

where σ is the conductivity of the composite membrane (S cm^{-1}), R the resistance (ohm), i is thickness of the membrane (cm) and S is contact surface area of the electrode (cm^2), P is power density, V is cell voltage and I is the current density [7, 8].

3. Results and discussion

3.1 Particle diameter of inorganic component in the Nafion matrix.

Solution phase sol-gel method had been used to produce Nafion-SiO₂-PWA composite membrane and could improve the membrane structure from micro structure to nano structure. Analysis using TEM found the particle diameter of SiO₂ and PWA in the NS10W, NS15W and NS20W composite membrane are 6.9, 7.86 and 12.64 nm respectively.

The particle size of SiO₂ and PWA in the NS10W, NS15W composite membranes found less than the size of the Nafion cluster. Therefore, it can be concluded that SiO₂ and PWA particles are in the Nafion cluster. The presence of inorganic particles in the Nafion cluster increase water uptake rate of the membrane. The water uptake rate of N112 (pure Nafion) membrane is 26.52 % weight, meanwhile of NS10W, NS15W are 30.25 g %, 33.43 g %, respectively. The increase of water uptake rate is identical to the increase in the membrane conductivity. At 90°C of temperature and at 40% RH, the conductivity of NS15W membrane is $2.85 \times 10^{-3} \text{ S cm}^{-1}$ while compared to Nafion membrane under the same condition to be only at $1.16 \times 10^{-3} \text{ S cm}^{-1}$.

3.2 Performance of PEMFC

The performance of the single cell MEA using N112, NS10W, NS15W and NS20W membranes were obtained from the cell voltage versus current density measurement. The results of the test at temperature range of 30 – 90°C of two different relative humidity, namely those are 40% RH and 100% RH, were recorded and presented as power density (m W cm^{-2}) vs current density (mA cm^{-2}) as shown in Fig. 3 (from a to g). All of the data are presented with the mathematical model of polarization curves. The electrochemical parameters was found from the optimization and experimental data in fitting with mathematical model to measure internal resistance (R), open circuit voltage (E_0), Tafel slope (b) and flooding constant (γ) as presented elsewhere [5]. Conductivity values were calculated from electrochemical parameters in which obtain from graphs in Fig.3 and the data is listed in table 1. The best cell performance was recorded 90°C, 1.7 atm at 40% RH with using NS15W membrane.