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Reinforced Conductive Membrane Integration: Enhancing Performance and Durability of PEM Fuel Cells

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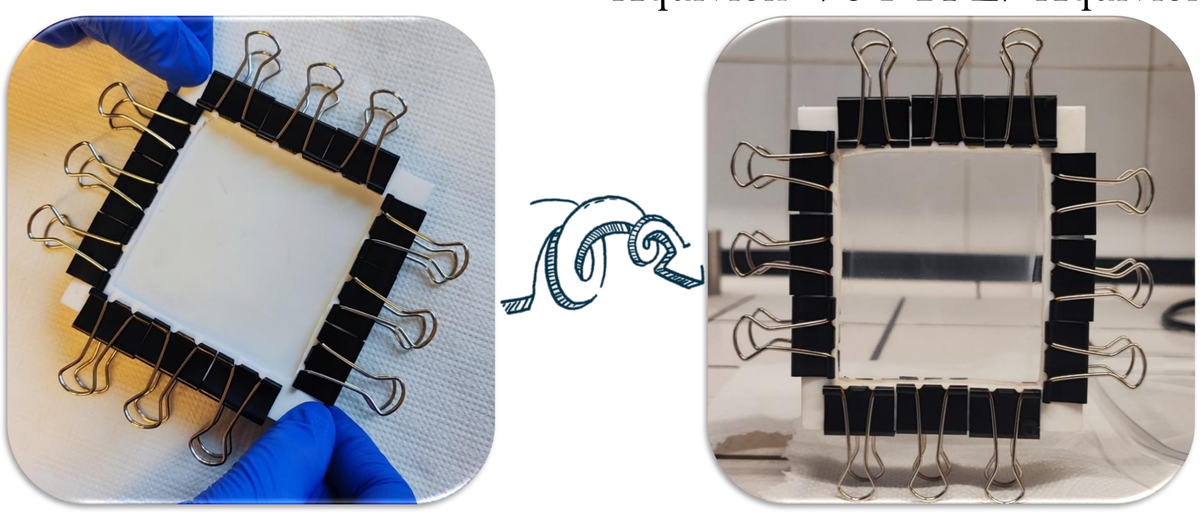
Abstract

Proton exchange membrane fuel cells (PEMFCs) are a promising clean energy solution, but their widespread adoption is hindered by limitations in the proton exchange membrane (PEM) component. Conventional PEMs exhibit mechanical fragility, restricted proton conductivity, and vulnerability to chemical degradation. This study presents the development and integration of a novel reinforced conductive membrane to overcome these challenges. The reinforced membrane is formulated by blending the high-performance proton exchange polymer Aquivion® and the mechanically robust and chemically resistant polytetrafluoroethylene (PTFE). The incorporation of PTFE enhances the membrane's mechanical integrity, while the synergy between Aquivion® and PTFE improves proton transport efficiency and resistance to chemical degradation.

