Water Permeation Resistance of a Bipolar Plate Material

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Abstract

Polymers offer a necessary alternative to metals in the fuel cell industry. In addition to their many desirable properties, such as low cost, ease of processing, light weight, strength and ductility, polymers can be created that are free of metals ions and inorganic constituents that may interfere with sensitive fuel cell systems. To ensure optimum performance in materials integrity management and long life, a number of properties, including permeation resistance, must be considered when engineering materials for fuel cells. This study explores the permeation of deionized (DI) water through a highly loaded, thermoset composite that is used for bipolar plates.

Materials and Methods

Deionized (DI) water (18 MΩ) was used as a permeant in all experiments. The bipolar plate (BPP) material was a polymer composite consisting of a vinyl ester thermoset binder that had been highly loaded with conductive graphite powder. Test specimens were produced by first compression molding thicker plates and then machining them to produce thin, featureless plates with thicknesses (B) of 10 mil and 20 mil (0.254 mm and 0.508 mm).

Permeation measurements were made by the inverted cup method (1). Circular cups were constructed from stainless steel and were approximately five inches (13 cm) in diameter and one inch (2.5 cm) deep. Specimens were prepared for testing as follows. Cups were filled with DI water. A thin plate of BPP material was clamped onto the top of each cup with a retaining ring and then sealed with wax. Cups were inverted (so that liquid water directly contacted the specimen) and placed in an environmental chamber at 30°C and 0% relative humidity. (At 30°C, water has a vapor pressure of 3.19 cmHg (2).) Relative humidity was controlled in the environmental chamber by maintaining a steady flow of dry nitrogen gas. Cups were periodically removed from the oven and weighed to determine the mass of water (-Δm) that had permeated. Measurements were performed in triplicate for each thickness.

Analysis

Liquids permeate through flawless materials by first dissolving and then diffusing as a gas (3). It is common practice to convert the mass (-Δm) of the permeant to an equivalent volume of gas (V) at standard temperature (T_o) and pressure (Δp_o),

$$V = -\Delta m \cdot R \cdot T_o / \Delta p_o \cdot M, \qquad (1)$$

where R is the ideal gas constant, M is the molar mass of the permeant, $T_o = 273\text{K}$ and $\Delta p_o = 1$ atm. The volume (V) of gas that permeates through a thin plate with time (t) under steady state conditions depends on the permeability coefficient (P) (4,5),

$$V = P \cdot A \cdot \Delta p \cdot t / B, \qquad (2)$$

as well as plate thickness (B), plate area (A), and the applied pressure (Δp). (In this study, the applied pressure is the vapor pressure of water.)

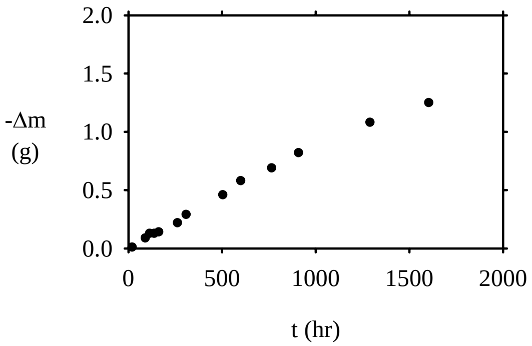

Figure 1. Mass (-Δm) of water that has permeated
through a 0.254 mm plate *versus* time (t).

Results and Discussion

Figure 1 shows the mass change with the passage of time for water permeating through a 0.254 mm plate. The mass of permeant increased linearly with time. Permeation was sufficiently fast and the plate was sufficiently thin that it was not possible to discern a break through time. Other samples behaved similarly. However, thicker plates slowed the transfer rate.

The masses of water that had permeated through the 0.254 mm plate were converted to vapor volumes at standard temperature and pressure (equation (1)) and then plotted in Figure 2 as V·B/A·Δp *versus* t according to equation (2). The points are experimental data and the solid line represents linear regression. The slope of the line in Figure 2 is equal to the permeability coefficient (P), which for this plate, has a value of $P = 244 \times 10^{-10}$ $cm^3 \cdot cm/cm^2 \cdot s \cdot cmHg$.

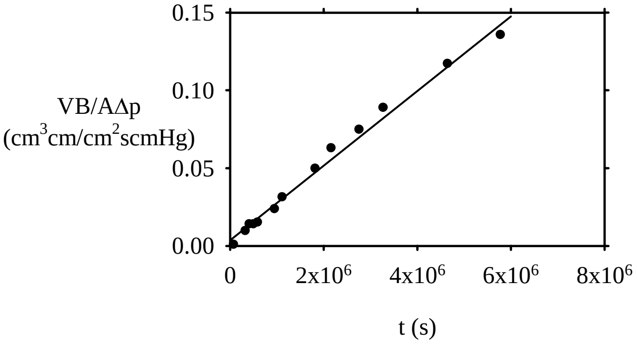

Figure 2. A plot of V·B/A·Δp *versus* time (t), according to equation (2), for a 0.254 mm plate.

Table 1. Permeability coefficients (P) of water through different plate thickness (B) of the BPP material at 30°C.

B (mm)	P ($10^{-10} cm^3 \cdot cm/cm^2 \cdot s \cdot cmHg$)
0.254	238 ± 28
0.508	228 ± 28
Average:	233 ± 28

Table 1 shows average P values from triplicate measurements of each plate thickness. Standard deviation was about 10% of the average P value. Even though the mass transfer rate through the thicker plates was much slower, the agreement between the P values for the two thicknesses was excellent. Thus, the permeability coefficient estimated here is an intrinsic property of this BBP material that can be used to estimate transfer of water through plates of different thickness and area.

Table 2 lists permeability coefficients at room temperature of the BBP material along with values for unfilled polycarbonate (PC) and polystyrene (PS). The P value for PC, measured in this study using 5, 10, and 20 mil films, agreed well with previously reported findings (6). The P value for PS was taken directly from the literature (6). Like the vinyl ester polymer binder in the BBP material, PC and PS are glassy and amorphous. PC and PS also are polar and a have a chemical functionality similar to the BBP polymer binder.

The vinyl ester thermoset examined in this study exhibited less permeation than the comparable glassy plastics due to the high loading level of the conductive graphite filler. If one accounts for the reduction in permeation due to the filler, the polymer binder in the BPP material by itself would still show less permeability than PC or PS.

Table 2. The permeability coefficients of water through the BPP material at room temperature as compared to two other amorphous, glassy polymers of similar chemical composition.

Material	P ($10^{-10} cm^3 . cm/cm^2 . s . cmHg$)
BBP (at 30°C)	238 ± 28
Neat PC (at 30°C)	1240 ± 60
Neat PS (at 25°C, from ref. 6)	1800

Conclusions

The inverted cup method is well suited for measuring liquid permeation through BPP materials. By using thin specimens to shorten the test time, it was possible to measure an intrinsic permeability coefficient that described the mass transfer characteristics of water through this BPP material. Subsequently, this permeability coefficient can be used to estimate transfer of water through plates of different shape and thickness. Relative to comparable glassy plastics, the vinyl ester thermoset examined here exhibited a lower permeation rate, in part due to the high loading of conductive graphite filler.

Acknowledgments

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