DEVELOPMENT OF DIRECT ETHANOL FUEL CELL

by

HIRALAL PRAMANIK

Chemical Engineering Department

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Ethanol (2) Fuel cells

Dedicated to my parents,

wife and son

CERTIFICATE

This is to certify that the thesis entitled **Development of direct ethanol fuel cell**, being submitted by **Mr. Hiralal Pramanik** to the Indian Institute of Technology Delhi is a record of bonafide research work carried out by him. He has worked under my guidance and supervision and has fulfilled the requirements, which to my knowledge, has reached requisite standard for the submission of this thesis. The results contained in this thesis have not been submitted in part or full to any University or Institute for the award of any degree or diploma.

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(Dr. Suddhasatwa Basu)
Associate Professor
Department of Chemical Engineering
Indian Institute of Technology Delhi
New Delhi-110016, India.

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(HIRALAL PRAMANIK)

ABSTRACT

Energy independence is the key to the economic growth and development of any country. The energy needs are generally provided from fossils fuel using internal combustion engine and thermal power plant. The problems of limited resources and environmental pollution by fossil fuel have given momentum to think over the alternative energy generating methods using renewable resources. The fuel cell technology is found very promising device for converting chemical energy into electrical energy using hydrogen or hydrogen rich organic and inorganic compounds. Towards this approach, a direct ethanol fuel cell is developed for the use of ethanol directly as fuel. The use of ethanol fuel in the half-cell studies in acid medium and as well as scanty literature on fuel cell are reported but the complete analyses are not discussed in the open literature.

The electrode prepared using noble metal electrode-catalysts, Pt-Ru (40%:20% by wt.)/C or Pt-black HSA or Pt (40% by wt.)/C, were tested as anode and cathode. The electrodes are prepared by spreading electrode-catalysts slurry on the carbon paper using paint brush technique and the electrodes were sintered at high temperature. The sintered electrodes are characterized by scanning electron micrography and cyclic voltammetry in half-cell mode using three-electrode cell assembly. The oxidation and reduction reaction mechanisms at anode and cathode are derived based on analyses of the reaction products, results of cyclic voltammetry and literature data for the ethanol fuel under study.

The electrodes prepared were placed on either side of the cast Nafion® membrane and hot pressed to prepare Membrane Electrode Assembly (MEA). The prepared membrane electrode assembly was used to fabricate the direct ethanol fuel cell. A stainless steel plate or a Ni-mesh was used as current collector. The current density-cell voltage characteristics of the cell was determined by measuring voltage and current by varying load. The experimental parameters studied are concentration of ethanol, different type of electrode-catalysts at anode and cathode, electrode-catalysts loading, temperature, oxidant at cathode (air/oxygen), such that maximum power density is obtained. It should be noted that the cell was operated under temperature gradient. The maximum power density obtained is 10.27 mW cm^{-2} for 2M ethanol concentration at a temperature of 90 °C anode and 60 °C cathode with Pt-Ru (40%:20% by wt.)/C anode and Pt-black HSA cathode with 1 mg/cm^2 of loading. The maximum open circuit voltage of 0.815V was obtained for 2M ethanol with Pt-Ru (40%:20% by wt.)/C anode at 90 °C and Pt-black HSA cathode at 60 °C. The cell performance increases initially with the increase in ethanol concentrations from 1M to 2M and then it decreases with further increase in ethanol concentration. The Pt-Ru (40%:20% by wt.)/C at anode and Pt-black HSA at cathode give best performance in terms of power density obtained. The fuel cell performance improves with the increase in anode and cathode electrode-catalysts loading however beyond electrode-catalysts loading of 1 mg cm^{-2} the performance does not increase appreciably. The performance of DEFC increases with the increase in temperature because of higher reaction rate kinetics and decrease in activation overpotential. The maximum cell performance is observed at a temperature of anode 90 °C and cathode 60 °C. As temperature is further increased, the performance of direct ethanol fuel cell decreases. The DEFC performance was checked with different types of polymer electrolyte membrane (Nafion® SE-5112, 80% and 63% sulfonated polyether

ether ketone membranes). MEA prepared from Nafion® membrane gives higher performance of DEFC compared to that prepared from 80% and 63 % sulfonated PEEK membranes. The direct ethanol fuel cell performance increases significantly with the use of sulfuric acid in ethanol compared to that of no sulfuric acid use. However, the DEFC performance increases slightly with the increase in sulfuric acid proportion in ethanol.

A mathematical model for the direct ethanol fuel cell is developed based on reaction mechanism proposed earlier. The model takes into account activation, ohmic and concentration overpotentials and it provides cell voltage at a given current density. The model prediction is in reasonable agreement with the experimental data on j-v characteristics. The influence of process variables such as, ethanol concentration and cell temperature on the prediction of cell performance is reasonably reflected in the model.

The stability test of direct ethanol fuel cell was performed with different anode electrode-catalysts (Pt-Ru/C, Pt-black and Pt/C of 1 mg cm^{-2}) for 60 hours at a constant load to analyse the durability of the DEFC. Cathode was made of Pt-black HSA. The voltage of 0.570V, 0.470V and 0.250V were obtained at a current density of 10.70 mA cm^{-2}, 10 mA cm^{-2} and 8 mA cm^{-2} for Pt-Ru (40%:20% by wt.)/C, Pt-black HSA and Pt (40% by wt.)/C, respectively. The calculated efficiency of direct ethanol fuel cell with Pt-Ru/C (1 mg/cm^2) anode and Pt-black HSA (1 mg/cm^2) cathode is about 0.30 at a maximum power density of 7.83 mW cm^{-2} (temperature 42 °C ; pressure 1 bar). Thus, it is needless to say, DEFC based on PEM technology could someday be used to draw motive power (automobile) and as well as stationary power plant.

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