論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Systematic Design of Membrane Electrode Assembly for Anion Exchange Membrane Fuel Cells
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出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第12728号, 授与年月日:2024年3月26日, 学位の種別:課程博士, 審査員:山口 猛央,冨田 育義,荒井 創,平山 雅章,黒木 秀記
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第12728号, Conferred date:2024/3/26, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	応用化学 応用化学	系 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of	(Engineering)
学生氏名： Student's Name	DU YI		審査員主査： Chief Examiner	山口猛央	

要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

This thesis entitled "Systematic Design of Membrane Electrode Assembly for Anion Exchange Membrane Fuel Cells", is aimed to improve the performance and durability of Direct Formate Fuel Cells (DFFCs). It involves developing highly durable anion exchange membranes (AEMs) using polyfluorene-based polymers without ether linkages, controlling membrane properties, elucidating the relationship between developed AEM characteristics and DFFC performance, and reducing mass transfer resistance at the anode to design and develop high-performance and durable DFFCs. The thesis comprises six chapters.

Chapter 1 provides an overview of AEM fuel cells (AEMFCs) including membranes, catalyst materials, membrane-electrode assemblies, and DFFCs. It emphasizes the importance of developing durable AEM materials for operation in alkaline environment and the necessity of overall design of the membrane-electrode assembly for enhancing DFFC performance. This chapter highlights the importance of developing polyfluorene-based AEMs, considering membrane properties, and anode mass transfer processes in DFFC design.

Chapter 2 focuses on synthesizing ether-free polyfluorene-based polymers with controlled ion exchange capacity (IEC) and developing pore-filling membranes to suppress membrane swelling by filling polymers into cast films and porous substrates. The correlation between the degree of swelling and formate permeability in the developed membranes unveils that a lower degree of swelling resulted in decreased formate permeability, and the combination of low IEC membranes with the PF method led to the lowest formate permeability compared to other AEMs. Moreover, the membrane swelled more in OH^- than in COO^- counter anion species, leading to increased formate permeability. Also, AEMs with ether-free polyfluorene backbone demonstrated superior alkaline and oxidative stabilities.

Chapter 3 describes the development of polyfluorene-based AEM with a π-π stacking structure by introducing methyl side chain, exhibiting a layer spacing of 4.2 Å. This structure significantly suppresses formate permeability while maintaining high ion conductivity.

Chapter 4 deals with the application of the AEMs developed in Chapters 2 and 3 to DFFCs and an investigation of the relationship between membrane properties and DFFC performance. AEMs having high formate permeability showed a decrease in open-circuit voltage (OCV) due to an efficient formate permeation from the anode to the cathode where it reacts on the cathode catalyst. Thus, combining low IEC polymers with pore-filling methods in AEMs, as well as introducing π-π stacking structure in AEM, improved OCV values from the original 0.55 V to around 0.95 V by suppressing the formate permeation. This chapter provides the quantitative correlation between the formate permeability with OCV values and the ion conductivity of AEMs with the cell resistance of DFFC cells. Furthermore, this chapter also demonstrates the effectiveness of introducing a π-π stacking structure to balance high ion conductivity and low formate permeation, thereby enhancing DFFC performance.

Chapter 5 focuses on the design and development of DFFCs considering the mass transfer process at the anode using π-π stacking AEM showing both high OCV and low cell resistance. The dependence of DFFC performance on operating conditions such as formate concentration and flow rate, showed formate concentration polarization occurring in the anode electrode (catalyst layer + diffusion layer) at high current density regions. Both high formate concentration and high flow rate were found to reduce mass transfer resistance by facilitating fuel transport through the diffusion layer. Results from the DFFC tests using the diffusion layers with different thicknesses and pore sizes reveal significant reduction in anode mass transfer resistance with diffusion layers having larger pore sizes. Unlike conventional diffusion layers allowing permeation via molecular diffusion, diffusion layers with larger pores enable formate permeation through convection flow, promoting formate supply to the catalyst layer.

Chapter 6 summarizes the achievements of this thesis and outlines future prospects.
In summary, this thesis develops highly durable AEMs that significantly suppress the permeation of liquid fuel (formate) and successful design and development of the high-performance DFFCs. It elucidates the influence of AEM formate permeability and ion conductivity on DFFC performance and provides useful design guidelines for membrane materials. Furthermore, it demonstrates significant improvement in anode formate mass transfer resistance through structural control of diffusion layers. The results obtained in this research work provide the design guidelines for achieving high-performance and durable DFFCs, making significant contributions in the field of engineering, as it enables the development of AEMFCs using other liquid fuels and AEM-type water electrolyzers.