

## ASSOCIATED CONTENT

### Supplementary information

Three appendices are presented here. First one describes about the amount of Nafion required to fill the pores of UHMWPE, second one gives the calculation of amount of Fluorine in NPE composite while third one compares amount of Nafion used in NPE composite with Nafion 211.

#### Appendix A: Amount of Nafion required in NPE to fill the pores

##### Actual Amount of Nafion added in the pores:

Weight of porous PE of  $16\text{cm}^2 = 5.1\text{mg}$

Weight of porous PE of  $9.6\text{cm}^2 = 3.06\text{mg}$

Weight of porous PE of  $6.4\text{cm}^2 = 2.04\text{mg}$

Thickness = 10micron

Porosity ( $\varphi$ ) = 66%

The porosity of the membrane ( $\varphi$ ) was estimated by the following equation:

$$\varphi\% = 1 - W/(AT\rho)$$

Where W is the dry UHMWPE mass,  $\rho$  is the density of UHMWPE, A, T are the geometric membrane area and thickness, respectively.

Initial weight of PE = 3.06mg (for  $9.6\text{cm}^2$  area)

Final weight of (PE + Nafion) = 19.96mg (for  $9.6\text{cm}^2$  area)

Actually, we have  $16\text{cm}^2$  out of which  $9.6\text{cm}^2$  area was used to impregnate Nafion; hence we measure the weight of the whole  $16\text{cm}^2$  area and then subtract  $6.4\text{cm}^2$  area of un-impregnated PE.

(19.96mg for 9.6cm<sup>2</sup> = 22mg for 16cm<sup>2</sup> - 2.04mg for 6.4cm<sup>2</sup> PE)

Amount of Nafion added for 9.6cm<sup>2</sup> = 19.96-3.06 = 16.90mg

Actual amount of Nafion added = 16.90mg

**Theoretical amount of Nafion required filling the pores of 66% Porosity and 10µm thickness:**

Volume of porous PE= area\* thickness = 9.6\*10\*10<sup>-4</sup> = 9.6\*10<sup>-3</sup> cm<sup>3</sup>

Pore Volume = Porosity \* Pore volume = 0.66 \* 9.6\*10<sup>-3</sup> = 6.34 \* 10<sup>-3</sup> cm<sup>3</sup>

Amount required to fill the pores = (Density of Nafion) (Volume of pores) = 2\*6.34 \* 10<sup>-3</sup>

Theoretical amount of Nafion required to fill the pores = 12.67mg

% of Nafion added more than required = (16.90-12.67)/12.67 = 33.4%

## **Appendix B: Amount of Fluorine in NPE**

Calculations for amount of Fluorine in NPE sample if impregnation is fully accomplished

- Porosity = 66%
- F content in Nafion = 68% = 0.68g per g of Nafion
- The EW is defined as the weight of Nafion (in molecular mass) per mole of sulfonic acid group

Molecular weight = 12\*21 + 19\*41 + 1685 + 32\*1 + 1\*1 = 1144g

Total C = 252

Total F = 779

% of C in Nafion = 252/1144 = 22%

% of F in Nafion = 779/1144 = 68%

Name	No. of atoms	Atomic weight
C	21	12
F	41	19
O	5	16
S	1	32
H	1	1

- F content by Volume =  $M/D = 0.68/2.0 = 0.34\text{cm}^3$
- Volume of Nafion in NPE membrane =  $0.66\text{ cm}^3$
- Volume of PE in NPE membrane =  $0.34\text{ cm}^3$
- Weight of N per weight of membrane =  $V*D = 0.66*2 = 1.33\text{g}$
- Weight of PE per weight of membrane =  $V*D = 0.34*0.93 = 0.316\text{g}$
- Total weight =  $1.646\text{g}$
- Weight % of N in membrane =  $(1.33/1.65)*100 = 81\%$
- Weight % of PE in membrane =  $19\%$
- Also, F is  $68\%$  in Nafion, hence
- Amount of Fluorine required to completely fill the pores of PE =  $0.68*0.81 = 55\%$

#### Appendix C: Comparison of amount of Nafion used in NPE and Nafion 211

To prepare  $25\mu\text{m}$  of Nafion 211 having the size of  $4*4\text{ cm}^2$ , the quantity of Nafion required would be:

$$\text{Mass} = (\text{Volume}) (\text{Density of Nafion}) = 4*4*25*10^{-4} (2) = 80\text{mg}$$

To prepare our NPE having the size of  $4*4\text{ cm}^2$ , the quantity of Nafion required would be:

$$\text{Mass} = 17\text{mg}$$

Note that, in our method, we only need to fill  $9.6\text{cm}^2$  circular area with Nafion; the rest will be left as PE.

Also, Area of  $16\text{cm}^2$  is the typically used size of an electrolyte for the single Fuel Cell fixture with a  $5\text{cm}^2$  active geometrical area.

Table 5: Comparison of amount of Nafion used in our NPE with Nafion 211

<b>Membrane</b>	<b>Amount of Nafion (mg)</b>	<b>Thickness (<math>\mu\text{m}</math>)</b>
NPE	17	13.5
Nafion 211	80	25