Design and Simulation of Electroactive Polymer-Based Artificial Muscles for Biomedical Application

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Abstract

Electro-active polymer (EAP) based actuators are one of the suitable contenders for use in artificial muscles based bio-medical application because of their bio compatibility and lower active actuation voltage requirement phenomenon. At present Ionic polymer metal composites (IPMC), a type of EAP based actuator are being developed for various applications. IPMC actuator generally consist sandwiched ionic polymer (Nafion) layer between two metal electrodes. Nafion, a perfluorosulfonated based ionic polymer, having both hydrophilic (sulfonated side chains) as well as hydrophobic (teflon backbone) region is an attractive choice of material for developing the actuators. Hydrophilic region absorbs water based electrolyte having positive and negative ionic charges, for example diluted ions such as Li+ & Cl- , Na+ & Cl- helps in ion migration and provides good proton conductivity. Teflon backbone helps to provide stability to Nafion membrane at high temperature ambient. Due to applied electric field in IPMC, ionic current is produced, which helps to migrate the hydrated cations towards cathode, causing change in osmotic pressure near the electrodes region (contraction and swelling near the anode-cathode respectively), resulting in bending of the IPMC actuator towards the anode.

In this paper we did transient study to examine the electromechanical response of IPMC actuator based on applied voltage. Initially IPMC actuator strip of 20 x 1 mm2 area (17 mm free length), with 254.5 micron thickness has been fabricated by MEMS based fabrication technique. By simulation analysis we observed the bending deformation of a rectangular strip due to counter ions migration inside the polymer-electrode layers. This actuator will be useful for analyzing the tip displacement and stress generation required for bi-directional bending of the EAP based artificial muscles. Simulation work has been carried out in COMSOL Multiphysics® software, incorporating electromechanics, ionic transport and partial differential equations (PDE). The simulation results are presented in Fig.1 showing the voltage dependent IPMC tip displacement. Fig.2 shows the simulated characteristics of IPMC actuator.Fig.3 & 4 shows the transient analysis and strip length variation based results of IPMC actuator respectively.

Reference

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Figures used in the abstract

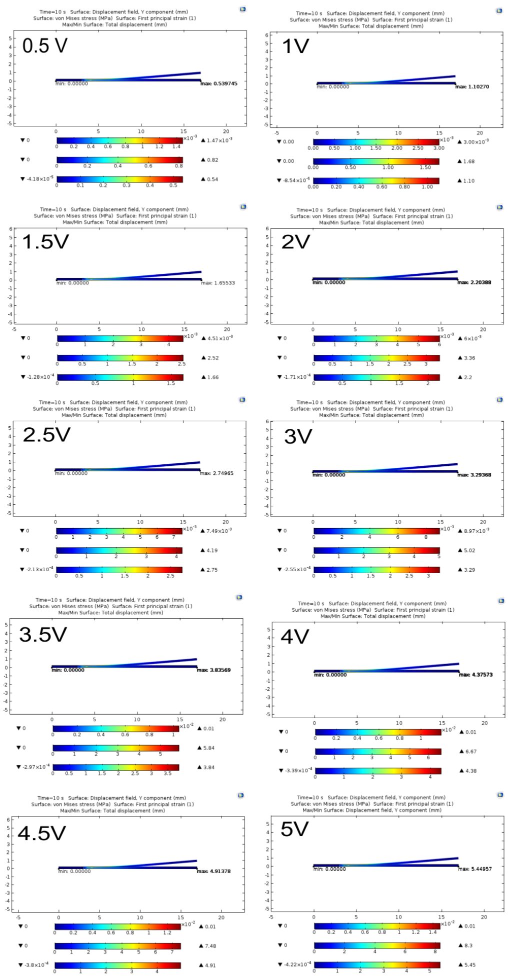

Figure 1: Voltage dependent response of IPMC actuator.

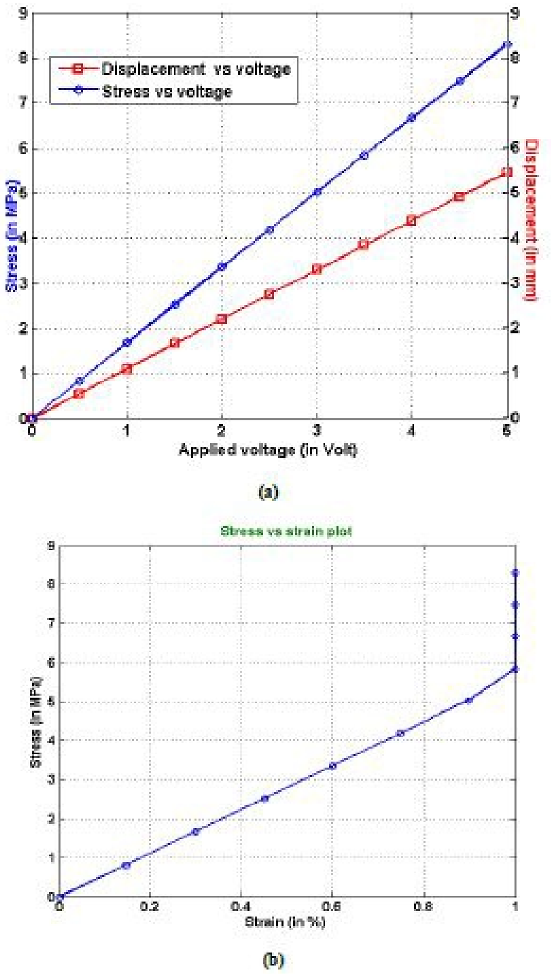

Figure 2: Simulated characteristics of IPMC actuator - (a) Stress & Displacement vs Voltage, (b) Stress vs Strain.

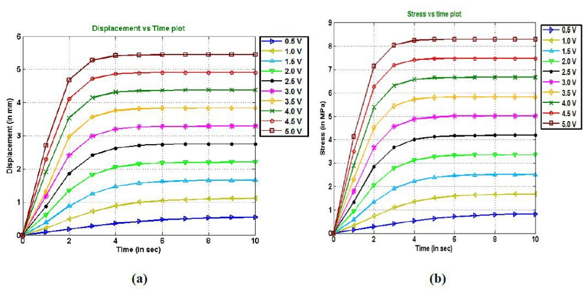

Figure 3: Transient analysis of IPMC actuator shows (a) Displacement and, (ii) Stress variation with time for various applied voltage.

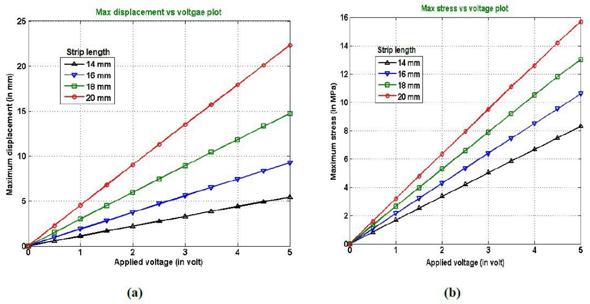

Figure 4: Variation of IPMC (a) Tip Displacement and, (b) Stress with applied voltage for different strip length.