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R&D activities of fuel cell Research at KFUPM

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Abstract

Development of systems with reduced emission of pollutants is one of the major challenges of this century. Fuel cells promise to provide clean and renewable source of energy, which can operate on many fuels. They are promising candidates for transportation and portable power source applications. These applications include battery replacement for potable telephones and computers, power sources in remote areas, etc. Fuel cells can also work using other fuels such as hydrocarbons including methanol either directly or indirectly. Since there is plenty of hydrocarbons resources available in the Gulf region such as gasoline, naphtha, and methane/natural gas etc., they can be utilized in the fuel cell to produce clean power without combustion. There has been tremendous research effort in other parts of the world, especially the Western world for the development of fuel cells. Research at KFUPM is focused on two different aspects, fuel for fuel cells (reformat feed) and PEM fuel cell system. Our research group at KFUPM is actively involved in fuel cell research since 1980s. Current focus is to develop PEM fuel cell system emphasizing three different aspects: (A) developing novel low cost proton conducting membranes, (B) developing multifunctional catalyst system and (C) development of hydrocarbon based fuel processing systems. In this communication research activities and/ongoing projects undertaken at KFUPM for fuel cell development will be presented.

Keywords: PEM fuel cell; Membranes; Electrochemical filter; Reformate

1. Introduction

Fuel cells do not need an introduction now. They are being considered as savior of environment without compromising society's energy addiction. They have gone through a long journey from their humble invention in 19th century to potential widespread automotive application. Fuel cells are now being seen as alternative to internal combustion engines in automobiles and batteries in so many portable applications.

The electrochemical research group at KFUPM has been actively engaged in fuel-cell research and development activities since early 1980s. Earlier work started with the development of alkaline fuel cells (AFC). The main

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contributions were basically in three areas, namely, electrode development [1–3], mathematical modeling of the electrode performance [4,5] and electrode performance testing [6–13]. In the recent years, the focus shifted from AFC to polymer electrolyte membrane fuel cell (PEMFC) and fuel processing system. Low cost membranes operable at relatively higher temperature are much needed. The efforts in this direction exploit the use of less expensive polymers to prepare membranes after their modification and also by blending them with inorganic proton conducting solid materials [14–23]. For direct methanol fuel cells (DMFC) we are working to develop a multifunctional catalyst which will be more efficient in the presence of higher local carbon monoxide concentration.

It has been observed that the practical fuel-cell automobile will run on hydrogen produced from fossil fuel because of two reasons: (a) alternative options to produce hydrogen are not commercially developed at this time and (b) there exists an efficient distribution infrastructure for fossil fuel. However the fuel processing for producing hydrogen suitable for fuel cells needs lots of effort. A group at KFUPM is engaged in the development of efficient catalyst to do the job. In addition, the group is also working on the development of low-cost polymer membranes, which is expected to reduce the permeation of methanol, a major problem in the DMFC, in addition to providing high conductance. Also, KFUPM is working on a novel concept of electrochemical carbon monoxide filters to process the output of a catalytic reformer. In this article all of these research and development activities are described.

2. Development of proton conducting membranes

The direct methanol fuel cell works by oxidizing the liquid methanol to CO_2 and water. This eliminates the need for an external hydrogen supply. A solid proton conducting membrane, used both as an electrolyte and separator between anode and cathode, is sandwiched between porous carbon structures. The relevant electrode reactions are

$$\text{Anode:}\quad CH_3OH + H_2O \rightarrow CO_2 + 6H^+ + 6e^- \quad E^0 = 0.046\ \text{V} \qquad \text{(I)}$$

$$\text{Cathode}\quad 3/2O_2 + 6H^+ + 6e^- \rightarrow 3H_2O \quad E^0 = 1.23\ \text{V} \qquad \text{(II)}$$

$$\text{Overall}\quad CH_3OH + 3/2O_2 \quad CO_2 + 2H_2O \quad E^0 = 1.18\ \text{V} \qquad \text{(III)}$$

The maximum voltage attainable from the overall reaction in the methanol–air fuel cell in is 1.18 V with a theoretical efficiency of 96.5%, but in practice it is not achieved due to the poor electrode kinetics and ohmic losses through the electrolyte [24,25].

Presently, perfluorosulfonic acid membranes, trade named as Nafion produced by Du Pont and Dow companies are widely used as solid polymer electrolyte. The membrane provides ionic communication between the electrodes as well as acts as a separator for the reactants.

Currently there are some obstacles [26,27] which need to be overcome before large scale commercialization of DMFC: (a) low activity and high cost of anode electrocatalyst, the anode reaction has poor electrode kinetics, particularly at lower temperatures, making it highly desirable to identify improved catalysts and to work at as high a temperature as possible; (b) the reduction of oxygen on cathode is also low though the problems are not so serious as with aqueous mineral acid electrolytes; (c) the permeability of the current perfluorosulfonic acid membranes, Nafion to methanol, which allow considerable crossover of methanol from anode region to cathode region. And the last, but not less significant is the high cost of Nafion membrane in the range of US$ 800–2000/m^2. The high price of Nafion provides incentive for the development of less expensive proton conducting membranes. A number of studies have