

# Development of nano-composite membranes to improve alkaline fuel cell performance

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## INTRODUCTION

Among various types of fuel cells comprising a polymer electrolyte membrane (PEM), direct methanol fuel cells (DMFCs) and alkaline fuel cells (AFCs) owing to their low weight, high energy density, simple system design, low emission and safety of fuel handling, are the most promising candidates as power sources for portable electronic devices and transportation applications [1,2]. Generally, PEMs are central and often performance limiting component of DMFCs [3]. To date, the most widely used PEMs have been composed of Nafion®, a perfluorosulfonic acid macromolecule developed by DuPont in the 1960s [1]. However, high methanol crossover and expensive cost are the critical limitations of Nafion® for DMFC applications [4]. In recent years, significant progress has been made to develop polymer electrolyte membranes for DMFCs in terms of reduced cost as well as improved functionality [5]. Recently, alternative materials (such as polysulfone) to Nafion have been developed with non-perfluorinated backbone chains that have high thermal, thermo-oxidative, chemical, and mechanical stabilities with lower costs. Polysulfones (PS) are commercially available materials, well known for their excellent mechanical, thermal, and chemical stability [6]. In alkaline fuel cells, the OH anions are produced at the cathode and then transported through the membrane to the anode where they are consumed (opposite to the movement of protons in acidic membranes). The pathway of the OH anions opposes the direction of methanol flux through the membrane leading to an intrinsic reduction in methanol crossover (Figure 1).

In recent years, polymeric/inorganic composite membranes have attracted great attention because of their dual functionality like specific chemical reactivity and flexibility of the organic polymer backbone, as well as the mechanical properties and thermal stability of the inorganic backbone [7]. Composite membranes based on zeolites [8], TiO<sub>2</sub> [9] and zirconium hydrogen phosphonate [10] have been investigated with improvements reported in many properties relative to their matrix materials.

The work presented here describe modification of commercially available polysulfone (PSU) as well as the formation of nano-composite membrane i.e. TiO<sub>2</sub> nano particles incorporated into anion exchange polymer matrix. A series of characterization studies which includes 1H-NMR, FT-IR, TGA and SEM were also performed.

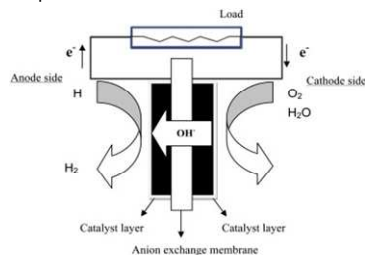
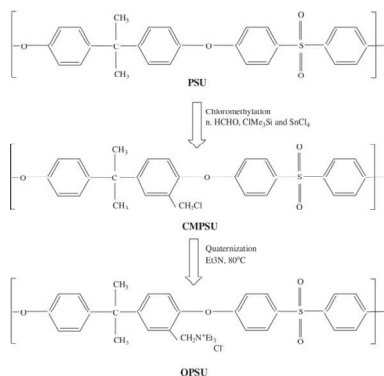


Figure 1: Schematic diagrams of alkaline exchange membrane fuel cells

## EXPERIMENT

### PREPARATION OF ALKALINE EXCHANGE MEMBRANE



Preparation of composite membrane: The OH form QPSU was dissolved in DMAc and inorganic TiO<sub>2</sub> nano filler was added to this solution and then subjected to ultra sonication for 1h, followed by casting. The membrane was dried at 80 °C overnight.

Scheme 1: Multi-step synthesis of quaternized polysulfones [11].

## RESULTS AND DISCUSSIONS

### 1. <sup>1</sup>H-NMR SPECTRA

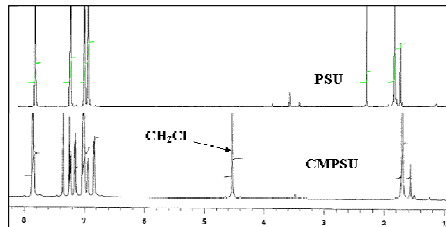


Figure 2: <sup>1</sup>H-NMR spectra of polysulfone (PSU) and chloromethylated intermediate (CMPSU). All spectra were recorded on a Varian 500 MHz spectrometer using CDCl<sub>3</sub> as solvent.

### 2. FT-IR SPECTRA

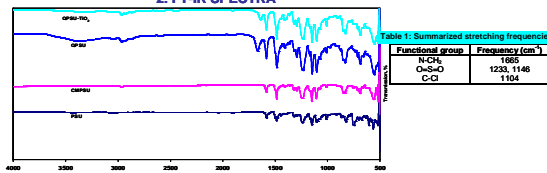


Figure 3: FT-IR spectra of PSU, CMPSU, QPSU and QPSU-TiO<sub>2</sub> respectively were recorded on a diamond plate.

### 3. THERMAL ANALYSIS

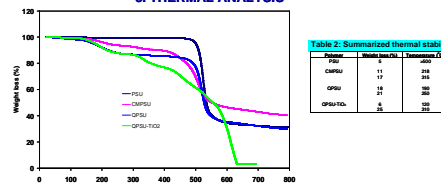


Figure 4: TG curves of compounds PSU, CMPSU, QPSU and QPSU-TiO<sub>2</sub>. All samples were heated at 10 °C/min under N<sub>2</sub>.

### 4. SEM

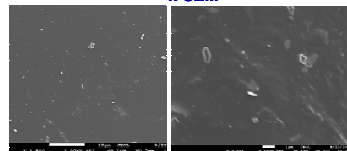


Figure 5: SEM images of QPSU (R) and QPSU-TiO<sub>2</sub> (L)

• The characteristic peak of -CH<sub>2</sub>Cl group at 4.5 ppm shown by <sup>1</sup>H-NMR confirms successful preparation of CMPSU with respect to the parent polymer (insert spectra) **Figure 2**.

• As the quaternized polymer was not soluble in CDCl<sub>3</sub>, no NMR spectra is presented.

• FT-IR spectra displayed additional absorbance at 1665 cm<sup>-1</sup> for quaternized polymers, indicated that the reaction proceeded as expected.

• TGA profile also showed the weight loss between 200 and 240 °C is due to the removal of quaternary ammonium groups and the second loss at higher temperatures above 400 °C is due to polymer backbone degradation.

• SEM images shows smooth, uniform and defect free surface of QPSU where as QPSU-TiO<sub>2</sub> surface showed uniform distribution of the filler without formal cracks.

## CONCLUSIONS AND FUTURE WORK

• FT-IR confirmed the formation of the anionic membranes while <sup>1</sup>H-NMR results confirmed the chloromethylated intermediates.

• Thermal studies demonstrated that the quaternized polymers has good thermal and higher degradation temperatures

• Future studies will be conducted to compare different composition of TiO<sub>2</sub> fillers onto quaternized membrane as well as ionic conductivity over a temperature range of 25 – 70 °C.

• Methanol permeability of the all membranes as a function of temperature will also be determined. From these results, it will be determined if the membranes are suitable for use in direct alcohol alkaline fuel cells.

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