Membrane water management is important for peak performance. Before water management in a PEMFC is important for peak performance and long lifetime. A large amount of research has been generated to verify the membrane’s surface after heat-treatment, including contact angle, atomic force microscopy, X-ray diffraction and X-ray photoelectron spectroscopy. We found that specific heat-treatment conditions led to the formation of either a hydrophobic or hydrophilic surface. The modified membrane’s surface remained intact even after the membranes were boiled in water for 1 h. Next, a 4-point conductivity technique was used to verify that the heat-treatment conditions which led to a hydrophobic surface did not negatively impact the membrane’s internal conductivity. Finally, this novel heat-treatment method was applied to the cathode catalyst layer of a H2-Air PEMFC to create a hydrophobic polymer-gas interface inside the gas pores of the cathode catalyst layer. Preliminary results showed 33% increase in peak power. The results of this research will guide the design of a new class of PEMFC catalyst layers.

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The ability to tailor a biphase polymer’s surface relies on an important material property called the glass transition temperature (Tg). The primary α-relaxation process is the temperature at which larger segments of the polymer become mobile, whereas the subglass transition temperature (also called the secondary β-relaxation process) involves localized motion of the polymer backbone and is a precursor to the primary α-relaxation process. Glass transition is a reversible process that takes place in amorphous materials or in amorphous regions of semi-crystalline materials. At Tg, the amorphous regions of the polymer start to change from a glassy hard state to a rubber-like state. The polymer will start to relax when heated above Tg, and the polymer becomes more flexible. The Tg is always lower than the melting temperature for the crystalline phase of the polymer. Additionally, the Tg is not defined as a phase transition even though the polymer becomes more amorphous. The Tg is always lower than the melting temperature for the crystalline phase of the polymer. The Tg is always lower than the melting temperature for the crystalline phase of the polymer. The primary role in determining the surface hydrophobicity/hydrophilicity after initial casting is the thickness of solution-cast Nafion thin films, which is similar to the surface structure dependence of commercially available Nafion membranes. Paul et al. showed the effect of water droplets on the surface structure of Nafion thin films, which is similar to the surface structure dependence of commercially available Nafion membranes. Allen et al. showed how annealing ultrathin Nafion films (~10 nm) leads to surface and bulk reorganization, which directly affects the thin film’s surface wettability and proton conductivity. Allen et al. showed that the thickness of solution-cast Nafion thin films plays an integral role in determining the surface hydrophobicity/hydrophilicity after initial casting. Sub-55 nm Nafion films resulted in hydrophilic surfaces, whereas thicker films led to hydrophobic surfaces. These studies did not attempt to create permanent ultrathin film surface structures. Weber et al. suggests that the unexplained transport resistances common with low Pt loading CLs may be due to a variety of interactions that occur in thin-film ionomers. Thin films have been shown to exhibit varying phase separation properties, confinement effects, and wetting characteristics not traditionally seen with conventional micron-thick membranes. Weber et al. concludes that possible solutions to reduce thin-film resistances include using different ionomer structures, different casting solvents, heat-treatment modifications, etc. Typical CL ionomer film thicknesses have been measured to be in the range of ~5–10 nm. Allen et al. showed the hydrophilic domain size of Nafion films to be around 3.5 nm (dry) – 5 nm (hydrated). Phase separation could prove to be difficult when the thickness of the thin film approaches the hydrophilic domain size. Exploratory research on thin film properties and phenomena is a growing area and the outcome will be of great importance to future CL designs. The work done by Paul et al. and others promises promising extension of membrane skin phenomenon to the CL ionomer thin film.

To determine the feasibility of engineering the CL ionomer-gas interface to be either hydrophobic or hydrophilic by creating a skin rich in Teflon-like groups or in ionic sulfonate groups, respectively, we first demonstrated the heat-treatment method using a conventional biphase membrane (Nafion 212). Once the concept of being able to tailor the membrane’s surface was proven, we then attempted to incorporate the findings into engineering a new CL structure. A hydrophilic ionomer-gas interface inside the pores of the CL is preferred for electrodes with liquid reactants, such as the all-vanadium redox flow battery. A hydrophobic ionomer-gas interface inside the pores of the CL is preferred for electrodes with gaseous reactants, such as the H2-air PEMFC. The novelty of this new approach involves the creation of a surface skin (hydrophobic or hydrophilic) on conventional membranes that survives extreme conditions (1 h water boil) and the application of similar heat-treatment conditions to the membrane electrode assembly (MEA) fabrication process in order to create a desired ionomer-gas interface (hydrophobic in this case) inside the pores of the CL. The improved MEA fabrication process leads to better performance during high current density operations.

