

One step direct deposition of durable cathodes for high temperature Proton Exchange Membrane Fuel Cells (PEMFC)

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PEMFCs are typically operated at temperatures around 80°C. At these low temperatures, several issues have been identified: (1) Slow reaction kinetics, particularly for the ORR, which hinders cell performance even at very high Pt loading; (2) Low tolerance of the catalyst towards impurities; (3) Slow heat rejection; and (4) Complex water management [1]. To overcome these disadvantages, fuel cell operation at 95 °C or higher is desirable. Currently, well-developed PEMFC technology is based on perfluorosulfonic acid (PFSA) polymer membranes (e.g., Nafion®) [2]. These systems face two main limitations, which does not allow for PEMFC systems that operate at elevated temperatures. First, PFSA polymer membranes require excessive humidification to maintain ionic conductivities high enough for PEMFC applications. This complicates the design of the fuel cell system balance of plant. Secondly, CO impurities seriously poison the Pt/C catalysts below 100 °C. To address the limitations of PFSA-based PEMFCs, researchers have recently developed a H₃PO₄/PBI HT-PEMFC that operates at temperatures around 120 °C without humidification [3]. This not only resolves the above mentioned problems, but also provides other advantages such as enhanced reaction kinetics at both electrodes, elimination of cathode flooding from water management issues and simplified heat management [4]. However there are two key issues with H₃PO₄/PBI-based HT-PEMFCs: 1) oxygen has limited permeability and slow reduction kinetics in phosphoric acid compared to sulfonic acid; and 2) phosphoric acid can be lost in the HT-PEMFC exhaust (phosphates and impurities can also adsorb on platinum).

In an electrochemical system, the redox reactions take place at a three-phase boundary where the electrolyte, electrocatalyst and gaseous reactants are all in intimate contact. This three phase boundary directly dictates the Pt electrochemically active area and utilization. The extent of the three-phase domain depends significantly on the electrode fabrication procedure.

In this study Reactive Spray Deposition Technology (RSDT) was used as a single-step dry process to deposit the electrodes (catalyst, support, ionomer) onto the electrolyte membrane. In the RSDT process, a thin-film catalyst layer is directly deposited onto the polymer electrolyte through a flame-initiated mechanism. RSDT not only has more precise control over electrode microstructure and component-level dispersion than traditional ink processes, it also eliminates several traditional manufacturing steps [5]. The RSDT method also allows for direct catalyst coated membrane (CCM) depositions onto the polymer electrolyte at temperatures below 100°C. CCMs have significant benefits over GDE

based MEAs, including improved contact between the catalyst layer, lower electrolyte reducing contact resistance, and improved catalyst utilization. A gas quench is incorporated into the RSDT process that allows for the introduction of carbon and ionomer at lower temperatures than the primary flame zone, which prevents thermal damage during deposition.

The membranes under study included a Celtec-P polybenzimidazole based membrane. Catalyst layers with platinum loading of 0.3 mg/cm² and electrode thickness of ~4 μm were produced; see Figure 1. Observations on the physical, microstructural and electrochemical properties of the RSDT produced catalysts will be presented along with 25 cm² electrochemical full cell tests.

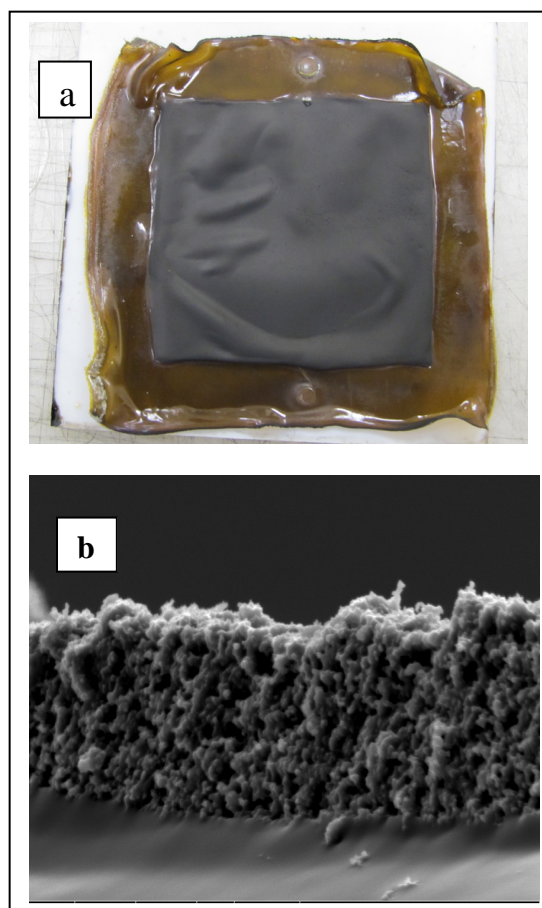


Figure 1. a) PBI CCM structures prepared by RSDT; b) SEM image of 5 μm thick Pt-carbon-PBI.

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