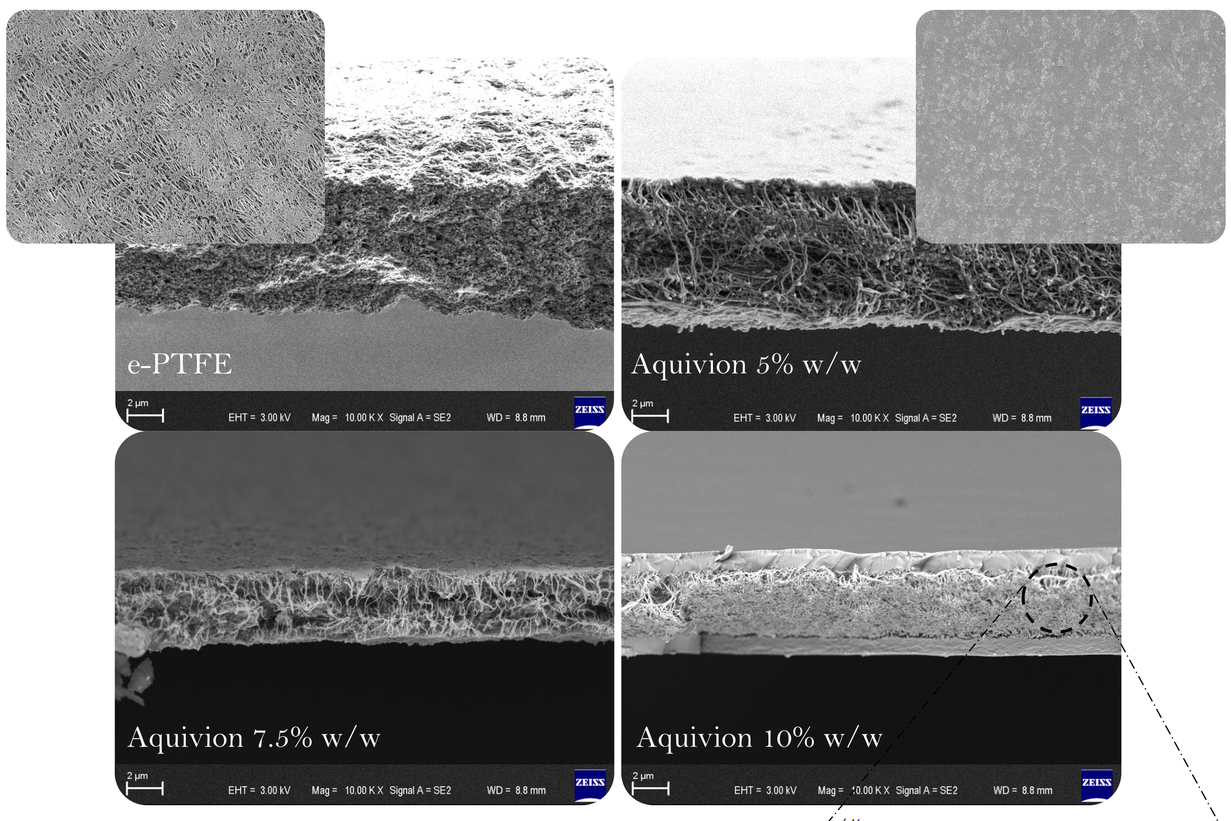
Membrane Preparation

e-PTFE → Aquivion® /e-PTFE/ Aquivion®

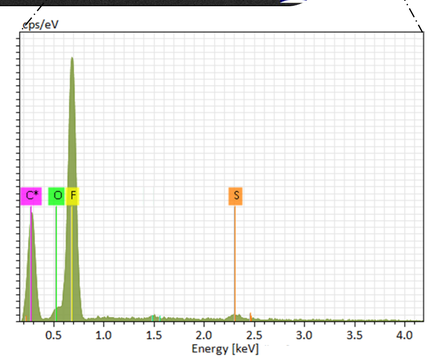


- Preparation of casting solution including DI water, Aquivion® D72-25BS, and Propanol
- Using drop-coating method to deposit Aquivion layer on the both sides of e-PTFE for 150 sec
- Initial heat treatment to remove extra solvents at 90℃ for 10 min; The initial heat treatment at 90℃ helps to facilitate the integration and bonding of the Aquivion and PTFE components, while also initiating the removal of the propanol and water solvents.
- Final Heat treatment at 140℃ for 30 min; The second heat treatment at 140℃ completes the solvent removal process, ensuring a solvent-free Aquivion/PTFE/Aquivion membrane structure.

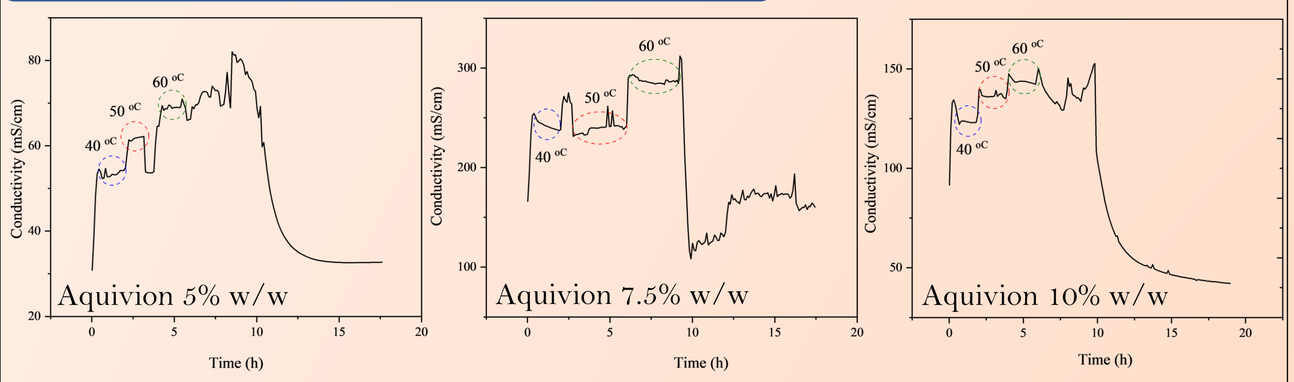
SEM & EDS



- The viscosity of the solution plays an important role in determining the monolayer/multilayer structure.
- Based on the EDS analysis, it is clear that the Aquivion has diffused into the e-PTFE pores.

