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In-situ Measurement of Oxygen Partial Pressure in the Cathode Flow Field with Hydrophilic Surface

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Oxygen concentration in the cathode flowfield is vital for the performance of proton exchange membrane fuel cells (PEMFC). Particularly, providing high oxygen concentration at high current density operations is critically important to enhance the area specific power density, which is a significant opportunity to reduce the total active area of the membrane electrode assembly (MEA). In the PEMFC, oxygen concentration at the oxygen reduction reaction (ORR) area is locally lowered by imbalanced oxidant flow distribution and/or unsatisfactory water management. A recent publication introduced a novel method to directly detect oxygen partial pressure in the cathode flowfield while the fuel cell is operating [1, 2, 3]. The principle of this measurement is to use fluorophore molecules which are sensitive to oxygen quenching, as described by the Stern-Volmer equation. A platinum porphyrin based fluorophore shows strong oxygen quenching sensitivity and is used with the polymer binder to form the fluorophore layer and is exposed to the cathode gas flow field in the visualization cell. The higher oxygen partial pressure promotes oxygen quenching; therefore, the intensity of the fluorescent luminescence is lower. From previous work by T. Ono et al [3], the oxygen partial pressure was measured at approximately 25 kPa. Meanwhile, the oxygen partial pressure of a typical high end operating condition is significantly higher, e.g. the cathode air pressure is around 2.5 bar and about 53 kPa oxygen partial pressure in the dry operating state. It is necessary to be within these operational limits to obtain these useful data.

In this study, a different binder material composition is used to extend the measurement limit. Poly-heptafluoro-n-butly methacrylate-co-hexafluroisopropyl methacrylate (FIB polymer) is used as binder with the same platinum porphyrin base fluorophore. The intensity of this fluorophore layer covers up to 53 kPa of oxygen partial pressure which is within the typical operating condition range of an automotive PEMFC. This significant characteristic change of fluorescent luminescence is considered as a change of the quenching rate by the composition of the polymer binder material. Measurement of oxygen partial pressure shows good reproducibility with various pressures (Figure 1). The FIB polymer also exhibits suitable oxygen permeability. However, the glass transition temperature is around 60 degrees C; therefore it hasn't been recommended to use this fluorophore for oxygen measurement above this temperature. The normal operating temperature of an automotive PEMFC is 60 to 90 degree C. Figure 2 shows temperature sensitivities of this measurement system between 40 to 90 degrees C. This fluorophore exhibits stable operating characteristics, even though it is operated above the transition temperature of this binder. The surface of the fluorophore layer with this binder is hydrophobic. Additional experiments were performed to observe the effects of using a hydrophilic surface treatment. Figure 3 shows oxygen mapping in the cathode flow field with and without a hydrophilic surface treatment. The hydrophilic treated cathode flow field surface exhibited an evenly distributed partial pressure map and significantly better performance.

The polymer binder modification and surface treatment described in this report enabled accurate *in-situ* oxygen partial pressure measurements in the cathode flow field. The partial pressure maps could be used to characterize fuel cell flow field design and material selection to mitigate areas of low oxygen concentrations which would result in enhancing the area specific power density for various operating conditions.

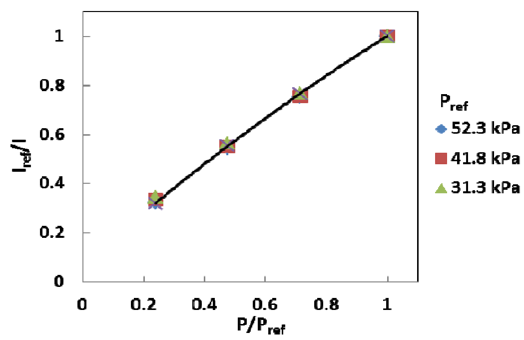

Figure 1: Stern-Volmer plots with various reference oxygen partial pressures at 80 degree C.

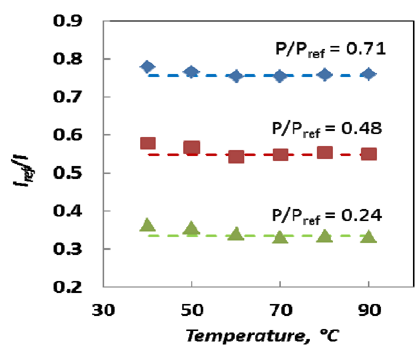

Figure 2: Temperature sensitivity of Stern-Volmer relationship with various oxygen partial pressures

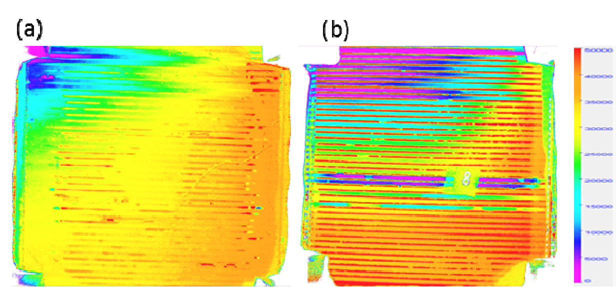

Figure 3: Oxygen partial pressure distributions in the cathode flow field at 0.5 A/cm2, H2/Air (λ=2), 70 degree C, Dew Point 60 degree C, (a) hydrophilic surface, (b) hydrophobic surface.

Reference

1. J. Inukai, *et. al*, Angewandte Chemie International Edition, 47(15):2792-2795
2. T. Hyakutake, *et. al*, Macromolecular Chemistry and Physics, 212(1):42-47
3. T. Ono, *et. al*., Shimadzu Review, Vol. 67, No. 1-2 (2010), 71-76