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STUDY ON INHOMOGENEITY OF LARGE FORMAT PEM FUEL CELL

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ABSTRACT

The inhomogeneity of gas concentration is a key factor which can influence the fuel cell performance. This paper proposed a multi-point gas sampling system which can sample gases in different locations of fuel cell and analyze the concentration distribution. Results prove that the gas concentration of large format fuel cell gradually varies along the channel, and the distribution between channels is also different.

Keywords: Multi-point gas sampling system, large format fuel cell, inhomogeneity

NONMENCLATURE

Abbreviations	
PEM	Proton Exchange Membrane
PEFC	Polymer Electrolyte Fuel Cell
I	*Current*
U	*Voltage*
Van	*Velocity of gas flow in anode*
Vca	*Velocity of gas flow in cathode*

1. INTRODUCTION

Fuel cell vehicles, with the advantages of zero pollution and high efficiency, are favored by more and more people. The working principle of fuel cell is relatively simple, which is the process of hydrogen and oxygen reacting to produce water. The reaction with the transfer of charged particles can convert chemical energy into electrical energy. The performance of fuel cell is closely related to the current density distribution. It is found that the current density distribution of large format fuel cell is not uniform. And the gas concentration is one of the key factors which can cause different current density. This paper focus on the inhomogeneity of gas concentration by using a single piece of large format PEM fuel cell for simplification of the research.

Nishikawa et al. established a method for measuring relative humidity and current distribution inside PEFC cells using some sensors [1]. Yang et al. developed an experimental technique but it's only for little format single-piece fuel cell whose active area is 50 cm2 with two-pass serpentine flow field which paired arrows for the anode and cathode indicate flow directions [2]. Jason et al. set a simple along-the-channel model and experimentally verified the evolution of liquid water and nitrogen fronts along the length of the anode channel in a fuel cell, but it's only for little format fuel cell with single sampling port [3]. Fang et al. designed a large electrochemical surface area single cell with multiple gas sample ports both in cathode and anode, which provides a reference for the study of large format fuel cell [4]. The method of sampling for the internal gas concentration of different positions in large format fuel cell is not so mature, which is rarely documented in the literature.

In this paper, the multi-point gas sampling system for large format PEM fuel cell is proposed. By sampling the gas at different positions in different channels, the volume fraction of the gas is analyzed. Section 2 mainly

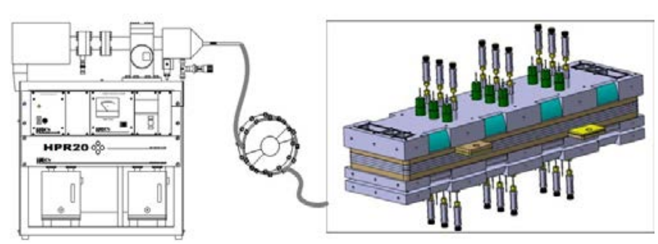

Fig 1 Multi-point gas sampling system

introduces the gas sampling system and experimental procedure. Section 3 shows the experimental results and data analysis. Section 4 summarizes this paper and gives some conclusions.

2. SYSTEM AND PROCEDURE

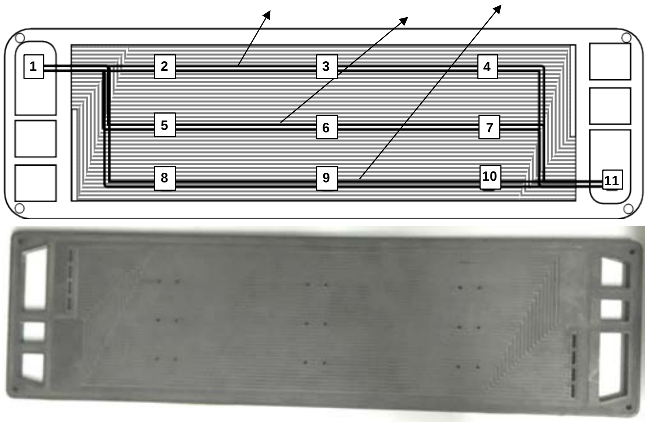

Fig 2 Bipolar plate with multi-point gas sampling ports

2.1 Multi-point gas sampling system

The system includes gas mass spectrometer, which can be used to analyze the sampled gas. Fig 1 shows the device diagram of the multi-point gas sampling system. The mass spectrometer is connected to the sampling pipeline through a multi-way valve. More detailed aspect is that the capillary is used to connect the multi-way valve and the sampling sport. In order to avoid the influence of non-sampled gas or external impurities, O-ring is used to compress and seal the capillary end face and sampling port. It should be noted that in order to avoid blocking the pipeline by condensation of water vapor into liquid water in the sampled gas, resulting in an increase in sampling time and affecting the sampling results, the sampling pipelines in the system are all winded with heating-belt to keep the temperature at 120 ℃.

