

Direct Alcohol Alkaline Fuel Cell as Future Prospectus

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ABSTRACT

Fuel cells are called the fourth electricity power generation after water, nuclear power generation devices. Fuel cells are widely recognized as very attractive devices to obtain directly electric energy from the electrochemical combustion of chemical products. When fuel cells are continuously supplied fuel and oxidant, electricity can be made constantly. According to the different electrolytes, fuel cells can be divided into different types among them, alkaline fuel cell is best as compared to others ones. Due to the activation overvoltage at the cathode is generally less than that with an acid electrolyte and there are very few standard chemicals that are cheaper than potassium hydroxide. These fuel cells have longer lifetimes, and do not require expensive noble metal catalysts to be used. Noble metal catalysts may be used, but less is needed to achieve a similar reaction rate. The main objective of the study is to use different kind of alcohols in alkaline fuel cell and determined the characteristics at different parameter.

Keywords:

current, ethanol, methanol, resistance, voltage,

1. INTRODUCTION

Fuel cell is an electrochemical device which converts chemical energy into electrical energy in an eco-friendly manner. Fuel cells are one of the oldest energy conversion technologies, but the exact origin of their invention is not clear. According to the Department of Energy of the United States [1], Christian Friedrich Schonbein discovered the concept; his work was published in Philosophical Magazine in the January issue of 1839 [2]. According Grimes [3], Sir William Grove who also published his work in Philosophical Magazine in 1839 [4], but in February devised the fuel cell [5]. Basically fuel cells are categories into five types depending upon the types of electrolyte used and working temperature (PAFC, AFC, PEMFC, MCFC, and SOFC)[6]. The operation of fuel cells are carried out in three steps, i.e. (i) reactant delivery (transport) into the fuel cell, (ii) electrochemical reaction ionic conduction through the electrolyte and electron conduction through the external circuit Electron conduction and (iii) product removal from fuel cell. The performance of the fuel cell device can be summarized by current-voltage graph (Activation polarization, Ohmic losses and Concentration polarization).

Fuel cell is generally more efficient than combustion engines whether piston or turbine based. They are small system which can be just as efficient as large ones. This is very important in the

case of the small local power generating system needed for combined heat and power system. Fuel cells are not limited due to the Carnot theorem therefore; they are more efficient in extracting energy from a fuel than conventional power plant. Waste heat from some cells can also be harnessed, boosting system efficiency still further. Among different types of fuel cells, alkaline fuel cells (AFCs) are the most matured. The AFCs were developed and studied extensively throughout the 1950s to the 1980s [7]. AFCs [8–10] are the oldest fuel cells that combine hydrogen with oxygen to produce water and electricity in presence of potassium hydroxide. It is a flow process which draws liquid or gaseous fuel from separated tank and if necessary converts it to hydrogen in reformer. The energy conversion process in the fuel cell is therefore intrinsically clean and silent. The fuel for the fuel cell system will vary with different applications. In transportation, it may be methanol, gasoline, or diesel. In stationary systems, it is likely to be natural gas, but it could also be propane. In certain niche markets, the fuel could be ethanol, butane, or biomass-derived materials. It was first described by Reid [11–13] and has been developed for space programs since the 1950s. The commercialization of this fuel cell, especially for automotive applications [14], has been considered possible thanks too many investigations explored by Kordesh [15–32], since the 1970s, and the British ZEVCO Company, now ZETEK POWER. However, the use of a potassium hydroxide solution raises some issues because of the high basicity. Besides, the yield of the fuel cell decreases because of the carbonation phenomenon arising from the presence of carbon dioxide in the hydrogen [10, 33]. In fact, the generated potassium carbonate settles on the electrodes, making them less conducting. Since several methods have been developed to successfully resolve the AFC CO₂ poisoning problem in recent years, AFC re-emerged as a possible low temperature, moderate power generator for terrestrial applications. It is well known that oxygen reduction reaction kinetics is much faster in alkaline environment than in acidic environment; therefore, cheap nickel and silver, instead of expensive platinum, can be used as catalyst materials in AFC [34]. The low cost of catalyst and electrolyte materials result in a higher cost-effectiveness for AFC in comparison with other low temperature fuel cells, i.e. PEMFC.

