

# Nafion/Titanate naotube hybrid Electrolyte Membranes for PEFC operating at Elevated Temperature

K. Ketpang<sup>a</sup>, A. K. Sahu<sup>a</sup>, Osung Kwon<sup>b</sup>, Sang C. Lee<sup>b</sup>,  
Sangaraju Shanmugam<sup>a\*</sup>

<sup>a</sup>Department of Energy Systems Engineering,

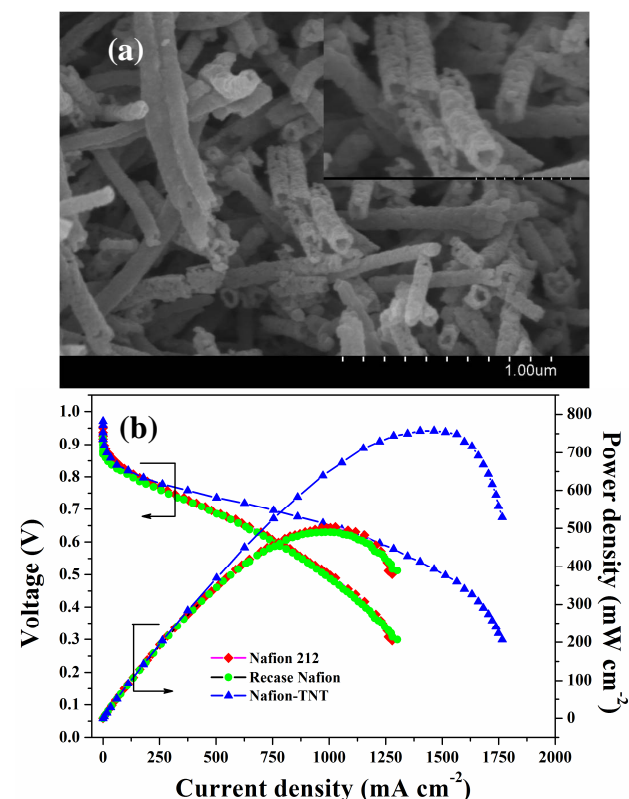
<sup>b</sup>Robotics System Research Division, Daegu Gyeongbuk  
Institute of Science & Technology, 50-1, Sang-Ri,  
Hyeonpung-Myeon, Dalseong-Gun, Daegu, Republic of  
Korea, 711-873  
sangaraju@dgist.ac.kr

Polymer electrolyte fuel cells (PEFC) have been widespread accepted as one of the most promising power sources for automobile application due to high energy conversion efficiency and environmental compatibility. However, the current PEFC technology, utilizes perfluorosulfonic acid (PFSA) polymer membranes, e.g., Nafion, as electrolyte, is limited owing to expensive components and poor performance at elevated temperature (100 – 200 °C). PEFC operated at elevated temperature results in enhancing the performance due to improving electrode kinetic and reduction of adsorption poisoned species such as CO. The deterioration of PEFC performance at elevated temperature is mainly attributed to the loss of proton conductivity of the Nafion membrane which results in drastic increase in the ohmic over potential. Proton conductivity of Nafion membrane is strongly influenced by the water content and the conductivity is maximum when the membrane is fully hydrated. Operating PEFC at elevated temperature leads to membrane dehydration which dramatically reduces the proton conductivity in order of magnitude. Thus, it is highly desirable to enhance proton conductivity Nafion membrane at elevated temperature in order to achieve high PEFC performance [1, 2].

One of the effective approaches to improve the proton conductivity of Nafion at elevated temperature is to incorporate the bifunctional ceramic/inorganic fillers such as SiO<sub>2</sub>, TiO<sub>2</sub>, ZrO<sub>2</sub>, zirconium phosphate and zeolites etc., which are both hygroscopic and proton conductor, in membrane. Hygroscopic inorganic fillers contain water in the molecular framework and it does not evaporate even the temperature greater than 100 °C due to the electrostatic attraction within the electrical double layer. In addition, the insolubility of these compounds in aqueous media is one of the benefits preventing them from leaching. However, incorporating hygroscopic materials in Nafion often reduce the proton conductivity owing hindering the proton transport though the sulfonic acid group in Nafion membrane [3, 4]. Thus, creating the proton transport channel in Nafion membrane by incorporating hygroscopic nanotube filler could be one of the effective approaches to enhance to proton conductivity of Nafion.

The present work directed towards fabrication of Nafion hybrid membranes with different diameter size of porous titanium dioxide nanotube (TNT) (Figure 1 a). The inorganic filler have high affinity to water which facilitates the proton transport across the electrolyte membrane of the PEFC even at 100 °C. The water uptakes, ion-exchange capacity, proton conductivity, phase behavior of the hybrid membranes in conjunction with PEFC performance will be discussed in detail. Figure 1 (b) illustrates the polarization and power density plots obtained at 100 °C. It was found that the power

density at 0.6 V obtained from Nafion-TNT composite membrane operated at 100 °C was 730 mW/cm<sup>2</sup>, which is 268 mW/cm<sup>2</sup> higher than commercial membrane (N-212) and 278 mW/cm<sup>2</sup> higher than recast nafion. The higher PEFC performance at 100 °C was due to the hygroscopic property of TiO<sub>2</sub> which can retain water at 100 °C and due to the nanotube morphology which facilitates the proton transport channel through membrane.



**Fig. 1.** (a) Morphology of porous TiO<sub>2</sub> nanotube and polarization curves of various composites membrane operated at and 100 °C (b)

## References

- [1] S. Bose, T. Kuila, T. X. H. Nguyen, N. H. Kim, K. T. Lau and J. H. Lee, *Prog. Polm. Sci.*, 2011, 36, 813
- [2] K. A. Mauritz and R. B. Moore, *Chem. Rev.*, 2004, 104, 4535
- [3] B.P. Tripathi, and V. K. Shahi, *Prog. Polm. Sci.*, 2011, 36,945
- [4] E. Chalkova, M. B. Pague, M. V. Fedkin, D. J. Wesolowski and S. N. Lvov, *J. Electrochem. Soc.*, 2005, 152, A1035