High ionic conductivity and mechanical strength of solid polymer electrolytes based on NBR/ionic liquid and its application to an electrochemical actuator

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Abstract

In this study, a dry type conducting polymer actuator was prepared. Nitrile rubber (NBR) containing ionic liquid, 1-butyl-3-methyl imidazolium bis(trifluoromethyl sulfonyl)imide (BMITFSI), was utilized as the solid polymer electrolyte exhibiting high ionic conductivity as well as electrical stability. Various grades of NBRs having different amounts of acrylonitrile (ACN), viz. 23, 35 and 40 mol%, were found to be well compatible with BMITFSI. The thermomechanical property and ionic conductivity of the solid polymer electrolyte were characterized by dynamic mechanical analysis and impedance analysis, respectively. A maximum conductivity of $2.54 \times 10^{-4} \text{S cm}^{-1}$ at 20 °C was achieved in the NBR sample containing 40 mol% ACN activated in BMITFSI. A conducting polymer, poly(3,4-ethylenedioxythiophene) (PEDOT), was synthesized on the surface of the solid polymer electrolyte by chemical oxidative polymerization to yield the structure of solid polymer actuator. The effect of the NBR composition on the actuation behavior was examined.

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1. Introduction

Conducting polymers exhibit electrochemically driven expansion and shrinkage due to the migration of dopant ions in response to the doping and dedoping process. The volume change depending on the applied potential is associated with actuation motion. Several soft actuators based on conducting polymers during redox processes have been studied [1,2], most of which had a bilayer or trilayer configuration working in the liquid electrolyte [3–6]. Recently, actuators working in air were introduced in the literature using solid polymer electrolytes as a matrix material [7]. In the preparation of solid type actuators, physical adhesion between the solid polymer electrolyte layer and conducting polymer layers can encounter a delaminating problem initiated by repeated volume alternation at the interface [7]. One possible solution to this problem is the use of a single layer actuator. An example, which was based on a poly(3,4-ethylene dioxythiophene) (PEDOT) and poly(butadiene-co-ethylene oxide) interpenetrating polymer network (IPN), was fabricated by Vidal et al. [8]. Sansinena et al. also reported monolithic type polyaniline electrochemical actuators [9]. Recently, we also introduced a single layer actuator system based on a PEDOT and nitrile rubber (NBR) containing room temperature ionic liquid (RTIL) as a solid polymer electrolyte, which exhibited improved actuation performance [10–12]. The anion size of the ionic liquid has previously been shown to affect the actuation characteristics [12]. The displacement increased with increasing the anion-size of the ionic liquids.

Solid polymer electrolytes (SPEs) should have a high ionic conductivity, chemical stability and mechanical strength for practical applications. For this purpose, NBRs containing different amounts of acrylonitrile (ACN) (23, 35 and 40 mol%) were selected as solid polymer electrolyte substrates. NBR contains...