The aim of this work is to use the alcohols as fuel for fuel cell. Different concentrations of KOH is used as electrolytes, different concentration of ethanol and methanol is used as fuel at the anode side and current density and voltage are measured under different load conditions.

2. EXPERIMENTAL

Set-up and method

The experiments were carried out in a 7cmx7cm stainless steel plate in which a special new designed electrolyte carrier plate is shown Fig. 1 (Silicon) is fitted with bolts. The cathode (5cmx5cm) and anode (5cmx5cm) is placed in front and back side of electrolyte carrier.

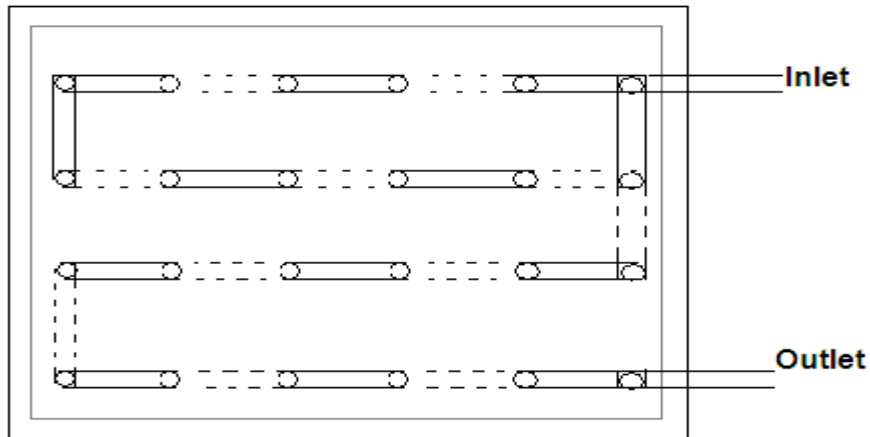


Fig. 1 New fuel electrolyte carrier for fuel cell

Fig. 1 shows the new fuel electrolyte carrier for fuel cell it is made of silicon hard plate in which grooving/ slotting in arranged manner e.g. first the when fuel enter to the carrier it distributes in to two parts. Those slotting is shown in dash line which is back portion of the carrier, so first it come to first portion than it moves to second portion of the carrier. In this way whole fuel and electrolyte is distributed over the anode and cathode catalysis. Flowing of electrolyte designs is one of the big challenges for successful running of the fuel cell. The design of electrolyte carrier is play important role for open matrix that allows the electrolyte to flow either between the electrodes (parallel to the electrodes) or through the electrodes in a transverse direction. In parallel-flow electrolyte designs, the water produced is retained in the electrolyte, and old electrolyte may be exchanged for fresh. In the case of parallel flow designs, greater space is required between the electrodes to enable this flow, and this translates into an increase in size and cell resistance, decreasing power output compared to immobilized electrolyte designs. A further challenge for the technology is the potential severity of the permanent blocking of the cathode by K_2CO_3 .

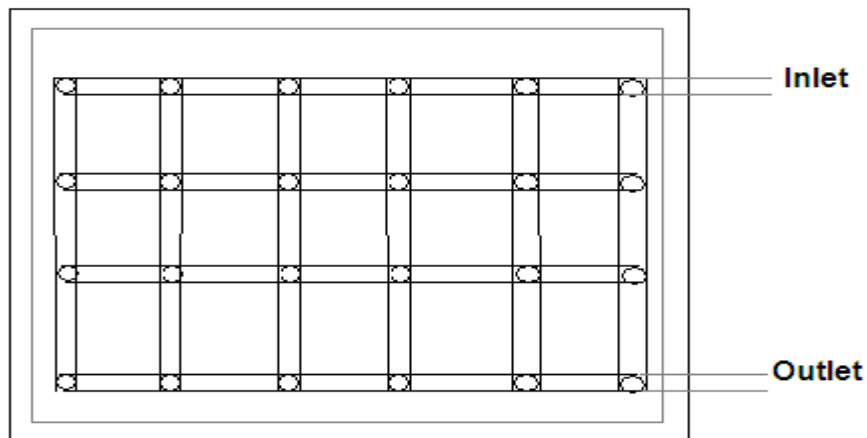


Fig.2. Old fuel electrolyte carrier for fuel cell

Fig. 2 is shows the old fuel electrolyte carrier for fuel cell. In this arrangement fuel inter from the top of the carrier and distribution of electrolyte is depend upon the feed rate of electrolyte e.g. if pressure is low it will not goes to diagonal end of the carrier. In this way improper distribution of electrolyte is occur and some part of the anode and cathode is also left to take part in reaction. After finalized the new carrier we are place the electrodes in on both side and tide with the nut and bolts to prevent the leakage of electrolyte. A schematic diagram of the alkaline fuel cell is shown in Fig. 3.

