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Experimental investigation of operating condition and membrane effects on anion exchange membrane fuel cells

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ABSTRACT

Anion exchange membrane is the core component, and also the key development direction of alkaline fuel cells. In this paper, three popular commercialized anion exchange membranes (Orion 30 μm mechanically reinforced membrane, Orion 5 μm mechanically reinforced membrane, and Alkymer 25 μm membrane) were selected to investigate the effects of different temperature, humidity, stoichiometric ratio and other operating condition factors on the alkaline fuel cell. The experimental results show that the Orion membrane has more stable performance than Alkymer when the cathode stoichiometry ratio changes. The ohmic impedance and activation impedance of the Alkymer membrane decrease as the temperature increases, and thus the operating temperature can be properly increased to improve the fuel cell performance for Alkyme. Humidity change would significantly change the level of membrane hydration, which influences the membrane conductivity. It is also found that the ohmic impedance of Alkymer is more stable than that Orion when the humidity is reduced, and a slight reduction of humidity could improve the fuel cell performance in our experiments.

Keywords: Anion exchange membrane, Alkaline fuel cell, Experimental, Operating condition effect, Orion and Alkymer.

1. INTRODUCTION

Alkaline anion exchange membrane fuel cell has good application prospects due to its advantages of using non-precious metal catalysts. Many studies focused on the development of alkaline anion exchange membrane fuel cells in recent years. Huang et al. [1] obtained the performance of 3.4 W/cm^2 after optimizing the water management of alkaline fuel cells. Meek et al. [2] comparative experiments with a variety of commercial membranes demonstrated the high performance as well as the high durability of the membranes they developed. Miyanishi et al. [3] developed the membranes with high swelling resistance, shows that the spirocyclic structure contributes to durability. Han et al. [4] found that the introduction of cross-linked structures improved the mechanical properties.

The improvement of membrane performance brought about the expansion of application prospects, and also brought about a turnaround in the performance of alkaline fuel cells. However, the improvement of membrane performance alone is not enough; water management accounts for a large part of the fuel cell performance optimization, so the effect of different temperature, humidity and other conditions on the performance of fuel cells assembled from these membranes needs to be revisited.

2. METHODS

2.1 Experimental preparation

In order to compare different membrane performance as well as sensitivity, the same platinum loading and spraying process was used for MEA fabrication, and 60% carbon loaded platinum was used as catalyst, the same brand of ionomer provided by the corresponding manufacturer of the membrane. We chose isopropyl alcohol as organic solvent,

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which was sprayed after ultrasonic shocking of ink and treated with potassium hydroxide solution for cell assembly. Also 80% compression rate was taken for the gas diffusion layer, and the same plan was used for all three membranes made fuel cells to ensure that other variables were excluded when comparing the experimental results.

In this paper, different flow fields were used at the cathode and anode, including a serpentine flow field at the anode and a parallel flow field at the cathode, and GDL with MPL at the anode and GDL without MPL at the cathode, while hydrogen and oxygen were used as the reaction gases in all cells with a reaction area of 25 cm^2 , which was the best cell assembly scheme compared in the previous experiments.

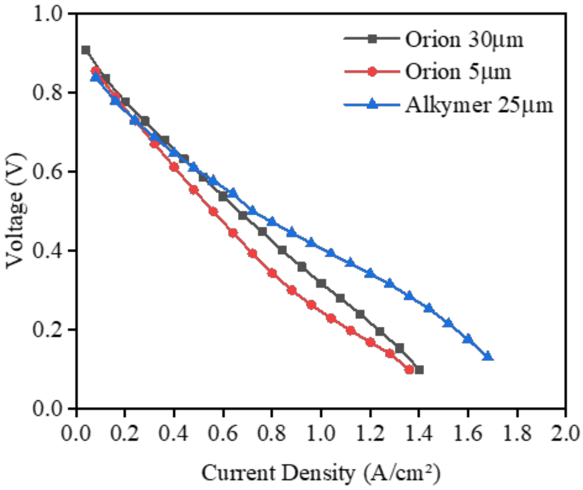

Fig. 1. Polarization curves of different fuel cells

2.2 Experimental procedure

In this experiment, 60℃ and 80℃; 80% RH and 100% RH; and 0.5L/min and 0.3L/min cathode inlet were selected for the fuel cells with different membrane in comparison experiments, and 60℃, 100% RH, and 0.5L/min for both cathode and anode inlet were selected as basic conditions for the basic control group, and then the three fuel cells under this condition were derived polarization curves.