Experimental

A stainless steel cylindrical vessel (internal dimensions: 0.152-m diameter and 0.152-m height) was constructed for heat treating membranes in order to control the membrane’s exposure to humidity, temperature, and pressure. The heat-treatment vessel layout is provided in Figure 2. The typical operating temperatures and pressures inside the vessel were 20–160°C and 0.0–0.618 MPa, respectively. Maximum design operating temperature and pressure were 190°C and 1.27 MPa. Therefore, a pressure relief safety valve was installed on the vessel to vent at 1.48 MPa. Dry argon was preheated using high temperature heating tape and insulation prior to introduction into the vessel chamber.

Membranes (25 cm²) were mounted inside the vessel with an adequate amount of water and heated above the Tg. By controlling the initial amount of liquid water added to the vessel, one can control the final RH for a given temperature. The amount of water added to the vessel was calculated from the ideal gas law using the vapor pressure of saturated steam, maximum operating temperature, and the internal volume of the vessel. An excess of water (1.1x) was added to the vessel to ensure saturated steam conditions (100% RH) at maximum operating temperature. As the vessel was heated using heating rods inside the vessel’s base, the water inside the vessel flashed to create a saturated steam environment. In this first step, heating the membrane above Tg using saturated steam ensured the membrane was relaxed and hydrated to ensure adequate ionic group mobility. Next, steam in the vessel was either vented or maintained in order to create the conditions necessary for creating a hydrophobic or hydrophilic surface, respectively. For the hydrophilic case, saturated steam was vented while maintaining the membrane’s temperature above Tg. Subsequently, dry argon heated to above Tg was directed through the vessel to remove any remaining steam. After the heated argon had been flowing for 1 h,
the vessel was allowed to slowly cool to ambient temperature. The vessel was slowly cooled in order to crystallize the membrane and lock the membrane’s surface structure in place. For the hydrophilic case, the saturated steam environment was maintained throughout the heat-treatment process. Membrane exposure conditions for both the hydrophobic and hydrophilic cases are summarized in Table I.

The ability to characterize the surface of the heat-treated membranes was important in order to validate that the exposure conditions create a durable hydrophobic or hydrophilic surface. In this work, we used several surface characterization techniques, including contact angle, multi-mode atomic force microscopy (AFM), X-ray diffraction (XRD), and X-ray photoelectron spectroscopy (XPS). The contact angle formed by placing a water droplet onto the surface of the membrane will be larger for a hydrophobic material than a hydrophilic one. The repulsive forces a hydrophobic material imparts onto a water droplet will tend to make water form a spherical bead on the surface. However, a hydrophilic material will allow the water droplet to spread out and wet the surface. All contact angle measurements were completed using 2 μL of water delivered to the membrane’s surface with a micro-syringe. A high resolution camera mounted on a tripod was used to capture the contact angle formed between the water droplet and membrane surface. We expect the hydrophobic treated membrane not to be completely void of ionic groups at the membrane’s surface. Therefore, the ionic groups will form nanometer-sized ionic pathways from the surface into the internal ionic matrix of the membrane. After a water droplet has been placed onto the membrane’s surface, the water will be absorbed into the internal ionic matrix. The speed to which the water droplet will move into the internal ionic matrix will be directly proportional to the relative amount of ionic domains on and near the membrane’s surface. Therefore, a more hydrophobic surface will absorb a water droplet placed on the membrane’s surface more slowly than a hydrophilic surface. In order to capture the speed at which a water droplet is absorbed into the membrane, high resolution images were captured every 5 min for a total of 20 min.

For the next surface characterization technique, multi-mode AFM (Nanosurf FlexAFM) was employed. The AFM has the ability to be operated in either contact or tapping mode and is able to collect various surface properties, including topography, phase contrast, and conductivity. Phase contrast is able to detect differences in material composition in order to determine the location of ionic and Teflon-like domains on the membrane’s surface. Past research has shown that conductive mode is only able to detect the membrane’s surface ionic groups that are connected to the internal ionic matrix through the membrane. If a surface ionic group is not connected to the internal ionic matrix, then no current will flow when the AFM tip comes into contact with an ionic domain. Therefore, phase contrast mode was employed for this work in order to measure the relative amounts of ionic and Teflon-like domains on the membrane’s surface.

Grazing incidence XRD (GIXRD) was used to measure the relative amounts of amorphous, crystalline, and ionic domains near the membrane’s surface. GIXRD data was collected on a Bruker D8 Discover DαVinci system with a Gobel Mirror and thin film stage, equipped with parallel beam optics, using CuKα radiation (λ = 1.5418 Å) at a scanning speed of 4 sec/step with a step size of 0.04°. The angle of X-ray incidence was varied incrementally over a range of 0.1° to 4.0°. Additionally, PXRD patterns were collected using a Bruker D2Phaser equipped with a CuKα radiation source (λ = 1.5418 Å) and 1D Lynxeye detector at a scanning speed of 1.0 sec/step with a step size of 0.03° (Bragg-Brentano geometry). Deconvolution was completed using the Bragg-Brentano measurements on the broad amorphous peak centered about 8–22° and the sharp crystalline peak centered at 17.5°. Blanton et al. demonstrated that deconvolution of these two peaks can be used to calculate relative percent crystallinity of Nafion membranes.

