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INORGANIC PROTON EXCHANGE MEMBRANES

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ABSTRACT

Direct Methanol Fuel Cells (DMFCs) offer advantages from quick refills to the elimination of recharge times. They show the most potential in efficient chemical to electrical energy conversion, but currently one major source of inefficiency within the DMFC system is the electrolyte allowing fuel to cross over from the anode to cathode. Proprietary DuPont^{TM}Nafion®117 has been the standard polymer electrolyte thus far for all meso-scale direct methanol power conversion systems, and its shortcomings consist primarily of slow anodic reaction rates and fuel crossover resulting in lower voltage generation or mixed potential.

Porous Silicon (P-Si) is traditionally used in photovoltaic and photoluminescence applications but rarely used as a mechanical filter or membrane. This research deals with investigations into using P-Si as a functioning electrolyte to transfer ions from the anode to cathode of a DMFC and the consequences of stacking multiple layers of anodes.

Porous silicon was fabricated in a standard Teflon cylindrical cell by an anodization process which varied the current density to etch and electro-polish the silicon membrane. The result was a porous silicon membrane with approximately 1.5 μm pore sizes when optically characterized by a scanning electron microscope. The porous membranes were then coated in approximately 0.2 mg/cm^2 Pt-Ru catalyst with a 10% Nafion®solution binding agent onto the anode. Voltage versus current data shows an open circuit voltage (OCV) of 0.25V was achieved with one layer when operating at 20^{o}C. When adding a second porous silicon layer, the OCV was raised to approximately 0.32V under the same conditions. The experimental data suggested that the current collected also increased with an additional identical layer of anode prepared the same way. The single difference was that the air cathode side was surface treated with 0.1 mg of Pt black catalyst combined with a 10% Nafion®binding agent to aid in the recombination of hydrogen atoms to form the water byproduct. Porous silicon endurance runs with 2ml of 3% by volume methanol (0.7425M) fuel dissolved in water showed an operating voltage was generated for approximately 3 hours before the level dropped to approximately 65% of the 0.25V maximum voltage. Endurance runs with a second layer added extended the useful cell life to approximately 5 hours under the same conditions. In an effort to quantify these layering results, Fourier Transform Infrared Spectrometry was conducted on a number of samples to verify decreased methanol concentration present in the second layer.

Keywords: direct methanol fuel cell, DMFC, porous silicon, DuPont^{TM}Nafion®117

INTRODUCTION

While hydrogen fuel cells are arguably the best in terms of performance and waste byproducts, DMFCs show similar promise in efficient chemical to electrical energy conversion without the negative fuel containment issues. Methanol fuel has about half the specific energy of gasoline at 5.54 kW-hr/kg (19.9