THE PERFORMANCE OF THE IONIC LIQUID-CONTAINING ELECTROACTIVE POLYMER ACTUATORS UNDER AMBIENT AIR CONDITIONS

I. Must*, I. Pöldsalu, F. Kaasik, U. Johanson, A. Punning, A. Aabloo
Intelligent Materials and Systems Laboratory, Institute of Technology, Univ. of Tartu, Estonia
* Corresponding author (indrekm@ut.ee)

Keywords: IEAP, carbide-derived carbon, ionic liquid, impedance, environmental conditions

Introduction
The stability and low melting point make ionic liquids favorable electrolytes to be used in a wide range of electrochemical systems. The application field includes lithium ion batteries, electric double-layer capacitors (EDLCs), and ionic electromechanically active polymer (iEAP) actuators.

The iEAP is a laminate structure that consists of electronically conductive high surface area electrodes bonded to the opposite sides of an ion-permeable polymeric separator [1]. When electric potential is applied between the electrodes, the laminate changes its size or shape, depicted as bending of the laminate in unobstructed cantilevered beam configuration in Figure 1. The structure of iEAPs is rather similar to the EDLCs and their energy storage properties are sometimes comparable [2].

The whole structure contains ionic liquid as an electrolyte. Ionic liquid is used due to its high stability and negligible vapor pressure, which makes possible to use the actuator devices in air. In addition to the melting point, viscosity, and conductivity; hydrophilicity data of ionic liquids is of great importance [3]. Ionic liquids are often classified to be either hydrophilic or hydrophobic; although, it has been claimed that all ionic liquids sorb considerable amount of water from the environment [4]. The water content has a considerable impact on the physiochemical properties. In some fields of application, the infusion of water into the structure must be avoided. However, there is a great demand in the industry for flexible, transparent and highly integrable electronics, which are expected to function under the atmospheric conditions.

The research on the physiochemical properties of ionic liquid-water mixtures has attracted an increasing attention in the recent years. Theories for sorption mechanisms have been proposed and water uptake kinetics has been investigated in numerous studies [3, 4], but to date only small attention has been turned on the impact of sorbed water on the performance of real electrochemical devices such as EDLCs or iEAP actuators.

In the current study, electrochemical impedance method is applied for investigation of the properties of an iEAP actuator working at different ambient conditions.

Material preparation
In the considered iEAP laminate, titanium carbide-derived carbon is used as electrode material, while Nafion is used as a separator and electrode binder. Carbide-derived carbon and Nafion are both strongly hydrophilic.

In the considered iEAP laminate, titanium carbide-derived carbon is used as electrode material, while Nafion is used as a separator and electrode binder. Carbide-derived carbon and Nafion are both strongly hydrophilic.

Fig. 1. The iEAP actuator at its maximum bending deflection at 2.8 V input voltage with opposite polarities.
current collector with 100 nm thickness is attached as the outmost layer to increase electrode conductivity. Finally, the laminate is compacted by hot-pressing. The manufacturing process and actuation properties of this material are presented in detail in [6].

**Actuation properties**

For investigation of the impact of water content on the actuation properties, the laminate is clamped between gold measurement terminals and placed in a chamber with controlled humidity and temperature. A CCD camera and a machine vision algorithm is applied to detect actuation properties. The changes in the actuation are explained by the impedance changes.

**Impedance measurements**

Impedance spectroscopy is used to characterize the properties and also analyze the working principles of the actuator material [7]. Previously, it has been shown that due to the non-ideal electrode conductivity, the actuator laminate can be modeled as a lossy transmission line consisting of distributed elements [8], and the cross-electrode impedance consists of capacitance and resistance in series, which respond to double-layer capacitance and ionic conductance. An additional resistance component describes the leakage current.

In the current research, the impedance of the laminate at various environmental conditions is measured. The results give new insights about the role of water in double-layer absorption-based electrochemical systems and evaluate the applicability of the electromechanical actuators in various ambient conditions.

**Acknowledgements**

This work was supported by the Estonian Science Foundation grants no. 7811 and 8553 and by targeted financing SF0180008s08 from the Estonian Ministry of Education.

**References**