As can be seen from the polarization curves, the performance of the three membranes under the experimental conditions was Alkymer, Orion-30 and Orion-5 in descending order, and the performance gap was more obvious at medium and high currents. The high frequency impedance spectra of the two groups Orion 5 and Alkymer at 25A current were selected for comparison, and it can be seen that the two batteries showed a large difference in the concentration loss, while the ohmic loss was smaller and the activation loss was larger in group Alkymer compared with group Orion-5. It can be explained that because the concentration loss of group Alkymer was smaller than that of group Orion-5 at high current density, the difference between the performance of two groups becomes larger and larger as the current increaseed, and the concentration loss accounted for the major part of the influencing factors. Therefore the stoichiometric ratio of the reaction gas needs to be adjusted to optimize the concentration loss and the adjustment of stoichiometric ratios also brings about other changes in impedance.

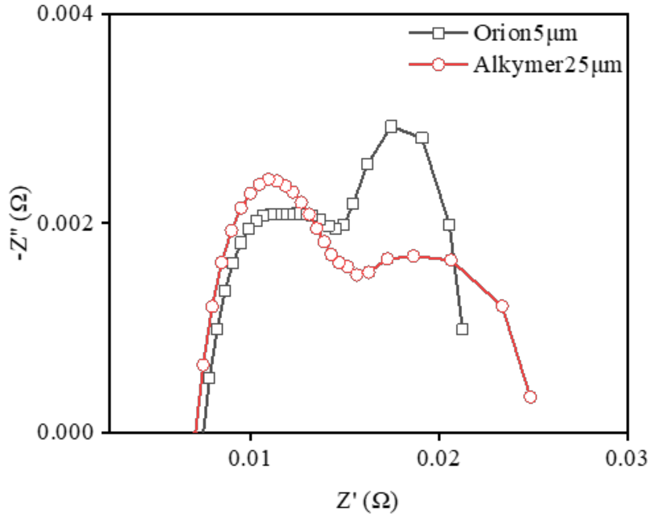

Fig. 2. EIS results of fuel cells made of Orion-5 and Alkymer

3. RESULTS AND DISCUSSION

3.1 Effect of stoichiometry ratio

Since the concentration loss was more influential in the above control experiments, the method of changing the cathode stoichiometry ratio was used to investigate for the two groups Orion-5 and Alkymer. When the cathode inlet volume was reduced from 0.5 L/min to 0.3 L/min, the two groups showed different impedance changes When the current of the cell was 20A. It can be seen in group Alkymer that as the cathode stoichiometry ratio decreases, the concentration loss increased significantly, while the impedance in group Orion-5 was basically unchanged, so it can be concluded that Alkymer is more sensitive to the change of stoichiometry ratio, and the optimization of the performance of this cell can be achieved by adjusting the stoichiometry ratio. The change of stoichiometry ratio has less effect on Orion-5 membrane, when this group faced different cathode stoichiometry ratios, the impedance is basically unchanged.

From the above analysis, it can be seen that when it is necessary to improve the performance of the two fuel cell groups, there are different options to consider for the two different membranes. Adjustment of the cathode gas flow rate for group Orion-5 did not affect the impedance, while the optimization of group Alkymer needs to take the influence of the stoichiometric ratio into account, increasing the cathode stoichiometry ratio properly can significantly optimize the performance of the fuel cell, but the air volume should not be too large, otherwise it will bring new problems. When two optimization methods conflict, the best solution needs to be selected for the working conditions.

