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Interest in polymeric actuators, sensors and super capacitors has increased dramatically over the past few years due to the need for artificial muscle including hearts, shear flow sensing in water and biological applications and charge carrying species for electrical applications. Polymeric electromechanical transducers are based on an ion-exchange membrane between two conductive metal layer electrodes. Imposed deformations and small electric fields allow both sensing and actuation applications. Relative to piezoelectric electromechanical transducers, soft polymeric transducers give enhanced strain output (>1% possible), produce strain at low voltage operation (below 5V) and give high-sensitivity to small deformations in the charge-sensing mode.

Soft actuator materials based on ionic polymer transducers can produce large bending displacements when only a small voltage is applied across the membrane electrode assembly. The motion of charges from one pole to the other is produced by the electromechanical coupling effects in the ionic materials. By increasing the surface area of the electrodes, thereby increasing the capacitance, it has been recently shown that the motion of charges and actuator performance increases, thus indicating a strong correlation between the capacitance and charge motion/performance.<sup>1</sup> The large capacitance in these ionomeric materials is mainly due to the electric double layer that is formed by the electrode and mobile ions.<sup>2</sup>

By manipulating the morphology of the electrodes by enhancing the capacitance and effective interfacial area of the conductive electrodes, major effects on performance and transduction can occur. Therefore, this research employs a novel electroding technique that not only increases performance, but increases the capacitance and interfacial area of the active conductive electrodes. The current state-of-the-art electroding technique employs an impregnation-reduction method. This technique uses a platinum salt solution, PtNH<sub>2</sub>Cl<sub>2</sub>, that diffuses into the ionic membrane and is then reduced by sodium borohydride, NaBH<sub>4</sub>, to form Pt<sup>0</sup>.<sup>3</sup> However, a novel method as discussed here uses knowledge based on membrane electrode assemblies for use in fuel cells. This technique allows various metal powders, such as RuO<sub>4</sub>, Pt/C, or Pt, to be incorporated into the electrodes by mixing with dispersions of ionic polymeric materials. By first painting decals, and then hot pressing the decals to the membrane, electrode assemblies containing various morphologies have been produced.

Experimental:

Ion Exchange Membranes: Nafion 117, 1100 equivalent weight and 7 mils thick, was obtained from Electrochem Inc. and used in the proton form (Figure 1A). Disulfonated poly(arylene ether sulfone) copolymers (Figure 1B) based on biphenol and diphenyl sulfone monomers (BPSH) were synthesized, acidified and cast following the reported procedure.<sup>4</sup> Disulfonated poly(arylene thioether sulfone) copolymers (PATS) were synthesized, acidified and cast following the reported procedure (Figure 1C).<sup>5</sup>

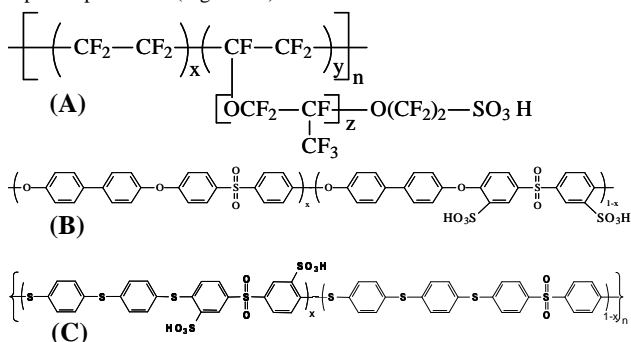


Figure 1. Chemical structures of Nafion (A), BPSH (B) and PATS (C).

Electrode Fabrication: Impregnation-reduction electroding of the ionomer membranes followed the reported procedures using four platinum layers for each membrane.<sup>6</sup> Novel polymeric electrode fabrication used a 1:1:2.5 ratio of 5 wt% Nafion 1100 dispersion in alcohols (1g dispersion) :glycerol (1g) :metal powder (0.125g). The glycerol was used as a viscosity controller and the metal powder ratio was calculated from the amount of polymer in the dispersion. Sonication and stirring allowed good dispersion of the metal powder. The dispersion was then painted onto glass fiber reinforced Teflon decals and allowed to dry. The membrane electrode assembly was then fabricated by hot pressing at a temperature of 210 °C and a pressure of 2500 lbsF.

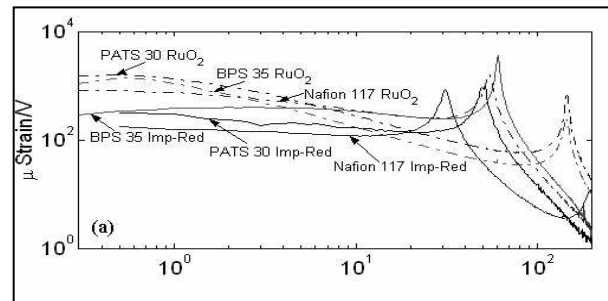


Figure 2. Frequency vs. displacement of Nafion 117, BPSH 35, and PATS 30. for both impregnation-reduction electroding (solid lines) and the novel electrode fabrication technique based on RuO<sub>2</sub> metal powder (dashed lines).

Results and Conclusions: Transducer actuation/performance at lower frequencies was enhanced by employing the novel electrode fabrication technique based on RuO<sub>2</sub> (Figure 2). At higher frequencies, mass transport and interfacial resistance appear to play pivotal roles in actuator performance.

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