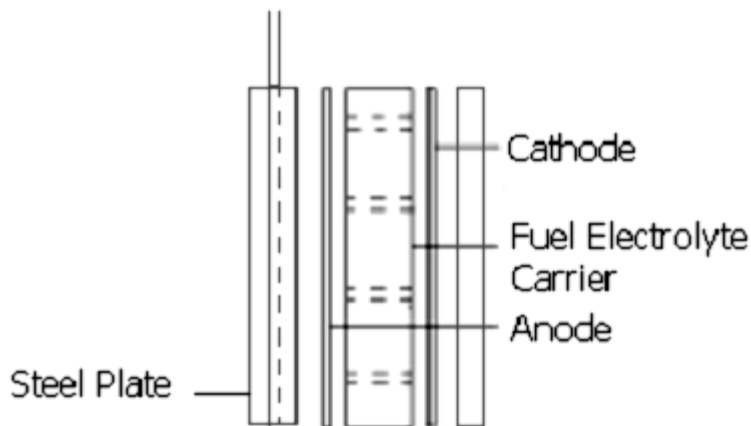


Fig. 3 Schematic diagram for fuel cell

The anode was prepared in the lab whereas a standard cathode made of $\text{MnO}_2/\text{C}/\text{Ni}$ (Electro-Chem-Technic, UK) was used. A wire is connected from the anode and the cathode is used as terminals for measuring current and voltage of the alkaline fuel cell. The space between the anode and the cathode was filled with a mixture of electrolyte and fuel (2 M) with help of peristaltic pump. The fuel and electrolyte mixture was feeded 1 ml min^{-1} , such that one side of the cathode was in contact with the fuel and the other side was exposed to air. Oxygen present in the air acts as oxidant. The two fuels were tested ethanol and ethanol. The fuel-electrolyte mixture in the beaker was continuously stirred by a magnetic stirrer to maintain a uniform concentration and temperature in the beaker and to reduce any concentration polarization near the electrodes. The voltage and current were measured after a steady state is reached. There was no significant change in performance of the cell after 1 h of operation, whereas the performance of the cell is reduced by 3% after about 10 h of operation.

Preparation of electrode

Platinum-black (Johnson Matthey) powder was first dispersed in the required quantity of Nafion® dispersion (SE- 5112, DuPont) for 30 min using an ultrasonic water bath to produce anodic slurry. The anodic slurry was spread on C paper (Lydall 486C-1) in the form of a continuous wet film. It was then dried in an oven for 30 min at $80\text{ }^\circ\text{C}$. A nickel mesh was used as current collector. The catalyzed carbon paper was pressed on to the nickel mesh using Teflon® (DuPont) dispersion. The prepared electrode was pressed at 60 kg cm^{-2} and $120\text{ }^\circ\text{C}$ for 10 min. Finally, the electrode was sintered at $250\text{ }^\circ\text{C}$ for 2 h. The size of the prepared anode was 10 cm^2 with 1 mg cm^{-2} of Pt-black loading.

3. RESULTS AND DISCUSSION

Effect of Electrolyte concentration

A higher current flow (amperage) through the cell means it will be passing more electrons through it at any given time. This means a faster rate of reduction at the cathode and a faster rate of oxidation at the anode. This corresponds to a greater number of moles of product. The amount of current that passes depends on the concentration of the electrolyte, it show different value in different concentration of electrolyte used. Figs. 4 and 5 show the current–voltage relationship (45 C) at four different KOH concentrations for ethanol and methanol respectively.

