A solid state actuator based on the PEDOT/NBR system

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Abstract

This paper reports the fabrication of a dry type conducting polymer actuator using nitrile rubber (NBR) as the base material for a solid polymer electrolyte. Thin films of NBR (150–200 μm) were prepared by using a compression molding process. A conducting polymer, poly(3,4-ethylenedioxythiophene) (PEDOT), was synthesized on the surface of the NBR layer by using a chemical oxidation polymerization technique, and room temperature ionic liquids (RTIL) based on imidazolium salts, e.g. 1-butyl-3-methyl imidazolium X [where X = BF4−, PF6−, (CF3SO2)2N−], were absorbed into the composite film. The effects of the anion-size of the ionic liquids on the displacement of the actuator were examined. The displacement increased with increasing the anion-size of the ionic liquids. The cyclic voltammetric responses and the redox switching dynamics of the actuators using different ionic liquids were examined.

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1. Introduction

Electro-active polymer (EAP) actuators have attracted considerable attention on account of their high strength and large strain [1,2]. In an EAP actuator system, the applied redox potential can render ions transportable between a conducting polymer and a polymer electrolyte. The use of conventional liquid electrolytes is not practical, because the leakage or loss due to evaporation results in a limited working life time [3]. Clearly the choice of solvent can dramatically influence both the electrolyte and the anion stability but in an unpredictable manner [4]. Therefore, there is a need for improved electrolytes that satisfy the requirements of a high ionic conductivity, fast ion mobility during the redox events, and low volatility. Certain materials known as ionic liquids meet all of these requirements. Ionic liquids can be obtained in a very dry state, making them particularly suitable for applications in electrochemical systems where moisture must be excluded over a long period of operation. Recently, Cooper and Sullivan described an air- and moisture-stable room temperature ionic liquid consisting of the 1-ethyl-3-methylimidazolium (EMI) cation and trifluoromethanesulfonate (TFSI) anion, which maintains many of the required physical and electrochemical properties [5]. In addition, Fuller [6] demonstrated the utility of the EMIBF4 ionic liquids as a versatile electrolyte.

The preparation and actuation of the dry type actuator, PEDOT/NBR/ionic liquid was previously reported [7–9]. In preparing the actuator system, nitrile rubber (NBR) was used as the base material for the solid polymer electrolyte. Nitrile rubber contains 40% of polyacrylonitrile (PAN), which has a high dielectric constant compared with polybutadiene, and the high polarity of PAN facilitates the absorption of a polar liquid electrolyte into the rubber matrix. It should be pointed out that the choice of the solid polymer electrolyte is critical when operating in air. It should not only have enough polarity for impregnating liquid electrolytes but also have sufficient flexibility for allowing actuation of the conducting polymer. In addition, it should have good adhesion with conducting polymer layers to prevent the delaminating problem. In our research, thin NBR film (150–200 μm) were prepared by using a compression molding process. A conducting polymer,