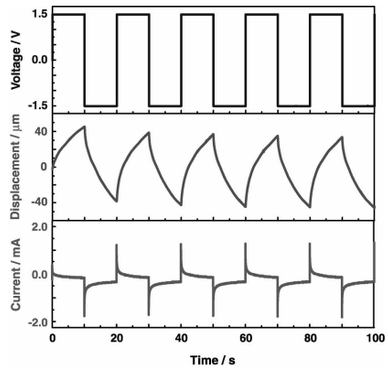

Fig. 1 Displacement response of EDLC composed of ion gel and carbon powder electrodes driven by rectangular wave form voltage at a cycle of 20s.

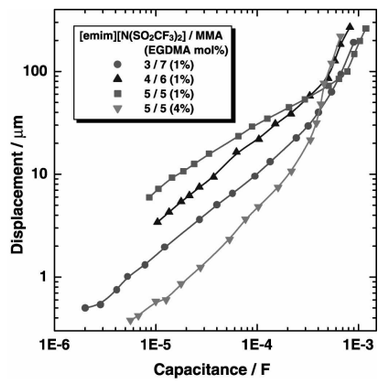

Fig. 2 The dependence of the displacement on capacitance.

CONCLUSIONS

It is demonstrated that the EDLCs using the ion gels as the polymer electrolyte can be applied to EAP actuators. We succeeded in the invention of the new actuator driven at a low voltage under an atmospheric condition. Their displacement responses give an indication that the actuators partly convert the electric energy stored at the electric double layer into the mechanical energy.

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