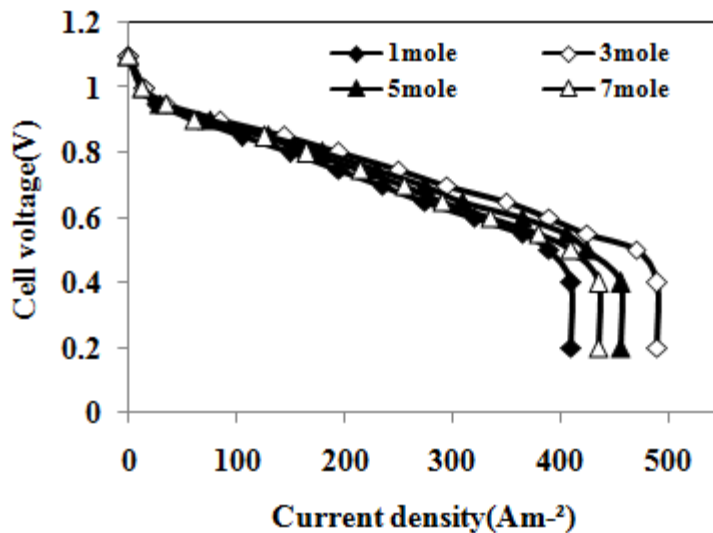


Fig. 4 Current density-voltage variations at four different KOH concentrations for 2 M ethanol in alkaline fuel cell at 45 °C, Anode: Pt Black; Cathode: MnO₂

Fig. 4 shows that the cell voltage increases with the increase in KOH concentration from 1 to 3M for a particular load and then it decreases with further increase in KOH concentration. The reason for the decrease in voltage may be because of the relative decrease in the concentration of ethanol in the presence of a high concentration of KOH. It is well known that the initial and final voltage losses with an increase in current consumption are attributed to activation and concentration overpotentials, whereas the over-potential in the flattened portion of the curve is due to ohmic loss.

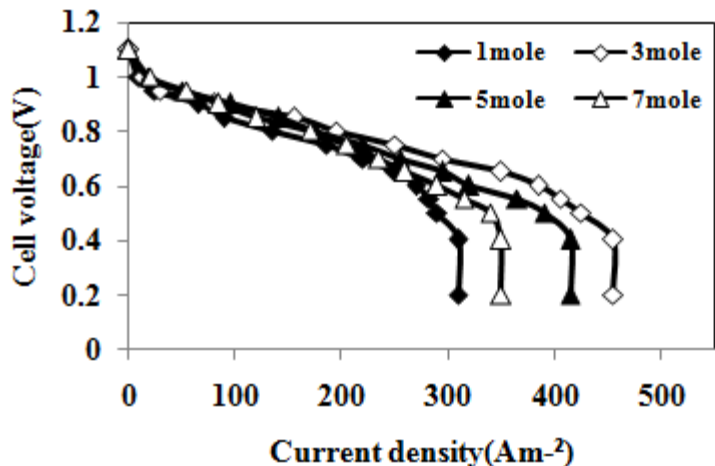


Fig. 5 Current density-voltage variations at four different KOH concentrations for 3 M methanol in alkaline fuel cell at 45 °C, Anode: Pt Black; Cathode: MnO₂

It is apparent from Figs.5 that the increase in KOH concentration has minimum effect on activation over-potential while the concentration over-potential first decreases and then increases with the increase in KOH concentration. The concentration polarization increases at a higher KOH concentration because of less availability of ethanol at the anode. On the other hand, the lowering of the KOH concentration increases the ionic conductivity of the medium or decreases the ohmic loss. It is seen in Figs. 4 and 5 that the cell performance is highest in the ohmic loss region for both the fuels, e.g., ethanol and methanol, when 3M KOH was used with 2M fuels.

Effect of Fuel Concentration

Fuel is the supporter for the fuel cell which donates hydrogen to the reaction to increase the rate if hydrogen rich compound is used.

