Membraneless Fuel Cells: their Pros and Cons

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Current efforts to develop micro fuel cells have mostly focused on polymer electrolyte membrane (PEM)-based designs. However, several technological challenges have prevented wide scale introduction of these fuel cells into commercial applications to date. Two of these technological challenges are fuel crossover and membrane dry out, with most of the direct liquid fuel cells employing methanol as the fuel. Recently we have developed a *membraneless* fuel cell that utilizes a characteristic of fluid flow at the microscale, *laminar flow*, to keep two streams containing fuel and oxidant, respectively, separated while still in diffusional contact (Fig. 1).[1] Two physicochemical phenomena govern the chemical conversion and accompanied energy and mass transport phenomena in these laminar flow-based fuel cells: depletion of reactants at the electrode walls and diffusion across the mutual liquid-liquid interface. The membraneless fuel cell system eliminates several of the technical issues related to the use of polymer electrolyte membranes including the occurrence of fuel crossover and membrane dry out. In addition, the membraneless design is less complicated and thus easier/cheaper in fabrication and assembly. In this paper the characteristics of membraneless microfuel cells will be discussed and compared to more conventional membrane-based fuel cell technology.

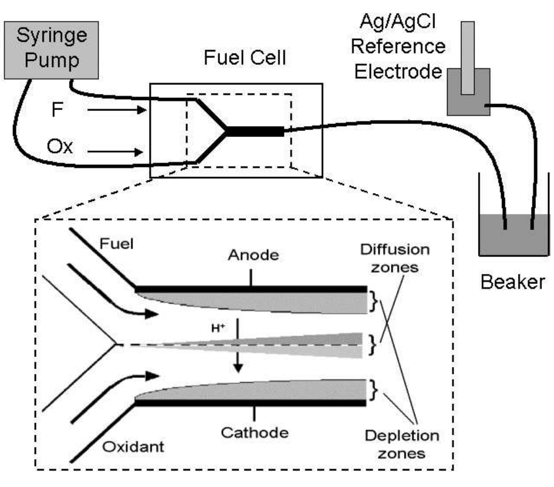

Figure 1. Schematic of a membraneless fuel cell with an external reference electrode for system characterization.

Integration of an external reference electrode, as schematically shown in Fig. 1, has enabled the assessment of the performance of the anode and cathode separately and simultaneously in a single experiment. This allows for the determination of the limiting factor of the membraneless fuel cell and also makes use of the membraneless fuel cell possible as a tool for the optimization of catalyst under true fuel cell conditions.

Individual anode and cathode load curves of the membraneless fuel cell recorded using the external electrode indicate that the system is cathode limited by mass transfer at current densities > 7 mA/cm^2 (Fig. 2). The oxidant-containing stream is depleted first, as expected, due to the low solubility of oxygen in water. In other cases the cathode (or anode) was limited by electrode kinetics and an immediate drop-of of the potential at low current densities was observed with the two curves approaching each other asymptotically. When using other oxidants, such as permanganate, power densities of at least 50 mA/cm^2 can be obtained. This paper will present a range of fuel cell performance data using methanol or formic acid as the fuel.

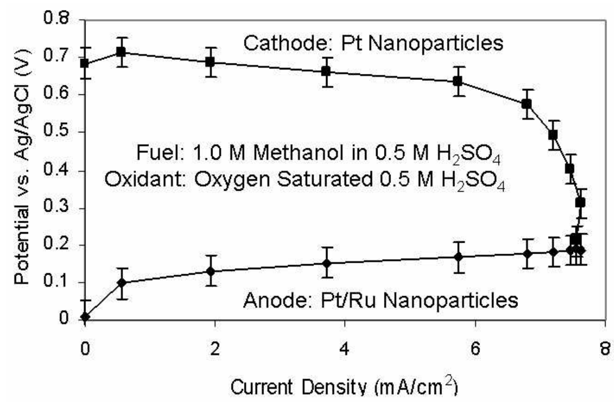

Figure 2. Reference electrode experiments to isolate cathode and anode performance of a laminar flow-based microfuel cell.

In order to further increase the performance of these membraneless fuel cells we have developed microfluidic channel designs that allow for the introduction of fuel and oxidant streams through multiple inlets along the electrodes, which enables replenishment of the depleted boundary layer, thereby improving the fuel utilization of the laminar flow based microfuel cell. Extensive modeling in FEMLAB software through linking the momentum and mass transfer equations with experimental data from detailed electrochemical characterization, allowed for optimization of the inlet-to-inlet distances.

In sum, the design and characterization of a novel, membraneless microfuel cell will be discussed. will be discussed. Also, are current efforts in improving fuel cell performance by adjustment of operation conditions, microfluidic channel designs, introduction of different catalysts and different fuels will be discussed. Finally, the advantages and disadvantages of these membraneless microfuel cells will be compared with those of the more conventional membrane based (direct methanol) fuel cells. At this point it is unclear whether the membrane-less fuel cell *as a system* will be superior over existing PEM-based microfuel cell technology. In this respect, we foresee that minimization of parasitic losses due to the need to pump the fuel and oxidant streams, and increasing the fuel utilization, for example through recirculation, will be key.

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References

1. E.R. Choban, L.J. Markoski, A. Wieckowski, P.J.A. Kenis, *Micro-Fluidic Fuel Cell Based on Laminar Flow. J. Power Sources*, 2004,**128**, 54-60.