Sampling ports are arranged along the channel and distributed in different positions of different channels. Fig 2 is a schematic diagram of bipolar plate with gas sampling ports used in the experiment. In order to simplify the device, three channels are selected in this paper. Channel 1 is in the upper, Channel 2 is in the middle and Channel 3 is in the bottom. In order to analyze the variation of concentration, it is assumed that the characteristics of three channels' inlets are the same as sampling port 1, and the characteristics of three channels' outlets are the same as sampling port 11. (Note: the example in the figure is cathode plate, the sampling point arrangement principle of anode plate is similar.) The active area of the single piece fuel cell is 266 m2.

2.2 Operating condition and procedure

In order to ensure the accuracy of sampling results, helium gas is used to clean the pipeline before sampling, as to eliminate the influence of residual gas in the pipeline on the sampling signal. In addition, the mass spectrometer needs to be calibrated with standard gas before sampling.

In order to cover more different working conditions, the experiment was divided into nine groups, and the experimental parameters of each group were shown in Table 1. It should be noted that: due to the low voltage limitation of the electronic load, the maximum current may not reach 120A. So, the experiment is carried out according to the maximum current that the electronic load can reach.

Table 1 Experimental parameters

Test	I/(A)	U/(mV)	Vca/(L/min)	Van/(L/min)
1	40	649	4	0.3
2	40	688	7	0.3
3	40	681	10	0.3
4	80	480	4	0.6
5	80	557	7	0.6
6	80	550	10	0.6
7	120	360	4	0.9
8	120	381	7	0.9
9	120	419	10	0.9

The single piece of fuel cell used in this experiment has 22 sampling points (11 in cathode plates and 11 in anode plates respectively). Each group of experiments needs to complete the sampling of all ports and repeat the procedure several times to reduce the error. Before each experiment, helium gas was used to purge the pipeline. Then set the corresponding temperature and flow parameters, gradually increase the electronic load to the set value, and then open the mass spectrometer for measurement after a period of stable state.

It should be noted that each time the sampling point is switched, the gas signal in the sampling channel will have a short dynamic process before reaching stable state. Especially when purging with helium, the instantaneous pulse may occur, because of the high pressure of purged helium.

3. RESULTS AND DATA ANALYSIS

In the cathode, the volume fraction of oxygen refers to the proportion of oxygen and total of oxygen and nitrogen. In the anode, the volume fraction of hydrogen refers to the proportion of hydrogen and total of hydrogen and nitrogen.

It is showed that the volume fraction of oxygen gradually decreases along the channel in Fig 3. Also, there are some difference of hydrogen concentration along channel and between channel in Fig 4. From left to right, same current but different velocity of gas flow in cathode. From top to bottom, same velocity but different current.

Especially in Fig 3-d) and g), the results are obvious that the value of inlet is highest and the value of outlet is the lowest. What's more, at the same distance, the values of the three channels increase in turn. It may because of the diffusion of gas due to gravity. While in other results show that the lowest is close to outlet. Such as in Fig 3-a), b), c), e), f), h) and i), there is a strange phenomenon, which shows that the lowest value is in the channel 3 but not outlet. This phenomenon is as a result of that it is located at the bottom and at the end of the channel. The liquid water is easily to accumulate, which results in the decrease of oxygen integral. It cannot be ignored that the outlet is a collection of all channels, and the gas in different channels mixes at the outlet. It also shows that there are differences in gas concentration distribution between different channels.

