Air Breathing MnO_2 Cathodes in Alkaline Electrolytes

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Inexpensive cathodes for alkaline based batteries and fuel cells are desired that can operate with ambient air. Using manganese oxide, MnO_2, we have developed electrodes on metallic nickel current collectors that are amenable to being flexed and rolled into cylindrical geometries. These electrodes have been optimized to operate with a 30% KOH electrolyte matrix placed on one side and ambient air diffusion on the opposing side.

Electrode slurry solutions containing MnO_2, carbon, binders, and solvents were developed that could be painted or rolled onto nickel current collectors. In support of using the cathodes in rolled cylindrical configurations, lateral electrical conductivity in the electrode and current collector assembly was characterized via mathematical models. Electrode layers of MnO_2 and carbon on expanded metal current collectors of varying thicknesses and mesh openings were modeled using finite element methods to describe the voltage drop over lateral dimensions. Selected expanded metal current collectors were coated with MnO_2 and evaluated using cyclic voltammetry as shown in Figure 1 for reducing oxygen in air. Experimental results supported modeling data in using an expanded metal current collector that was 3 mils thick with a mesh opening of 50 mils.

Electrical resistivities of just the electrode layers were measured using 4-pt probe and AC impedance methods. A resisitivity of 3.3 ohm-cm has been obtained with modest optimization of the electrode slurry solution with a targeted goal of 1 ohm-cm identified via modeling studies. Pre- and post-flex resistivity tests of the coated current collectors were also measured in support of flexible electrode/current collectors that could be wrapped into cylindrical configurations. The results indicated that by incorporating a small quantity of latex into the electrode ink we could obtain a flexible electrode structure without deleterious effects on its performance or electrical conductivity.

Optimization of the electrode slurry was examined by varying the content of MnO_2, carbon, binders, and solvents to obtain an ink that could be painted or rolled onto metallic current collectors. To assess the behavior of the cathodes for reducing ambient oxygen in air in an alkaline electrolyte, we set up an alkaline fuel cell apparatus that used a standard platinum/carbon gas-diffusion electrode for the anode, a 30% KOH electrolyte imbibed into a separator, and our MnO_2 coated current collectors on the cathode. The end-plate for the cathode side of the cell was an open-window design allowing ambient air to diffuse normal to the cathode electrode. Figure 2 shows the results for increasing manganese oxide loading ranging from 0 to 4.5 mg MnO_2/cm^2. Increased polarization behavior is shown for increased MnO_2 loadings.

A comparison of the catalytic behavior of MnO_2 for reducing oxygen in air was compared to platinum in support of using these cathodes for alkaline fuel cells. A platinum based gas-diffusion electrode with a platinum loading of 0.65 mg/cm^2 was used with ambient air in comparison to a 12.7 mg/cm^2 MnO_2 electrode. Figure 3 shows the polarization behavior indicating comparable performance in the activation region for the two different catalyst systems. Given the large cost difference between platinum and MnO_2, the use of MnO_2 will allow for an inexpensive cathode that can operate with ambient air in an alkaline environment.

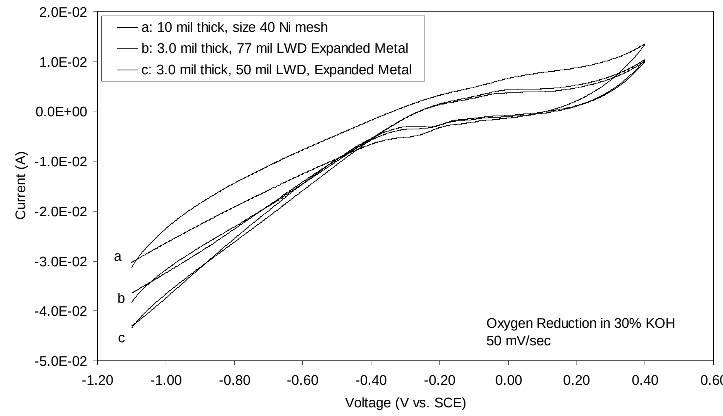

Figure 1. Oxygen reduction in 30% KOH on MnO_2 cathodes supported on varying nickel current collectors

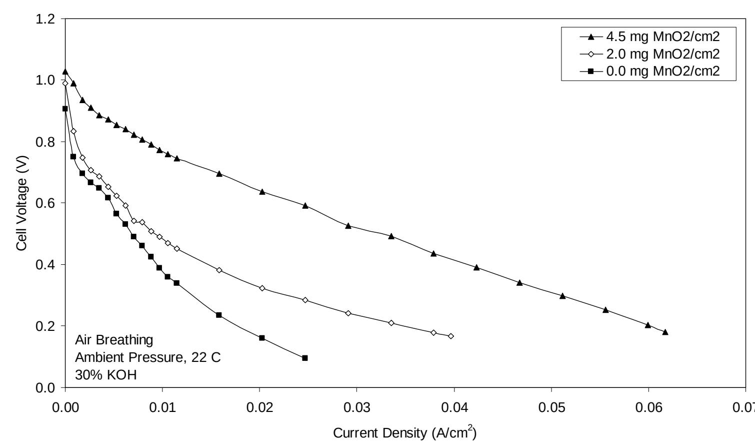

Figure 2. Comparison of MnO_2 loadings on ambient air reduction in 30% KOH

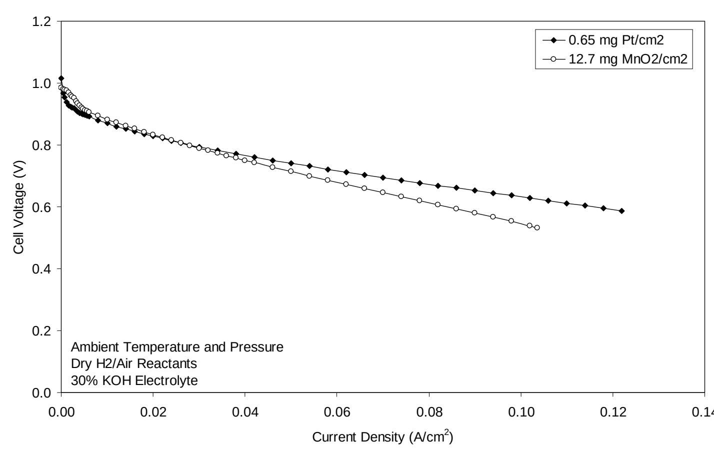

Figure 3. Comparison of MnO_2 and platinum catalysts on ambient air reduction in 30% KOH

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