DEVELOPMENT OF AN ALKALINE FUEL CELL FOR DIRECT USE OF LIQUID FUELS

by

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Fuel Cell 2. Liquid fuels

Imagination

is more important than

knowledge

- Albert Einstein

Dedicated to my parents,

wife, son

and family members

CERTIFICATE

This is to certify that the thesis entitled **Development of an alkaline fuel cell for direct use of liquid fuels,** being submitted by **Mr. Anil Verma** to the Indian Institute of Technology Delhi is a record of bonafide research work carried out by him. He has worked under my guidancc and supervision and has fulfilled the requirements, which to my knowledge, has reached the 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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ABSTRACT

Extent of energy generation and its use is the backbone of growth for any country. The energy needs are generally provided from fossil fuels using internal combustion engine and thermal power plant. The problems of limited resources and environmental pollution by fossil fuel have given thrust to the search for the alternative energy generating methods using renewable resources. Fuel cell technology is found very promising as an alternative method for converting chemical energy into electrical energy using hydrogen or hydrogen rich organic and inorganic compounds. Towards this approach, an alkaline fuel cell with liquid potassium hydroxide solution as an electrolyte is developed for the direct use of methanol, ethanol or sodium borohydride as fuel. The use of these fuels in the half-cell studies in alkaline medium is reported by investigators but the complete cell analyses are not discussed in the open literature.

Electrode prepared using noble metal catalysts, e.g. Pt-black or Pt/Ru (40%:20% by wt.)/C or Pt/C (40% by wt.), acts as anode and non noble metal catalyst, MnO_2 acts as cathode. The electrodes are prepared by spreading catalyst slurry on the carbon paper using paint brush technique. Nickel mesh is used as current collector. The 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 deduced based on analyses of the reaction products, results of cyclic voltammetry and literature data for the three fuels under study.

The prepared electrodes were used to fabricate the direct methanol or ethanol or sodium borohydride alkaline fuel cell. The current density-cell voltage characteristics of the cell was determined by measuring voltage and current by varying experimental

parameters e.g., electrolyte concentration, fuel concentration, temperature, catalyst type and catalyst loading at anode and cathode. The maximum power density obtained is 15 mW cm^{-2} with 3M KOH electrolyte concentration and 2M methanol concentration at 25°C with Pt-black loading of 1 mg cm^{-2} at anode and MnO_2 loading of 3 mg cm^{-2} at cathode. In similar conditions, the power density of 16 mW cm^{-2} and 21.5 mW cm^{-2} were obtained for ethanol and $NaBH_4$, respectively. The cell performance increases initially with the increase in catalyst loading at cathode and anode, electrolyte (KOH) and fuel (methanol or ethanol or sodium borohydride) concentrations and then decreases with further increase of the same. The performance of the fuel cell increases with increase in temperature for methanol and ethanol alkaline fuel cell. However, the cell performance does not increase proportionally with the increase in temperature for direct $NaBH_4$ alkaline fuel cell. These observations are explained based on the electrochemical reaction mechanisms. Lifetime testing of direct alkaline fuel cell with different fuel is evaluated. It is found that the alkaline fuel cell with ethanol as fuel has lifetime of more than 400 hours at 0.5 V, while the lifetimes for methanol and sodium borohydride based alkaline fuel cells are more than 380 and 510 hours, respectively. The performance of alkaline fuel cell could be restored by acid treatment of the electrodes.

A mathematical model for the direct methanol or ethanol or sodium borohydride alkaline fuel cell is developed based on reaction mechanism proposed earlier. The model takes into account activation, ohmic and concentration overpotentials and it provides cell potential for a given range of current density. The model prediction is in fair agreement with the experimental data on j-v characteristics. The influence of process variables such as, electrolyte concentration, fuel concentration and temperature on the prediction of cell performance is fairly well reflected in the model.

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