Gas concentration difference also exists in the anode channel. The results of Fig 4 are more interesting. The volume fraction of hydrogen is 100% at the inlet and at the font part of channel. At the end of the channel and at the outlet, the value is less than 100%. Nitrogen in the cathode channel is diffused to the anode. And because the flow of hydrogen supply is large, nitrogen gathers at the end of the channel, due to the opposite gas flow direction in the anode channel and cathode channel, thus making the volume fraction of hydrogen less than 100%. The system uses dead-end anode, which will cause the gas concentration distribution along the channel inconsistent. It's showed that the lowest value occurs at the end of channel 3 not at the outlet. This phenomenon can be explained that the position of the end of channel 3 is the lowest, where liquid water is easy to accumulate,

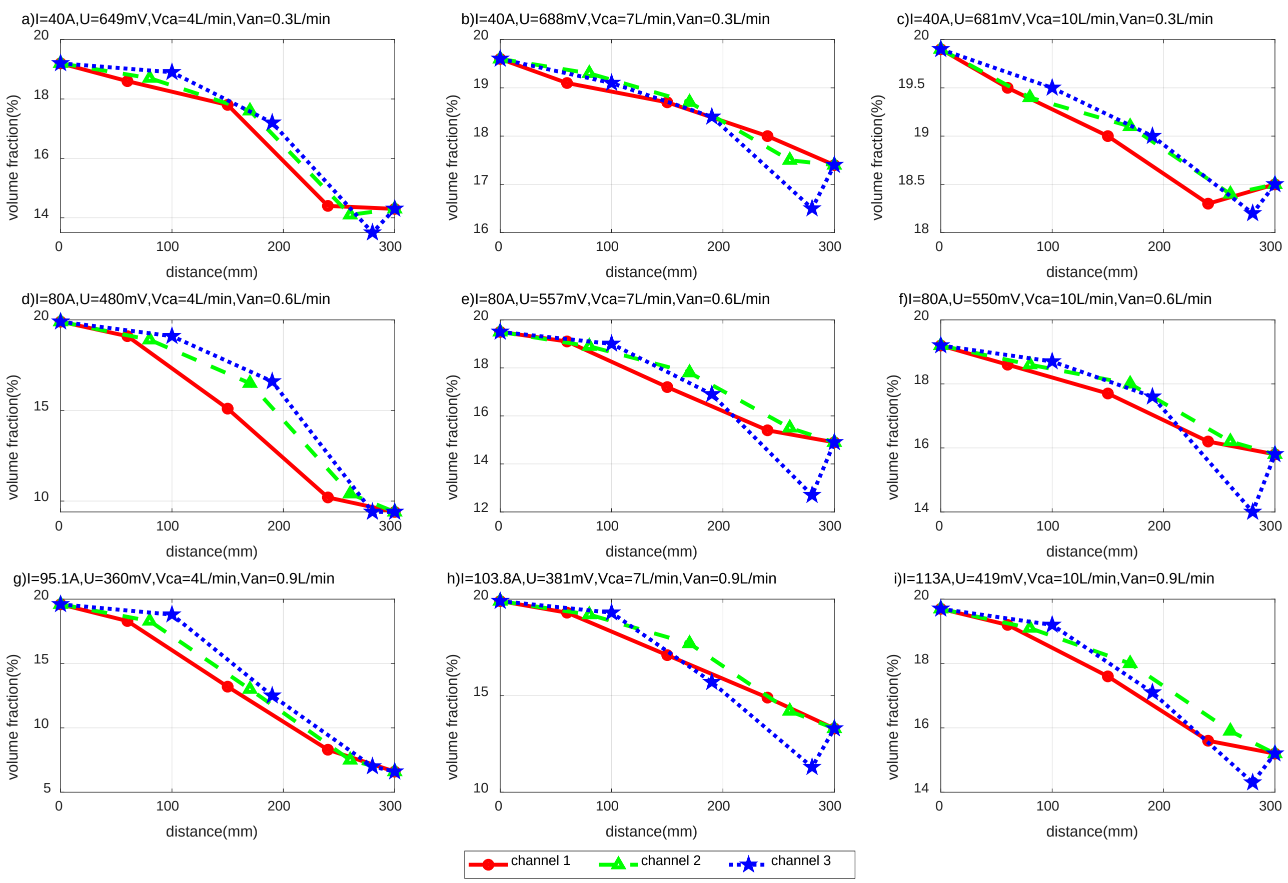

Fig 3 The volume fraction of oxygen at different locations of the cathode

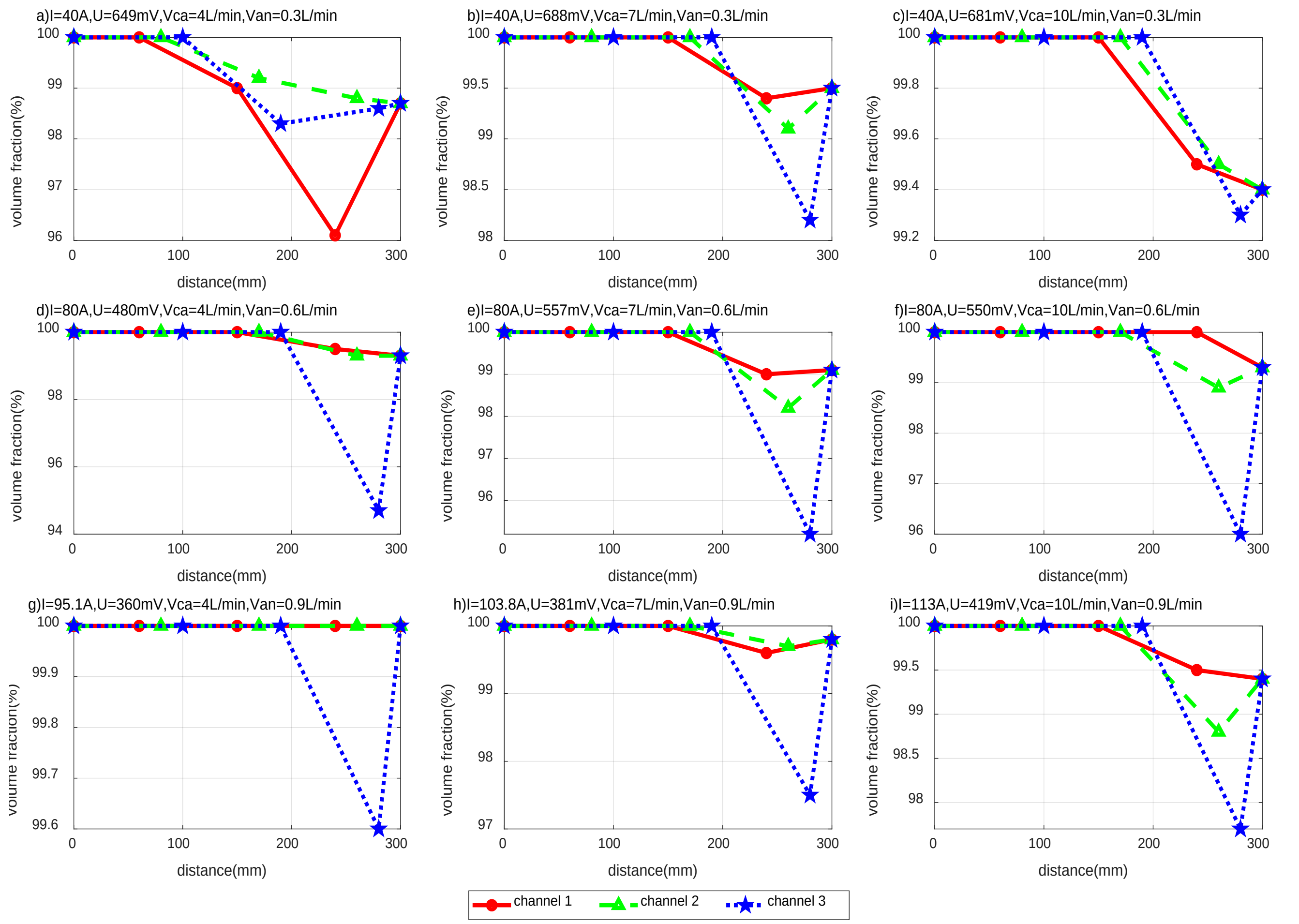

Fig 4 The volume fraction of hydrogen at different locations of the anode

thus forming slug flow, resulting in uneven distribution of gas concentration.

4. CONCLUSION

To study the fuel cell performance, the multi-point gas sampling system for large format fuel cell is proposed. By sampling the gas at different positions in different channels, the volume fraction of the gas is analyzed. The experimental results show that the gas concentration decreases gradually along the channel. In the cathode, the oxygen concentration decreases gradually along the channel because of the consumption of oxygen. In addition, the oxygen concentration in different channels is also different. The lowest concentration is not at the outlet of the channel, but close to the outlet of the channel, due to the accumulation of liquid water. In the anode, the concentration of hydrogen changes at the end of the channel. On the one hand, it is because the nitrogen diffused from the cathode channel. On the other hand, the flow of hydrogen causes nitrogen to accumulate at the end of the channel. The results show that the concentration of hydrogen in different channels is also different, for that under the driven by gravity, nitrogen accumulates at the bottom. It's proved that multi-point gas sampling system can be used to study the characteristic distribution of fuel cell, especially of large format fuel cell, which can directly get the gas by sampling and analyze the distribution without many complex sensors.

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