

A New Method to Study Permeation of Gases in Proton Conducting Membranes

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A new method to study permeation of gases in proton conducting membranes using a cylindrical microelectrode is presented. The focus of this work was to develop an in-situ method to study transport properties of hydrogen and oxygen close to real fuel cell operating conditions. The gas permeability is strongly affected by the change of water content in the membrane and it is therefore of advantage that, by using this method, measurements can be carried out at a wide range of relative humidities and at elevated temperatures. The method makes it possible to separate the diffusion coefficient and the concentration of dissolved gas in the membrane and can be used on different types of proton conducting membranes.

A numerical model was constructed using Fick's first and second law in cylindrical coordinates and an expression of the kinetically controlled current¹. The model was validated comparing calculated data to data obtained using the expression of the diffusion limiting current in the case of cylindrical diffusion, developed by Aoki et al¹. Numerical evaluation of experimental results was carried out by means of least-squares fitting, adjusting the diffusion coefficient and the concentration in the numerical model.

To prepare a cylindrical microelectrode, a platinum wire ($r_s=12.5 \mu\text{m}$, $l=8.5 \text{ mm}$) was hot-pressed between two Nafion 117 samples at a temperature of 160 °C for 5 minutes to ensure a good contact between the membrane and the wire. Two commercial fuel cell electrodes with gas backing (Elat/HL/DS/V2, Double Sided, 20% Pt/C, 1.0 mg/cm² Pt loading) were placed on each side of the sandwich construction so that the catalyst layers and the wire formed a microelectrode assembly. One of the catalyst layers acted as counter electrode and the other as a quasi-reference electrode. This membrane-microelectrode combination replaces the ordinary MEA in the fuel cell.

The experiments were carried out in hydrogen and oxygen atmosphere at a range of temperatures and relative humidities and the values of D and c_{bulk} were obtained by fitting the numerical model to the chronoamperometric results. The calculated current responses agree well to experimental data even at high temperatures and low relative humidities. Solubility and diffusion coefficients of oxygen and hydrogen at a temperature of 60 °C as a function of relative humidity are presented in Fig. 1.

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References

1. Peter Gode, Göran Lindbergh, Göran Sundholm, submitted to J. Electroanal. Chem.
2. K. Aoki, K. Honda, K. Tokuda and H. Matsuda, J. Electroanal. Chem., 186 (1985) 79.

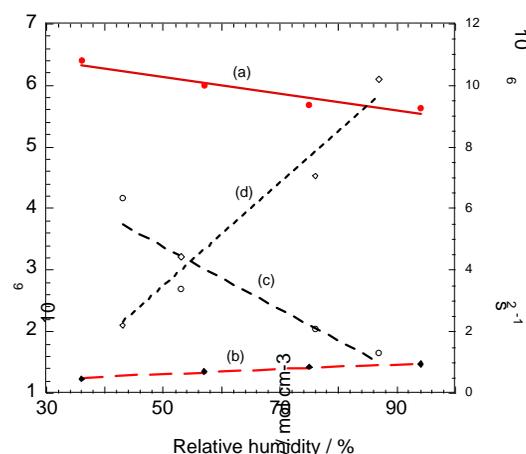


Fig. 1. Experimental data for Nafion 117 at 60 °C and 1 atm pressure. (a) Solubility and (b) diffusivity of oxygen gas. (c) Solubility and (d) diffusivity of hydrogen gas.