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Sensors for direct methanol fuel cells

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ABSTRACT

A sensor can be used to enhance the performance of a direct methanol fuel cell (DMFC). Sensors function as alarms for various problems encountered with DMFCs, of which methanol crossover is the primary problem. These sensors can significantly improve DMFC operation, thereby promoting the commercialisation of this product. Using sensors can also lower DMFC fabrication costs. For all of these reasons, an overview of sensor applications for DMFCs is presented in this paper. Different types of sensors and advances in sensor development are also discussed, particularly for DMFC systems. Finally, this paper highlights current issues and future improvements for the application of sensors to DMFCs.

Contents

1. Introduction

DMFCs are potential mobile and stationary power sources because of their high energy densities, easy operation and simple fuel supply requirements. However, methanol crossover is typically encountered with DMFCs, particularly for fuels with high methanol concentrations. Methanol solution is mixed with water and used as fuel for DMFCs. DMFCs do not require fuel storage and are therefore easy to handle. DMFCs can be microminiaturised because their operating temperatures are low [1–3]. A sensor is a device that responds to a physical stimulus, such as heat, light, sound, pressure, magnetism, or a particular motion, and outputs an impulse for measurement purposes or to operate a control. Sensors are critical in fuel cells for various tasks, such as detecting the fuel concentration and carbon monoxide emissions. Currently, the most popular sensors for overcoming the aforementioned problems are methanol concentration sensors, temperature sensors, humidity sensors, carbon monoxide detection sensors and

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flow sensors. Sensor-less approaches have also been used to determine the best method for upgrading DMFC efficiency and performance. Sensors for fuel cells can be classified into two main categories, which are based on the sensing mode employed: electrochemical sensors and physical sensors [4].

1.1. Electrochemical sensors

Electrochemical sensors can convert methanol concentrations into readable electrical signals via the electrochemical oxidation of methanol. These sensors are simple structures that are easy to operate and low in cost; however, problems such as the deterioration of the catalytic surface may arise during sensor operation. These sensor types are constructed similarly to DMFCs and are based on polymer electrode membranes (Zhao et al. [5]. Electrochemical sensors can be further classified into sensors based on fuel cells and those that use an oxidant current. In a fuel-cell-based sensor, the methanol concentration is determined by the measurement of operating characteristics, such as the open-circuit voltage and the short-circuit current, or the operating voltage for a constant resistor load. This type of sensor requires a continuous supply of oxidant to the cathode [6]. The second type of methanol sensor measures diffusion-limited concentration-dependent oxidation current of methanol at the anode under a constant applied voltage [5]. The associated reactions are given below.

The overall reaction for methanol oxidation is given as follows:

$$CH_3OH + H_2O \rightarrow CO_2 + 6e^- + 6H^+ \text{ (anode)} \quad (1)$$

The reaction for the fuel-cell-based sensor is as follows:

$$5O_2 + 6e^- + 6H^+ \rightarrow 3H_2O \text{ (cathode)} \quad (2)$$

The reaction for the sensor that uses an oxidation current is as follows:

$$6H^+ + 6e^- \rightarrow 3H_2 \text{ (cathode)} \quad (3)$$

1.2. Physical sensors

Physical sensors employ physical methods to measure physical properties such as the density, the viscosity, the infrared light transmittance, the dielectric constant, the refractive index, the heat capacity, or the speed of sound [5]. These sensors must be used with an auxiliary driving device and additional sensors, such as a thermometer or optical sensors [2,7]. Physical sensors are difficult to handle because of their bulky size and temperature dependence. These sensors also have a complex structure and are difficult to miniaturise [2]. Sung et al. fabricated an ultrasonic

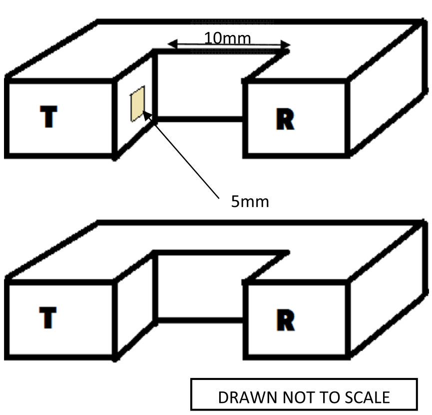

Fig. 1. Transducer in sensing methanol concentration [8].