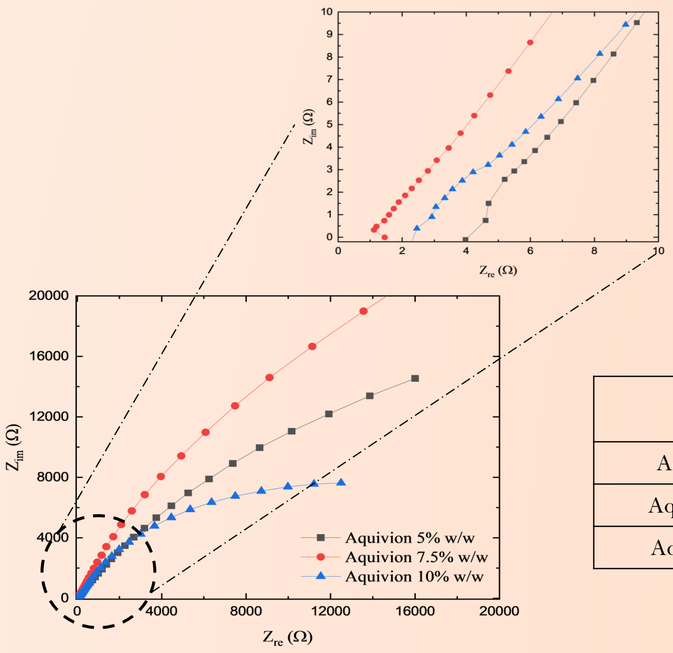


Conductivity measurements



In-plane Conductivity

Sample code	Conductivity (mS/cm) @ 60℃, humidity= 80%
Aquivion 5% w/w	70
Aquivion 7.5% w/w	280
Aquivion 10% w/w	140

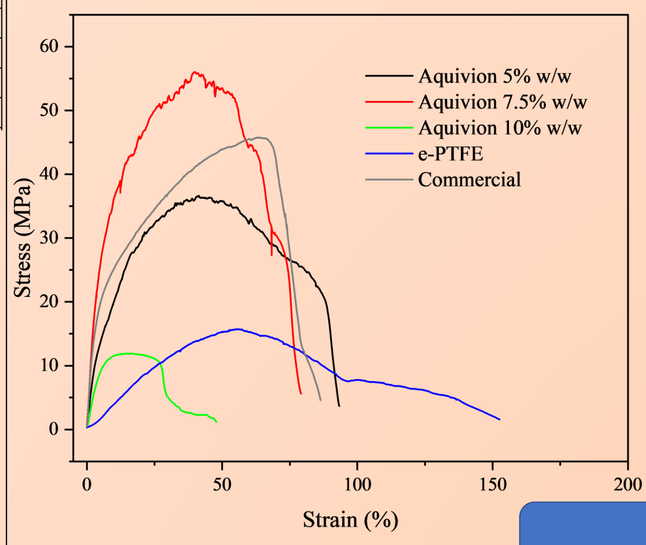


Through-plane Conductivity

Sample code	Conductivity (mS/cm) @ 25℃, humidity= 55%
Aquivion 5% w/w	0.271
Aquivion 7.5% w/w	1.657
Aquivion 10% w/w	1.726

Tensile analysis

- In a specific formulation, our engineered membrane exhibited enhanced tensile characteristics, ensuring more viable performance during extended evaluations.



Sample code	Yield strength (MPa)	Max Stress (MPa)	Max Strain (%)
e-PTFE	3.5	15.7	170
Aquivion 5% w/w	19.9	36.6	94
Aquivion 7.5% w/w	36.2	56	79
Aquivion 10% w/w	11.5	11.9	48
Commercial	25.15	45.8	86

Summary

- Conventional proton exchange membranes (PEMs) in fuel cells are hindered by mechanical fragility, limited proton conductivity, and vulnerability to chemical degradation.
- A novel membrane has been developed by blending Aquivion® polymer with polytetrafluoroethylene (PTFE), which enhances mechanical strength, proton conductivity, and chemical resistance.
- The membrane is created using a drop-coating method and two heat treatments to ensure proper integration of components and removal of solvents, resulting in a stable membrane structure.
- The engineered membrane demonstrates enhanced tensile characteristics, indicating improved durability and performance during extended evaluations