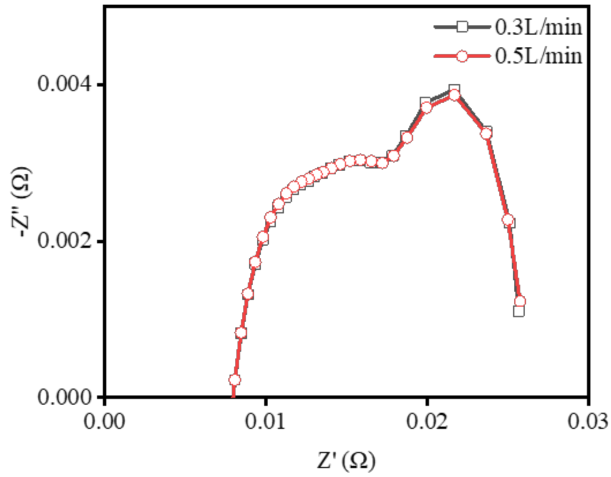

Fig. 3. EIS results of Orion-5 with different stoichiometric ratio

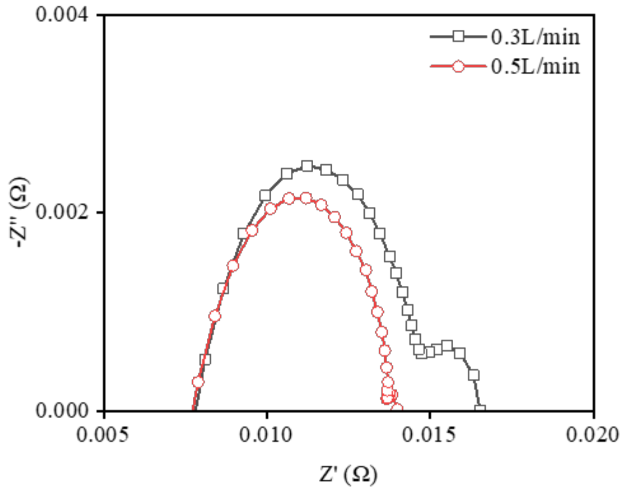

Fig. 4. EIS results of Alkymer-25 with different stoichiometric ratio

3.2 Effect of temperature

When the current of the cell was 5A, through the two sets of temperature change experiments, we can see that when the temperature increased from 60℃ to 80℃, the two groups showed different impedance changes, while the ohmic and activation impedance of group Orion-5 became smaller, and the activation impedance of group Alkymer became smaller but the ohmic impedance became larger. Therefore, Alkymer prefers to increase the temperature to reduce the impedance in order to optimize the performance of the fuel cell, and it is not advisable to increase the temperature too much for Orion membrane. At the same time, different operating conditions need to be considered. When the influence of the ohmic impedance of the operating conditions is not significant, the performance optimization can also be achieved by appropriately increasing the temperature for Orion-5.

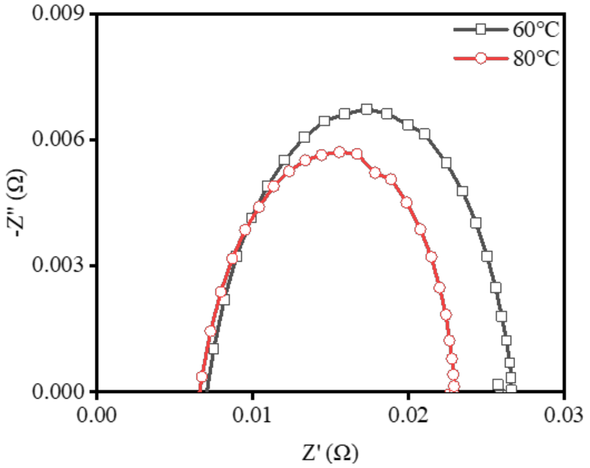

Fig. 5. EIS results of Alkymer-25 with different temperature

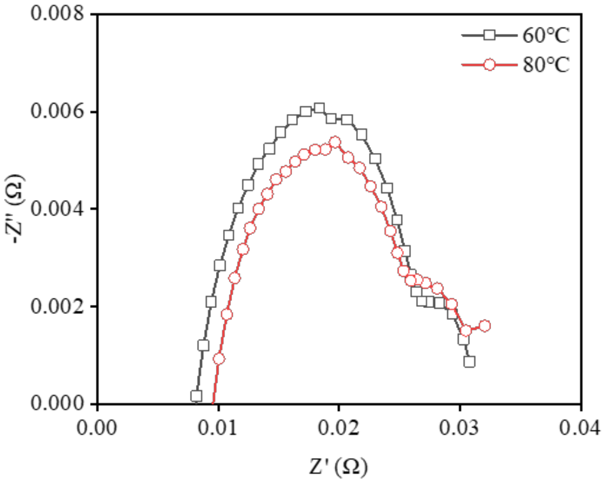

Fig. 6. EIS results of Orion-5 with different temperature

By analyzing the results above, we can see the decrease in activation impedance, which can be explained by the decrease in activation energy. The impedance of the membrane depends on the conductivity of the membrane, which is closely related to the hydration of the membrane. Therefore, the humidity of the inlet air has a great influence on the performance of the fuel cell, it needs to be analyzed.

3.3 Effect of humidity

The impedance of the two groups changed when the relative humidity was reduced from 100% to 80%, and the current of fuel cell is 25A. The ohmic impedance of group Orion-5 increased while that of group Alkymer remained unchanged. Then we can see the humidity effect is not significant for group Orion-5 with the ohmic impedance, while Anion exchange membrane fuel cell with Alkymer can optimize the performance by reducing the humidity of the inlet gas, but the inlet air humidity should not be too low.