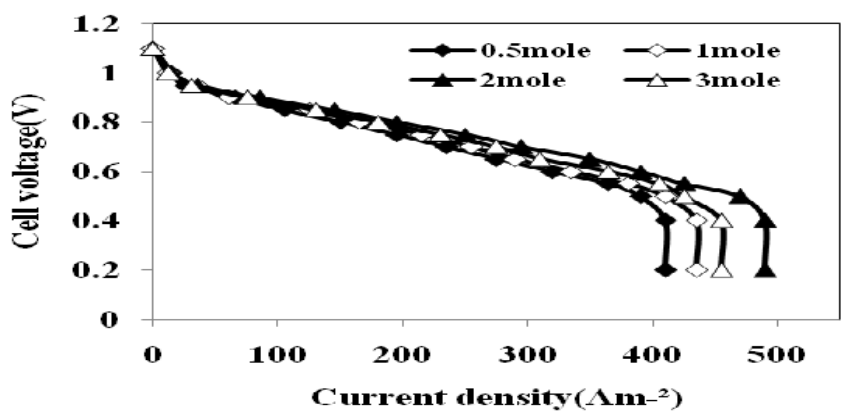


Fig. 6 Current density-cell voltage characteristics at different ethanol concentration in 3 M KOH electrolyte in alkaline fuel cell at 45 °C, Anode: Pt Black; Cathode: MnO₂

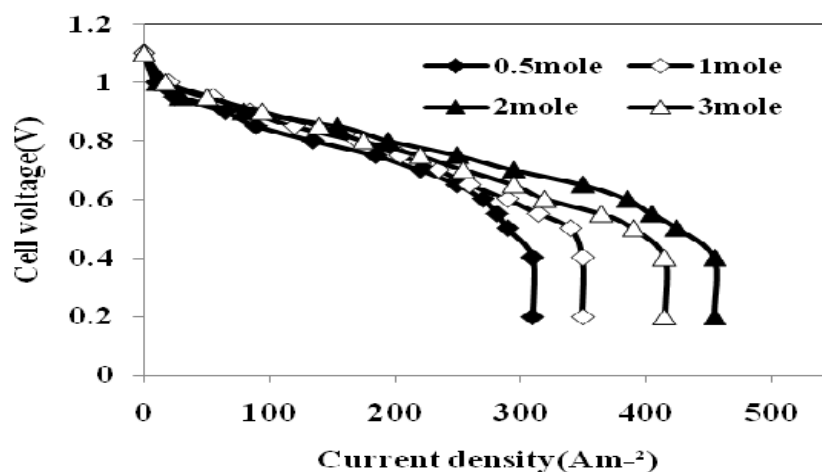


Fig. 7 Current density-cell voltage characteristics at different methanol concentration in 3 M KOH electrolyte in alkaline fuel cell at 45 °C, Anode: Pt Black; Cathode: MnO₂

Figs. 6 and 7 show the current–voltage relationship (45 C) at four different fuel concentrations for ethanol and methanol respectively. The CVs fig. 6 shows that the peak current decreases with the increase in ethanol concentration. However the current density increases with the increase in ethanol concentration form 0.5M to1M. And on further increase in concentration of ethanol to 2M the current density increases slightly. In this case initial increase in current density may be because of the increase in ethanol concentration. But the availability of OH⁻ ion at catalyst site decrease with the further increase in methanol concentration .As a result the ethanol oxidation reaction suffer due to lesser availability of adsorbed OH⁻ on the catalyst sites. Consequently the current density at higher ethanol concentration decrease .A similar trend is observed for the methanol electro-oxidation shown in Fig. 7. On increasing the concentration of methanol from .5M to1M the current density increases as more ethanol molecules are available for oxidation.

Effect of Temperature

In the cell reaction process becomes faster when the fuel entering and electrolyte is warm rather than cold .So the temperature plays an important role to develop the voltage across terminal.

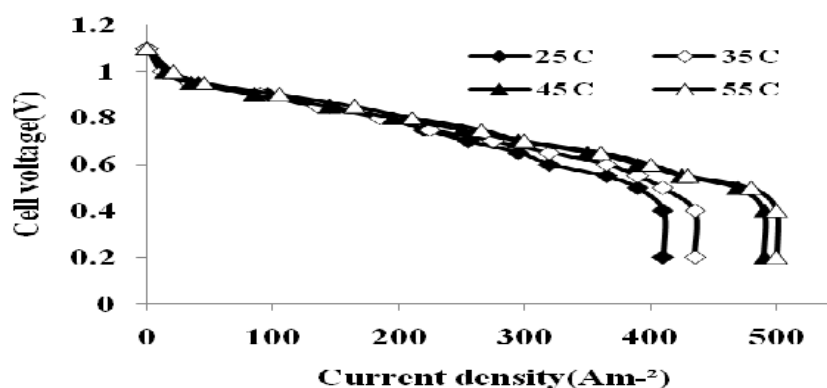


Fig. 8 Current density cell voltage characteristics for 2 M ethanol/3 M KOH fuel/electrolyte mixture at different temperature in alkaline fuel cell. Anode: Pt Black; Cathode: MnO₂

