An electroactive conducting polymer actuator based on NBR/RTIL solid polymer electrolyte

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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 in a solid polymer electrolyte. The conducting polymer, poly(3,4-ethylenedioxythiophene) (PEDOT), was synthesized on the surface of the NBR layer by using a chemical oxidation polymerization technique. 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 compatibility between the ionic liquids and the NBR polymer was confirmed by DMA. The effect of the anion size of the ionic liquids on the displacement of the actuator was examined. The displacement increased with increasing anion size of the ionic liquids. The cyclic voltammetry responses and the redox switching dynamics of the actuators were examined in different ionic liquids.

(Some figures in this article are in colour only in the electronic version)

1. Introduction
Recently, Baughman [1] reviewed the use of conducting polymers as artificial muscles and described their potential applications in areas including robotics and prosthetics. Many studies have demonstrated simple actuator devices using conducting polymers and solid-type actuators in which the liquid is replaced by a solid polymer electrolyte (SPE) [2, 3]. In conventional conducting polymer actuator systems, actuators working in air can be achieved by separating two conjugated polymer films by an SPE, leading to bending or linear extensional actuators [4]. However, a delaminating process can occur due to the poor adhesion between the conducting polymer film and the SPE layer, which can limit the lifetime of the actuator [5]. In order to solve the delaminating problem, the conducting polymer was embedded in an elastomeric and ionic conducting matrix. The matrix was immersed in liquid electrolyte. The SPE should have sufficient flexibility to allow mechanical motion. Therefore, a room-temperature ionic liquid (RTIL) for the liquid electrolyte and a synthetic rubber for the elastomeric conducting matrix were chosen in this system. The RTIL meets all of the actuator requirements: high conductivity and environmental stability [6, 7].

In this study, thin NBR films (150–200 μm) were prepared using a compression molding process. The conducting polymer, poly(3,4-ethylenedioxythiophene) (PEDOT), was synthesized on the surface of the NBR film by using a chemical oxidation polymerization technique. The PEDOT/NBR film was filled with an ionic liquid, e.g. 1-butyl-3-methyl imidazolium bis(trifluoromethylsulfonyl)imide (EMITFSI) in order to use it as a solid polymer actuator. The displacement rate in ionic liquids was greater than that observed in conventional electrolyte systems such as lithium perchlorate in propylene carbonate (PC). The actuators prepared in this study were activated in several ionic liquids: 1-butyl-3-methylimidazolium X (BMIX, where X = BF4−, PF6−, (CF3SO2)2N−), and 1-butyl-1-methylpyrrolidinium bis(trifluoromethylsulfonyl)imide. The