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Thesis Outline

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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 including membranes, catalyst materials, design of membrane-electrode assemblies, and DFFCs.

Chapter 2 focuses on synthesizing ether-free polyfluorene–based polymers with controlled ion exchange capacity and developed pore-filling membranes to reduce membrane swelling and formate permeability. Moreover, the developed AEMs demonstrates superior alkaline and oxidative durability owing to the heteroatom-free backbone.

Chapter 3 describes the development of polyfluorene-based AEM with a π-π stacking structure, 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. It demonstrates the impact of AEM membrane properties on DFFC performance and the benefit of introducing π-π stacking structure balancing high ion conductivity and formate permeation for DFFC performance enhancement.

Chapter 5 focuses on the design and development of DFFCs considering the process of mass transfer resistance at the anode using π-π stacking AEM as cell membrane. Results from DFFC tests using diffusion layers with varying thicknesses and pore sizes reveal significant reduction in anode mass transfer resistance with diffusion layers having larger pore sizes. Unlike conventional diffusion layers that allow molecular permeation, diffusion layers with larger pores facilitate formate permeation through flow, thereby promoting the supply of formate 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.

Flowchart illustrating the content of this study