DEVELOPMENT OF ANODE CATALYSTS FOR DIRECT GLUCOSE ALKALINE FUEL CELL

by

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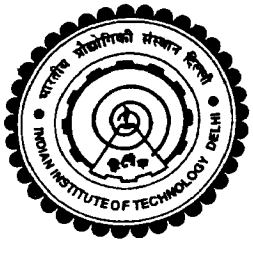
Submitted

in fulfillment of the requirements of the degree of

Doctor of Philosophy

to the



INDIAN INSTITUTE OF TECHNOLOGY DELHI

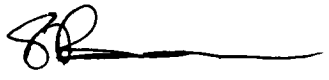
January 2012

Dedicated to my husband

Mr. Partha Sarathi Chandra

CERTIFICATE

This is to certify that the thesis entitled **Development of anode catalysts for direct glucose alkaline fuel cell,** being submitted by **Ms. Debika Basu** to the Indian Institute of Technology Delhi is a record of bona fide research work carried out by her. She has worked under my guidance 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

With an increasing demand of pollution free and cheap energy, investigators are focusing research on fuel cell technology. Recently, investigators have started working on metal catalysed direct glucose fuel cell (DGFC) which can be used in medical implants and non-enzymatic glucose sensors and also for powering small portable electronic instruments. In the present investigation, carbon supported platinum based bi- and tri- metallic catalysts with low metal loading (ca. 15 wt. %) are synthesized and tested to determine efficiency and stability towards glucose electro-oxidation through half-cell studies. The prepared electro-catalysts are then used as anode catalysts by fabricating DGFC with aqueous solution of KOH as electrolyte.

Electro-catalysts e.g., PtAu/C, PtBi/C, PtRu/C, PdPt/C, PtPdAu/C and PtPdBi/C are synthesized by aqueous phase reduction technique using $NaBH_4$ as reducing agent. The physical characterizations confirm the formation of nano-sized metal particles on carbon substrate and indicate that the presence of metal by wt. is 21% in PdPt/C and PtRu/C, 15% in PtPdAu/C and PtPdBi/C and 14.5% in PtAu/C and PtBi/C catalysts. The efficiency, stability and the rate of poisoning of the prepared catalysts are determined along with commercial PtRu/C for glucose electro-oxidation using cyclic voltammetry (CV) and chronoamperometry (CA) techniques. The charge transfer coefficient, α_a, for glucose electro-oxidation is estimated as 0.4 for PtAu/C, 0.26 for PtPdAu/C and 0.24 for PtBi/C from CV analyses. Chronoamperometry is conducted to find out the performance stability and the rate of poisoning of the anode catalysts. The long term poisoning rate found from CA analyses is lowest for PtPdAu/C (0.0037 % s^{-1}) followed by PtAu/C (0.0046 % s^{-1}).

The glucose-KOH solution is placed in between the electrodes in batch mode of operation. Commercial activated charcoal is used as cathode catalyst in DGFC. The cell performance is recorded by measuring current density and voltage (i-V) at varying operating conditions e.g., glucose and KOH concentrations, temperature, anode catalyst type and catalyst loadings. The DGFC performance decreases beyond 1.5 M KOH concentration and 40 °C temperature. The highest specific current and power density (specific peak power density: 2.22 mW cm^{-2} mg^{-1}) is obtained for 0.3 M glucose in 1 M KOH solution at 3 mg cm^{-2} PtAu/C anode catalyst loading at 30 °C. The longevity test of DGFC with commercial PtRu/C and prepared PtAu/C suggests that the DGFC performance can be improved by washing and re-feeding the cell with fresh glucose-KOH solution at regular intervals. The ohmic and charge transfer resistances of DGFC are obtained through impedance analyses for different anode catalysts and at different operating conditions. The lowest charge transfer resistance is observed for DGFC with PtAu/C anode.

A mathematical model is developed for DGFC considering activation, ohmic and concentration overpotentials for predicting cell voltage at a given current density. The model predicts experimental data on i-V characteristics fairly well for different anode catalysts e.g., PtAu/C, PtPdAu/C and PtBi/C, different anode loadings and different glucose and KOH concentrations.

Based on the experimental and theoretical analyses, PtAu/C found to be most suitable anode catalyst for DGFC in terms of cell performance, longevity and stability of the catalyst.

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