FUEL CELLS IN CARS AND BUSSES?

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To save the environment, fuel cells have been proposed for use in cars and busses. Various types of electrochemical fuel cells are well known [1]. The polymer fuel cell (PEFC), phosphoric acid fuel cell (PAFC) and the methanol fuel cell (DMFC and PEMFC) have been mentioned as serious candidates for use in cars and busses. The electrochemical behaviour and the problems related to these fuel cells are discussed extensively. Moreover, their usefulness in cars and busses is presented.

1. DIRECT METHANOL FUEL CELLS

The direct methanol/ oxygen (air) fuel cell (DMFC) uses an acidic electrolyte because of the need to reject the CO_2 produced during the electro-oxidation of methanol.
The anode and cathode are separated by a proton-conducting membrane. The H^+ concentration at the anode is extremely high, so that only noble metals can be used as electrocatalyst.
Platinum is the most active but is very sensitive to poisoning. To reduce its susceptability to these poisons Pt-Ru alloys with a Ru content larger than 10 % are used. It has been found that the activity of a Pt-Ru electrode in CH_3OH solutions at 70^{o}C decreases drastically as a function of electrolysis time [2]. From the temperature dependance [3] it will be shown that at 220^{o}C the rate of methanol oxidation at Pt is equal to the one at Pt-Ru with the optimal Ru content and that Pt is the preferred material at temperatures above 220^{o}C. For a Pt-Ru electrode a current density of 100 mA cm^{-2} was obtained at 170^{o}C and a 0.4 V cell voltage. The use of Pt-Ru-Me, where Me is Sn or Fe, is only useful for creating a catalyst with a smaller particle size [4,5]. Within a short time the Sn or Fe was dissolved from the anode material.
In a PEMFC cell, a PEFC cell with methanol as direct fuel, a polybenzimidazole doped with phosphoric acid is used as membrane above 130^{o}C [6]. The maximum working temperature is about 200^{o}C and because of the dehydratation of H_3PO_4, practically no experimental results have been presented up to now at temperatures of about 200^{o}C.

2. HYDROGEN FUEL CELLS

In the hydrogen fuel cell hydrogen is oxidised at the anode and oxygen is reduced at the cathode. The hydrogen source is important as the purity of the hydrogen gas plays a crucial rol in the cell energy efficiency and the cell power. For example, electrolytic hydrogen is free of CO and very useful as fuel, while hydrogen gas produced from methanol usually contains small quantities of CO, which causes a drastic decrease in the cell energy efficiency and the cell power.

2.1 Vehicle refuelling with methanol

In this case methanol has to be converted into hydrogen by methanol steam reforming on board of the vehicle. This conversion gives chemical hydrogen that usually contains CO. A few ppm of CO in the gas gives a drastic reduction of the fuel cell capacity at temperatures below 200^{o}C. Moreover, it may also be necessary to remove CO_2 from chemical hydrogen because of the Co formation from CO_2 and H_2.
No experimental results about this conversion in the fuel cell have been published. Moreover, CO can also be formed by oxidation of carbon [1], the supporting material of many commercial fuel cell electrodes. The production of pure hydrogen from methanol needs a very sophisticated process which must be carried out under well defined conditions. This is practically impossible to realize on board of cars and busses.

2.2 Vehicle refuelling with chemical hydrogen

The cell voltage strongly depends on the CO content of hydrogen gas. It has been found that for a PEM-cel at 89^{o}C and a cell voltage of 0.4 V, the current density is 0.4, 0.5, 0.6, 0.75 and 1.4 A cm^{-2} for H_2 gas with 10000, 1000, 100, 10 and 0 ppm CO, respectively [1]. Practically no research was carried out at temperatures around 200^{o}C and with H_2 gas containing 0-10 ppm CO, conditions very important for practical use.

2.3 Vehicle refuelling with electrochemical hydrogen

In this case probably no CO poisoning of platinum electrodes occurs. It has been found however, that poisoning of a platinum electrode occurs [7], probably by unknown organic compounds present in the solution. The purity of the hydrogen, oxygen and electrolyte solutions must be extremely high.
The reduction of oxygen is also a very slow electrochemical process. Its rate depends strongly on the temperature [8]. To obtain a high energy output also a temperature of about 200^{o}C is necessary. Knowledge about the durability of a cell fuelled with electrochemical hydrogen at 150-200^{o}C is needed.

Some expectations for car and bus applications:

- Direct methanol oxidation is not used.
- Chemical conversion of methanol on board is not attainable in practice.
- Use of chemical hydrogen produced in special plants is possible if the chemical hydrogen is sufficiently pure: a very big task.
- Use of electrochemical hydrogen is possible, although the hydrogen storage problem has not been tackled in the proper sense.
- No real break-through has been attained during the last 30 years and will not be expected during the next 30 year.

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