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Analysis of the Influence of a Filter for Traffic-related Gaseous and Particulate Contaminants on PEMFC

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1 Introduction

An important subject to increase the lifetime of PEM fuel cells is purity of the in-coming gases. Especially cathode air must be very clean. Impurities in the air can contaminate the catalyst, electrolyte or GDL [1, 2].

Degradation can be reduced by using a cathode air filter. Research about effects of contaminants on fuel cells has been carried out [3]. CO, NO_2, NH_3 and SO_2 have been fed consecutively to the fuel cell in ppm ranges with and without a fuel cell cathode filter. Results show that CO removal is not necessary as it is converted with O_2 to CO_2. But the used concentrations of the other corrosive gases significantly harmed the single fuel cell within the timeframe of only an hour.

Unlike the tests without filter voltage curves of the fuel cell by using a cathode air filter remain at a constant level and don't even fall over a longer period of contamination. However solely NO_2 is leading to a significant decrease in cell voltage over time. The filter used in this experiment is not effectively removing NO_x from air.

Further tests with particles and real depleted diesel exhaust gas have been conducted. The results have revealed that available filters can't separate a typical traffic-related contaminant mix effectively from incoming air.

2 Cell Degradation without Cathode Air Filter

Research about corrosive gases at road traffic areas in Germany and their effects on fuel cells has been done [3]. First CO, NO_2, NH_3 and SO_2 have been conducted through the fuel cell in a ppm range without an upstream filter. The test parameters at all experiments were identical to get comparable results. Cell temperature was 55 °C and the cathode gas was not humidified. A constant current density of 800 mA/cm² was adjusted.

A water cooled single cell was manufactured and integrated in a special test stand for corrosive gases. New MEAs were assembled for each measurement with a different corrosive gas. Fig. 1.1 shows the results without any filter materials. The used single cell is seen in Fig. 1.2.

Results show that CO filtering is not necessary as it does not affect fuel cell performance and is likely converted with O_2 to CO_2. But the used concentrations of the other corrosive gases significantly harmed the single fuel cell within one hour. After NO_2-poisonning the cell performance can be recovered completely, by running the cell with pure NO_2 free air for several hours. In a following test the single cell was fed with only 1 ppm NO_2. A voltage loss of 4 % could be seen within the first 10 minutes. After 220 minutes the cell performance declined by 10 % (Fig. 2.1).

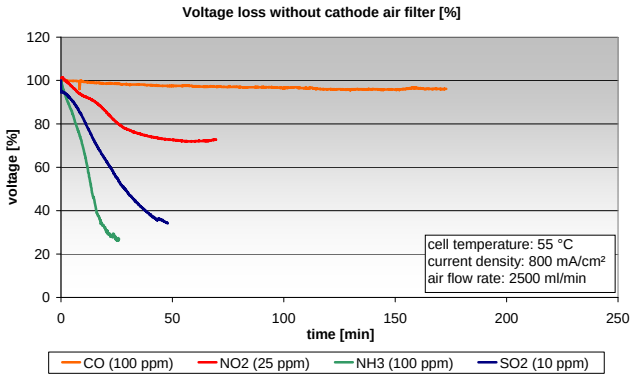


Figure 1.1: Voltage loss without a cathode air filter [%].

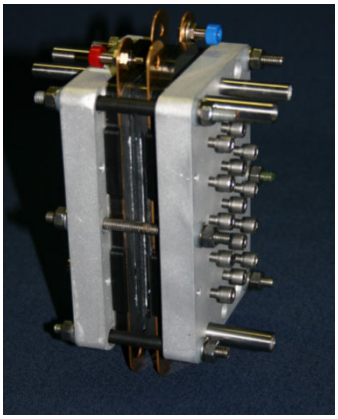
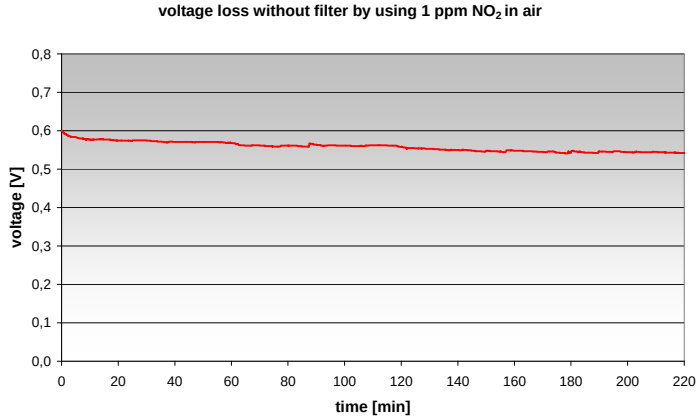


Figure 1.2: Water cooled single cell.



