Synthesis, Characterization and Ion conductivity Analysis of Pyridine, Meta, and Para-Polybenzimidazole based Membranes for High-Temperature PEM Fuel Cells

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A proton exchange membrane fuel cell is employed as the source of high-purity hydrogen gas fuel. Biomass, fossil fuels, and water electrolysis are just a few resources that can be used to produce hydrogen fuel for fuel cells. Carbon monoxide (CO), which can poison platinum (Pt) catalyst electrodes, is present in the reformed hydrogen gas supply. The poisoning effect of CO on platinum (Pt) catalyst electrodes may be reduced by high-temperature PEMFCs.[1][3]. Recent studies have focused on enhancing the performance of HT-PEMFC devices under ambient pressure, dry air, and temperatures between 120 and 200°C for a variety of reasons, including higher operating temperatures that improve cell efficiency, electrolytic reactions, and CO tolerance, as well as easy water and heat management.[3][4]. To overcome the limitations of other polymer membranes, PBI has attracted significant attention from researchers. However, despite its promising properties, PBI still has certain limitations that need improvement particularly in enhancing its acid doping level and proton conductivity. Therefore, synthesizing modified PBI polymers is preferred. In this study, three different PBIs were synthesized and characterized to enhance their performance and evaluate the relationships between their structures and properties. Polybenzimidazoles (PBIs) are linear heterocyclic polymers that feature benzimidazole units in their repeating structure. They are well known for their exceptional thermal stability, mechanical strength, and resistance to chemical degradation, making them ideal for high-performance applications.[4][5].Thermogravimetric analysis (TGA) tests were conducted in the polymer laboratory utilizing the TGA 1 STARe System METTLER TOLEDO. Integrated by Gas Controller GC-200 under air environment to evaluate the thermal stability of the synthesized PBI membranes with a heating rate of 10 °C min-1 in a temperature range from 25 °C to 900 °C.

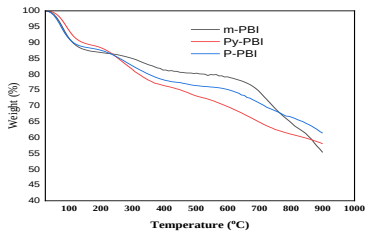

Fig.1 TGA graph for the synthesized PBI polymers

The TGA results show that P-PBI has the highest thermal stability with 61% residual weight at 900 °C, followed by Py-PBI (58%) and m-PBI (55%). This indicates that P-PBI degrades the least at high temperatures, suggesting superior thermal resistance among the synthesized PBI polymers. The FTIR results also confirmed the successful polymerization of the characteristic functional groups in the synthesized PBI.
The XRD patterns of synthesized PBI membranes showed broad peaks around 2θ = 20–30°, indicating amorphous structures. p-PBI exhibits the highest peak intensity.
The proton conductivity was then calculated based on the following Equation.

$$\sigma(s/cm) = \frac{L}{R*w*t} \quad [1]$$

Table1: Proton conductivity of the synthesized membranes at different temperatures and acid doping levels

Polymer membrane	Temperature ℃	ADL	Conductivity s/cm
p-PBI	160	14	0.1804
Py-PBI	180	19	0.224
m-PBI	200	12	0.232

Table 1 shows the proton conductivity of synthesized PBI membranes at various temperatures and acid doping levels. m-PBI had the highest conductivity (0.232 s/cm at 200 °C), followed by Py-PBI and p-PBI. Conductivity generally increased with temperature, but membrane structure and doping level also influenced performance.

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