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RECENT ADVANCES IN SOLID POLYMER ELECTROLYTE FUEL CELL TECHNOLOGY WITH LOW PLATINUM LOADING ELECTRODES

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There is great enthusiasm for the development of high power density fuel cell systems for defense and civilian applications. Taking into consideration the main causes for efficiency losses--activation, mass transport and ohmic overpotentials--the only fuel cell systems capable of achieving high power densities are the ones with alkaline and solid polymer electrolyte. High power densities (0.8 W/cm^2 at 0.8 V and 1 A/cm^2 with H_2 and O_2 as reactants), have already been well demonstrated in the International Fuel Cells/United Technologies Corporation alkaline fuel cell systems used in NASA's Apollo and Space Shuttle flights as auxiliary power sources. Even higher power densities (4 W/cm^2 - i.e., 8 A/cm^2 at 0.5 V) have been reported by the USAF/International Fuel Cells in advanced versions of the alkaline system.

Historically, the first type of fuel cell system to find a major application (auxiliary power source in the Gemini Space Vehicles) is the one with solid polymer electrolyte as the electrolyte. These fuel cell systems were developed by the General Electric Company. Since the sixties, great strides have been made in increasing the power density from 50 mW/cm^2 to about $2\text{-}3 \text{ W/cm}^2$. The latter performance was achieved at Ballard Technologies Corporation which used practically the same technology as General Electric Company/United Technologies Corporation--Hamilton Standard. The platinum loading in these fuel cells is 4 mg/cm^2 on each electrode.

Research and Development at Los Alamos National Laboratory and in our laboratory has led to the attainment of high power densities ($\approx 1 \text{ watt/cm}^2$) in solid polymer electrolyte fuel cells with ten times lower platinum loading in the electrodes (i.e., 0.4 mg/cm^2). The necessary criteria and the methods used to attain these goals are as follows:

- (1) Extension of the three dimensional reaction zone by the impregnation of a proton conductor (i.e., the ion-exchange membrane) into the electrode structure.
- (2) Hot pressing of the proton-exchange membrane and electrodes at a temperature above the glass transition temperature and at a pressure of 50 atm .
- (3) Adequate humidification of the reactant gases by passing these gases through humidification chambers set at temperatures of 10°C for H_2 and 5°C for oxygen or air higher than the cell temperature.
- (4) Enhancement of the electrode kinetics of the hydrogen oxidation and the oxygen reduction reactions and particularly of the mass transport rates of the reactant gases to the electrode by operation at elevated temperatures and pressures, say 95°C and 5 atm .
- (5) Localization of the platinum near the front surface of the electrode to reduce the thickness of the active layer and provide a higher concentration of platinum sites on the front surface to reduce mass transport and ohmic overpotentials within the porous electrode and at the electrode/electrolyte interface.

- (6) Improvement of the conductivity and water retention of the solid polymer electrolyte by use of perfluorinated sulfonic acid membranes with lower equivalent weight (i.e., more sulfonic acid groups per polymer molecule) than Nafion.

Using all the above methods, it is now possible to reach a cell potential of 0.620 V at a current density of 2 A/cm^2 and at a temperature of 95°C and pressure of $4/5 \text{ atm}$ with H_2/O_2 as reactants. The slope of the linear region of the potential-current density plot for this case is 0.15 ohm-cm^2 . With H_2/air as reactants and under the same operating conditions, mass transport limitations are encountered at current densities above 1.4 A/cm^2 . Thus, the cell potential at 1 A/cm^2 with H_2/air as reactants is less than that with H_2/O_2 as reactants by 40 mV, which is the expected value based on electrode kinetics of the oxygen reduction reaction, and at 2 A/cm^2 with H_2/air as reactant is less than the corresponding value with H_2/O_2 as reactants by 250 mV, which is due to the considerably greater mass transport limitations in the former case.