- 10 % voltage loss within 220 minutes
- 4 % voltage loss within only 10 minutes
- Reversible process

Figure 2.1: Voltage loss without a cathode air filter by using 1 ppm NO_2.

3 Cell Degradation with Cathode Air Filter

In a second experimental series a filter system was used for the cathode feed. The filter consisted of activated carbon layers and ion exchanger layers. The concentrations of the corrosive gases were the same as in Fig. 1.1.

Fig. 3.1 pictures the results with filtered cathode air. The voltage curves of the fuel cell with a cathode air filter are at a constant high level and don't fall over a longer period. However NO_2 is leading to a significant decrease in cell voltage over time. The filter used in this experiment is not effectively removing NO_x from air.

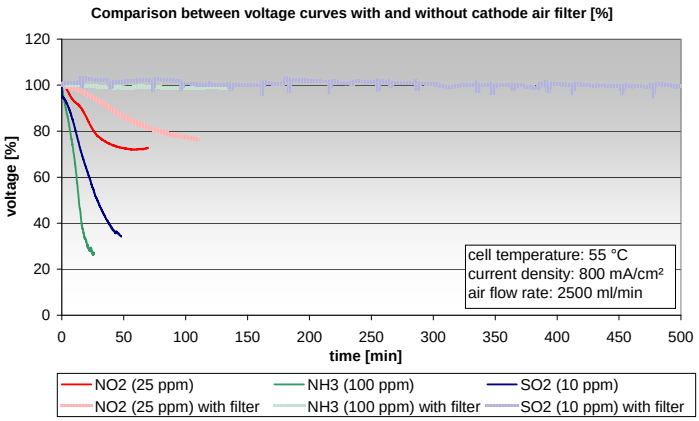


Figure 3.1: Voltage loss without a cathode air filter [%].

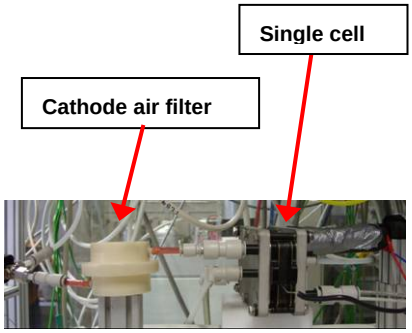


Figure 3.2: Filter with single cell.

4 Separation of NO_x

A further test series was made to analyse the filter efficiency of different materials for NO_x. The used filters were a column packed with activated carbon (potassium carbonate (K_2CO_3)) granules, a column packed with polyphenylene sulphide (PPS) granules and a filter consisting of Ion exchanger layers as well as activated carbon filter layers used in the experiment before [4]. Fig. 4.1 shows the results of a few tests with different filter materials.

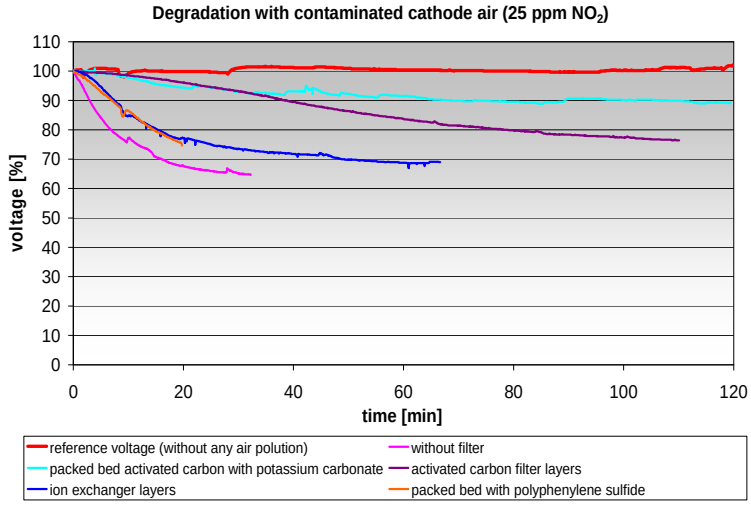


Figure 4.1: Voltage loss without a cathode air filter [%].