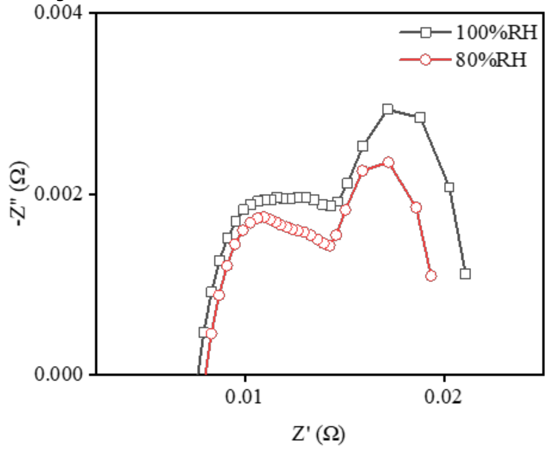

Fig. 7. EIS results of Alkymer-25 with different humidity

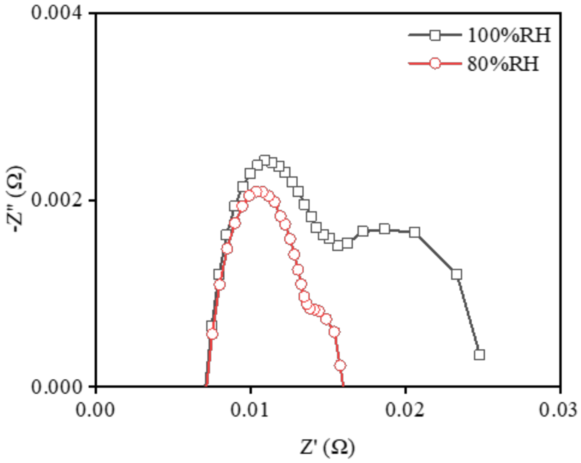

Fig. 8. EIS results of Orion-5 with different humidity

In this EIS results, we can see after reducing the inlet humidity, both activation impedance and concentration impedance were reduced in both cells, which should be attributed to the reduction of the flow channel flooding phenomenon, while the different ohmic impedance changes should be related to membrane materials, when the humidity changes, different membranes have different water retention ability. When a new anion exchange membrane is put into use, it needs to be understood for these properties to achieve better performance.

4. CONCLUSION

In this work, the effects of different working conditions for different anion exchange membranes are discussed through comparative experiments on several alkaline fuel cells. From these comparative experiments, we can see that increasing the temperature significantly reduces the activation impedance, and a small decrease in the inlet humidity reduces the activation impedance and the concentration impedance. But the effect on ohmic impedance varies depending on the membrane material, Alkymer shows better ohmic impedance under operating condition changing, such as temperature increasing and humidity decreasing. And the method of increasing the cathode inlet volume is only useful for Alkymer, it also means that reducing the cathode stoichiometry ratio will bring about a deterioration of its performance, but Orion is relatively stable in this case. The above results can provide guidance to achieve better performance of alkaline fuel cells, when using different membranes to assemble a fuel cell, the effect of temperature, humidity and other conditions on its performance needs to be considered. However, some common findings are valuable, such as raising the temperature can bring about a significant reduction in activation impedance, and Proper reduction of inlet air humidity can lead to performance improving.

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REFERENCE

[1] Garrett Huang, Mrinmay Mandal. Composite Poly(norbornene) Anion Conducting Membranes for Achieving Durability, Water Management and High Power (3.4 W/cm2) in Hydrogen/Oxygen Alkaline Fuel Cells. Journal of The Electrochemical Society 2019; 166 (10) F637-F644.

[2] Kelly M. Meek, Christopher M. Antunes. High-Throughput Anion Exchange Membrane Characterization at NREL. ECS Transactions 2019; 92 (8) 723-731.

[3] Shoji Miyanishi, Takeo Yamaguchi. Highly durable spirobifluorene-based aromatic anion conducting polymer for a solid ionomer of alkaline fuel cells and water electrolysis cells. Journal of materials chemistry A 2019; 7 (5) 2219-2224.

[4] Xu Han, Jilin Wang. Preparation of anion exchange membranes based on pyridine functionalized poly (vinyl alcohol) crosslinked by 1,4-dichlorobutane. Journal of applied polymer science 2018; 136(16) 47395.