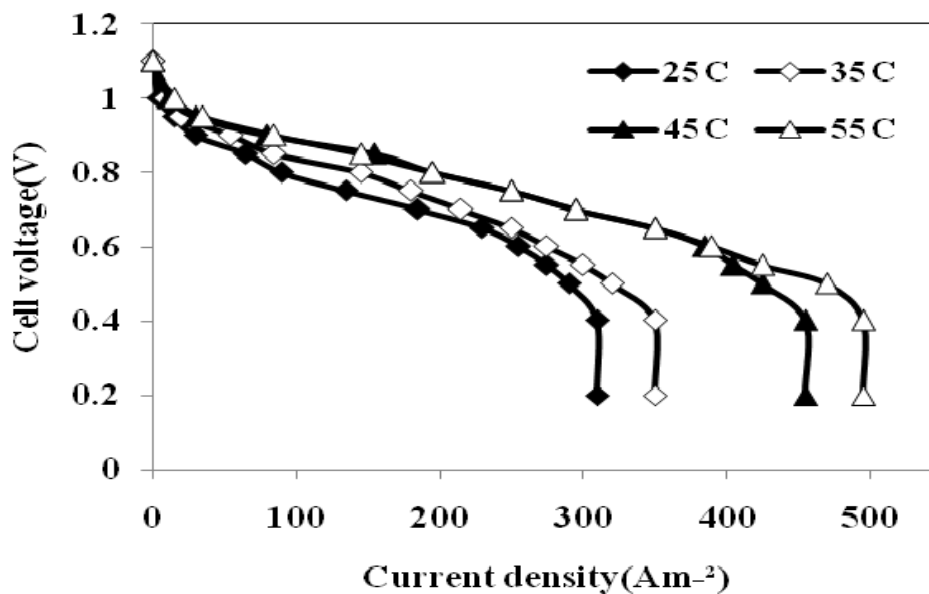


Fig.9 Current density-cell voltage for 2 M methanol/3 M KOH Fuel/electrolyte mixture at characteristics different temperature in alkaline fuel cell. Anode: Pt Black; Cathode: MnO₂

Figs. 8 and 9 shows the current–voltage relationship for ethanol and methanol fuel when 2M fuel and 3MKOH solution was fed to the alkaline fuel cell at different temperatures. It is seen that the cell performance increases with the increase in temperature because of decrease in the activation and concentration over-potentials. Although the direct methanol alkaline fuel cell performed well its performance is lower than that for direct methanol fuel cell based on PEM technology in the given process conditions. The lower performance of the direct alcohol fuel cell may due to cross over of alcohol to the cathode side since the fuel-electrolyte mixture was in contact with both the anode and cathode. Further, carbonate formation due to the presence of CO₂ might have affected the electrodes and the electrolyte. This may handled by recycling and recharging the cell with fresh KOH, as mentioned earlier.

4. CONCLUSION

A systematic study was conducted of the effect of electrolyte concentration, fuel concentration and temperature on the performance of an alkaline fuel cell in which methanol, ethanol were directly fed as fuel. The cell performance was highest when 3MKOH was used with 2Mfuel. The cell performance decreases with further increase in KOH concentration. This is attributed to the activation and concentration over-potentials at high KOH concentration. In general, the alkaline fuel cell performance increases with the increase in temperature for the fuels.

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NOMENCLATURE

PAFC	Phosphoric Acid Fuel Cell
AFC	Alkaline Fuel Cell
PEMFC	Proton Exchange Membrane Fuel Cell
MCFC	Molten Carbonate Fuel Cell
SOFC	Solid Oxide Fuel Cell
i	Current(Ampere)
C	Concentration (Mole)
T	Temperature (Centigrade)

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