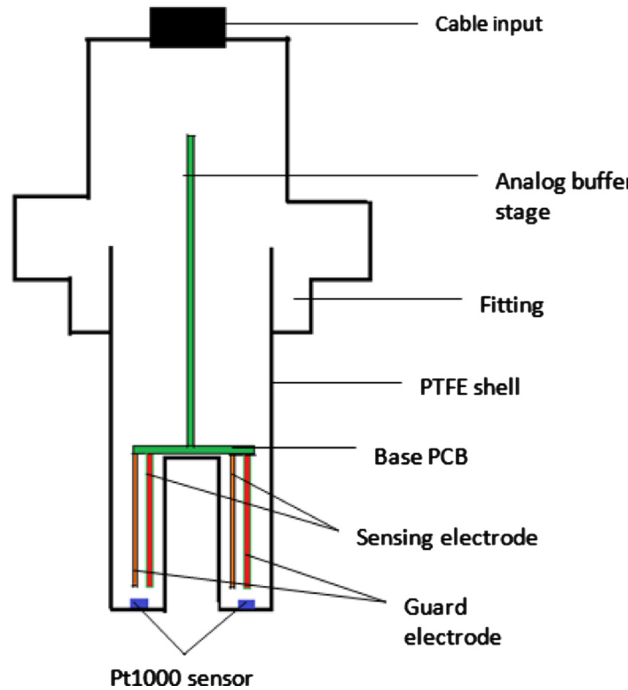

Fig. 2. Design of capacitive sensor; immerse probe [9].

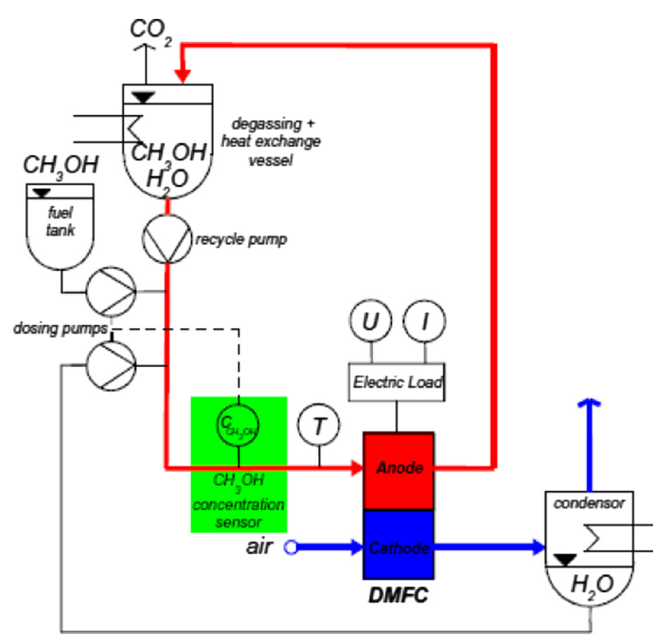

Fig. 3. Location of methanol sensor in the schematic diagram of DMFC power plant [9].

transducer to monitor and control the methanol concentration (see Fig. 1). However, this transducer produces results that do not agree with theoretical models, which predict that the speed of sound decreases as the temperature increases. Doerner et al. [9] subsequently fabricated a sensor for measuring the methanol concentration (see Fig. 2). The measurement technique uses impedance spectrum analyser electronics, which can be used under process conditions. Fig. 3 shows the position of the methanol sensor for a schematic of a direct methanol fuel cell (DMFC) power plant.