Figure 4.2: Activated Carbon.

According to the state of technology neither an air cathode filter nor a catalyst are able to separate NO_x from the cathode gas flow of PEM fuel cells adequately.

5 Analyzing the Effect Gas Mixtures on the Fuel Cell

In a final experiment the effect of a gas mixture on the fuel cell was analysed. A test stand with a real diesel engine at the partner institute IUTA was used. The diesel exhaust gas was

analysed and depleted to a defined degree. A 5-cell water cooled stack was fed with the diluted diesel exhaust gas at a ratio of 1:70 in air. This exhaust gas contained 0,9 ppm SO_2, 7,9 ppm CO, 7,5 ppm NO and less than 1 ppm NO_2. In addition soot particles are parts of the engine generated diesel exhaust gas. But former experiments with soot particles have shown that these particles don't contaminate the fuel cell. The tests were realized with and without a filter system (Fig. 5.1).

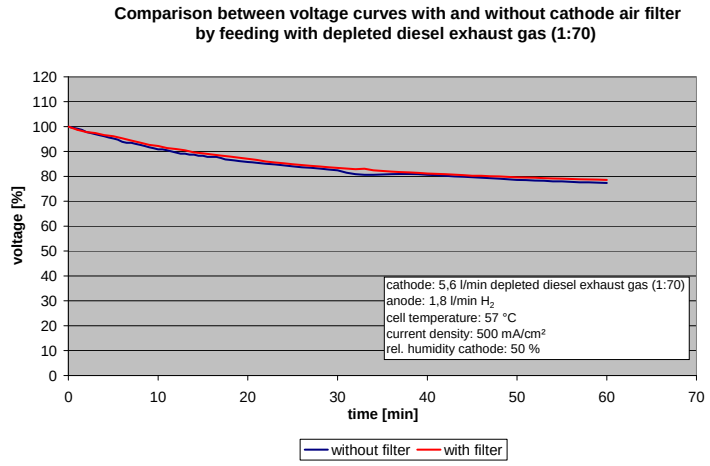


Figure 5.1: Voltage loss by using depleted diesel exhaust gas [%].

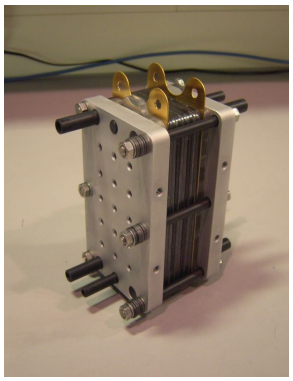


Figure 5.2: 5-cell-stack.

The voltage loss by using a filter is nearly identical to the voltage loss without any filter system. A voltage drop up to 20 % within one hour caused by the Diesel exhaust gas could be seen. But after charging with neat air the PEMFC is recovered completely, despite the presence of SO_2 in the diesel exhaust gas. Normally SO_2 leads to irreversible cell damage. So it is presumed that the presence of nitrogen-containing groups suppress the adsorption of SO_2 on the catalyst layer. The kinetic of the reversible NO_x absorption could be faster then the irreversible SO_2 absorption, so no irreversible performance lost could be detected. More experiments with mixed gases are necessary.

6 Conclusion

Experiments have shown that a cathode air filter can increase the lifetime of a PEM fuel cell except the degradation due to NO_2 which is fortunately a reversible effect. Further tests are mandatory. So a new project has been started in January 2010 which will deal with investigations on the damage mechanisms. Electrochemical Impedance Measurements (EIS) will be one of the methods to be applied [5]. Furthermore tests with different types of particles will follow.

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