Nanofibre-Reinforced Composite Proton Exchange Membranes for Fuel Cell Applications

Surya Subianto[a], Sara Cavaliere[a], Deborah Jones[a], Luca Merlo[b], and Jacques Rozière[a]
[a]*Institute Charles Gerhardt, Equipe AIME, Université Montpellier 2, France*
[b] Solvay Specialty Polymers Spa, Italy

In the development of fuel cell membranes, significant research effort has been given on improving their strength and durability in order to increase their lifetime[1]. However, perfluorosulfonic acid (PFSA) membranes such as Nafion which are considered the benchmark for fuel cell membranes generally presents an inverse relationship between mechanical strength and proton conductivity, with more conductive membranes (lower equivalent weight) showing lowered mechanical properties especially under hydration due to excessive swelling.

One way to overcome this issue is to incorporate a mechanically robust reinforcing matrix within the membrane, producing a composite membrane where the reinforcement provides the required mechanical integrity. At the same time, this approach allows a reduction of membrane thickness which decreases the membrane area resistance, improves cell efficiency and facilitates water back-diffusion. Traditionally, porous PTFE or PTFE fibrils have been used, however this approach may result in a barrier layer with low proton conductivity in the centre of the membrane.

More recently, some studies have explored the use of nanofibres made by electrospinning as possible reinforcing matrix for PFSA membranes[2]. Electrospinning has emerged as a versatile and powerful tool for the fabrication of nanofibres due to its ease of use and greater morphological control that is difficult to achieve by conventional fibre processing techniques. Nanofibre mats fabricated by electrospinning possess high porosity and homogeneity. Their mechanically interlocked, very long nonwoven fibres provide strength and flexibility desirable for a reinforcing matrix in composite membranes, thus offering an alternative to expanded PTFE.

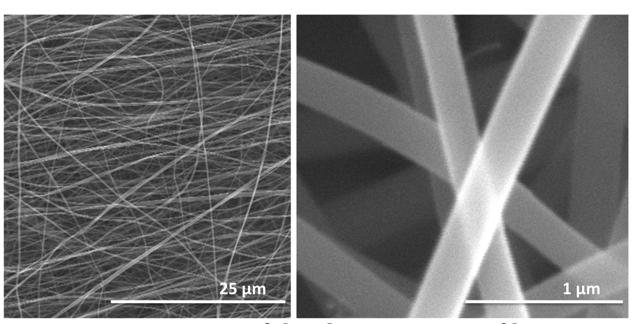

Figure 1. SEM images of the electrospun nanofibre mat

In this presentation, we describe the fabrication of a nanofibre-reinforced composite membrane with a mechanically robust electrospun nanofibre mat (Figure 1) within a matrix of highly proton conductive, low EW PFSA. The nanofibrillar morphology and high porosity of the electropsun mat allows full impregnation by the PFSA, producing a good interface between the two phases (Figure 2) while maintaining a high PFSA volume fraction and thus high proton conductivity. The mechanical strength provided by the reinforcement also allows the use of a low EW PFSA in the membrane, which would otherwise show very poor mechanical properties under hydration.

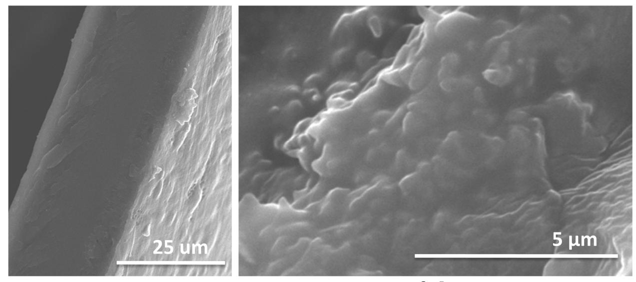

Figure 2. Cross-section SEM images of the composite membrane

Incorporation of the electrospun, non-conducting nanofibre mat significantly reduced swelling upon water uptake and greatly improved mechanical properties of the composite compared to unreinforced membranes. Fuel cell performance tests of the material shows that the reinforced membrane has equal or greater performance compared to a commercial membrane, but with significantly improved mechanical properties, stability, and lifetime as determined by mechanical and OCV hold testing.

References

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2. S. Subianto, M. Pica, M. Casciola, P. Cojocaru, L. Merlo, D. J. Jones and G. Hards, *J. Power Sources*, 2012, **submitted**.