Carbon Monoxide Sensors for Application in Polymer Electrolyte Membrane Fuel Cells

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Polymer electrolyte membrane (PEM) fuel cells are currently being developed for transportation and stationary applications. Since fossil fuels account for greater than 85% of our total energy consumption,[1] much research is being conducted to optimize low cost fuel reformer systems that convert this fuel (natural gas, petroleum or methanol) to hydrogen.[2] This hydrogen gas typically feeds a PEM fuel cell stack utilizing platinum based anodes. However, low concentrations of carbon monoxide (~ 10-100ppm) impurities in hydrogen can severely degrade the performance of PEM fuel cell anodes due to the strong adsorption of carbon monoxide on the electro-active platinum surface sites where hydrogen is normally oxidized to protons.[3] Therefore, detection and measurement of carbon monoxide in high temperature reformate streams is of vital importance to the successful implementation of fuel cells.[4]

Current reformer systems that process hydrocarbon fuels utilize multiple reforming steps in order to reduce the CO concentration in the hydrogen fuel to < 10ppm. The hydrocarbon fuel is first subject to a combination of steam reforming and partial oxidation that results in a fuel with 15-25% CO content. This fuel then undergoes a water gas shift reaction that decreases the CO content to approximately 1%. Finally the fuel is sent through a preferential oxidation (PrOx) reactor where the CO content is reduced to < 10ppm. The optimization of the reforming process and the operation of the fuel cell can benefit greatly from the availability of CO sensors that can accurately measure the CO concentration in hydrogen containing streams in real time. In this paper we present the development of both PEM-based and oxide-based CO sensors for PEM fuel cell applications.

The oxide-based carbon monoxide sensors utilize the difference in electrode kinetics of various metal/ electrolyte (oxygen-ion conducting) interfaces. Hashimoto et. al. have reported a fuel-cell type CO sensor that can measure CO concentrations in a hydrogen stream.[4] In this paper we will discuss the performance of various ceria and zirconia electrolyte based sensors using Ni, Pt and Pd as electrodes. A Pd/YSZ/Ni sensor had a response of 60mV to 100ppm CO at 185^{o}C. However, the response of all these sensors were found to decay over time due to some irreversible CO poisoning of the electrodes.

The PEM-based carbon monoxide sensors utilize the reversible carbon monoxide adsorptive poisoning of precious metal electrodes. An amperometric sensor that senses the CO inhibition of the hydrogen oxidation reaction has been fabricated from a platinum (Pt) electrode, a proton conducting electrolyte (Nafion®), and a platinum ruthenium alloy (Pt/Ru) electrode. The Pt electrode serves as the sensing electrode while the Pt/Ru alloy electrode serves as a pseudo reference electrode.

Several sensor configurations with different catalyst loadings and various temperatures of operation will be reported. The performance of a sensor with a Pt electrode loading of 0.2mg/cm^2 is illustrated in figure 1. This sensor is sensitive to low concentrations (10 - 100ppm) of CO and can be used to measure the CO concentration in the exhaust stream of a PrOx reactor. The performance of a similar sensor with a Pt electrode loading of 10mg/cm^2 is shown in figure 2. This sensor responds to CO concentrations in the 100 – 2000ppm range and can be used to sense the CO concentration in the input stream of a PrOx reactor. The performance of these sensors is comparable to that of analytical IR CO detectors (also shown in the figures) and they have the potential to be used in PEM fuel cell systems.

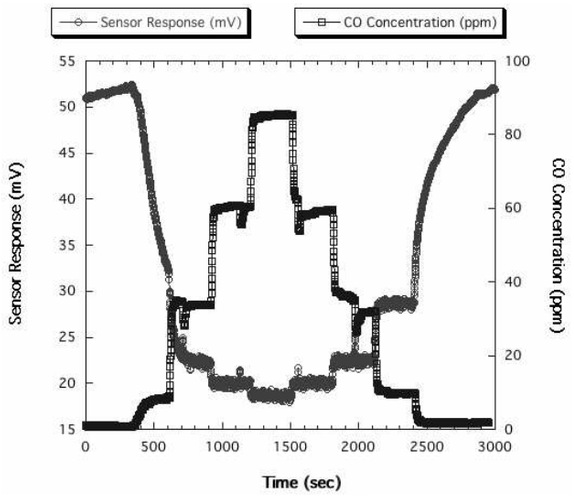

Fig. 1. Response of a "Pt(0.2mg/cm^2)/Nafion(117)/Pt-Ru(10mg/cm^2)" sensor to 25, 50, 75, 100 ppm CO at 85^{o}C and V = 0.3V.

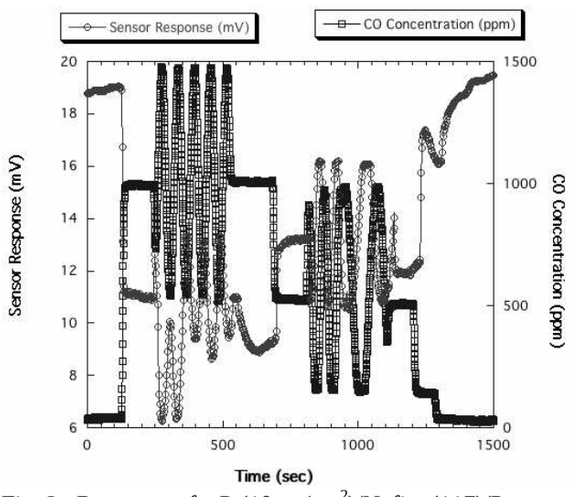

Fig. 2. Response of a Pt(10mg/cm^2)/Nafion(117)/Pt-Ru(10mg/cm^2) sensor to CO cycling at 80^{o}C and V = 0.1V.

References

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