Additionally, the Physical Electronics (PHI) VersaProbe III XPS was used to capture high resolution scans in order to measure the sulfur and carbon atomic percentages near the surface of the membrane. Angle resolved XPS allowed us to rotate the sample stage in order to vary the take-off angle of the photoelectrons reaching the energy analyzer detector. The take-off angle was adjusted in 5° increments over a range of 20–70°. At shallow take-off angles, photoelectrons reaching the detector originate at shallower membrane depths. At

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Table I. Experimental design conditions.

| Step Number | Hydrophobic Case | Hydrophilic Case |
|-------------|------------------|------------------|
| 1           | Heat membrane above Tg using saturated steam for 1 h | Heat membrane above Tg using saturated steam for 1 h |
| 2           | Vent steam while maintaining temperature above Tg | Allow vessel to cool to ambient temperature with saturated steam locked-in |
| 3           | Flush vessel with heated dry argon for 1 h | |
| 4           | Allow vessel to cool to ambient while flowing dry argon | |

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steps outline a common MEA preparation technique. First, a catalyst ink (composed of a mixture of Pt-coated carbon powder, Nafion, water, and IPA) is applied to one side of a gas diffusion layer (GDL) and the ink is allowed sufficient time to dry. Then, two catalyst ink coated GDLs are hot pressed onto a polymer electrolyte membrane such that they form an electrode-membrane-electrode sandwich with the catalyst layer side of the GDL facing the membrane. Hot pressing is completed at a temperature above Nafion’s glass transition temperature \( (T_g) \) \((\sim 110^\circ C)\) to ensure that Nafion inside the catalyst layer will form an ionic pathway from the catalyst to the polymer electrolyte membrane. During hot pressing, water absorbed into the membrane will flash to steam and form a saturated steam environment in the gas channels of the catalyst layer. The steam is unable to escape because a PTFE gasket (used to prevent crushing the GDL) forms a barrier between hot press plate and membrane surface (the GDL is located inside the PTFE gasket). Upon cooling the MEA below \( T_g \), steam in the gas channels of the catalyst layer is expected to result in a hydrophilic polymer-air interface. During operation, a hydrophilic interface would allow water to wet the surface of Nafion phase in the catalyst layer, creating an additional layer of water that oxygen would need to diffuse through in order to reach the catalyst reaction site, and, therefore, negatively impact mass transport of oxygen into the cathode active catalyst layer. On the other hand, if the steam created during MEA hot pressing was allowed to escape, so that a dry environment was present at the polymer-air interface, then the Nafion phase in the catalyst layer could be made to have a durable hydrophobic polymer-air interface. A hydrophobic polymer-air interface in the catalyst layer is expected to lead to higher peak power and higher current densities. In order to provide a pathway for steam to escape during the MEA hot pressing procedure, a stainless steel 50.8-mm diameter, 1.575-mm thick, 100-micron average pore size porous disk was placed between the cathode GDL and heat press plate during MEA fabrication. Therefore, heat was thermally conducted through the porous metal disk to the cathode GDL during hot pressing, instead of heat being thermally conducted directly to the GDL. Subsequently, steam created during hot pressing was able to flow out radially through the porous stainless steel disk instead of being trapped inside the catalyst layer. Flowing a heated dry inert gas through the cathode would be expected to remove generated steam more efficiently by forced convection rather than allowing the steam to escape solely by natural convection, but the heated inert gas method would lead to a more complicated MEA setup. In this study, the porous disk hot pressing technique was explored to determine if sufficient steam could be removed from the CL solely by natural convection. A simpler hot pressing design is more likely to be adopted by industry for incorporation into a large-scale manufacturing process. The MEA hot pressing layouts for both the conventional and porous disk methods are shown in Figure 4.

For the PEMFC study, discharge performances at room temperature \( (\sim 22^\circ C) \) were collected for both a conventionally-prepared MEA and a MEA prepared using the porous disk heat-treatment method outlined above. Fuel cells were tested at room temperature in order to operate the cells in a worst-case condition to ensure flooding occurs at the cathode during high current density operations. For operation at elevated fuel cell temperatures \( (>50^\circ C) \), a hydrophobic ionomer-gas interface in the CL is expected to result in better performance over the baseline case anytime the cathode is subjected to flooding conditions. Sigracet GDL-25BC carbon GDLs were used for both the H2 and air electrodes. A Pt/C/Nafion ink was prepared by mixing (sonicating) appropriate amounts of carbon-supported Pt catalyst, Nafion ionomer, isopropyl alcohol, and water. Then, the microporous layer side of the GDLs were coated with a Pt/C/Nafion layer (0.5 mg/cm² Pt geometric area, 0.14 mg/cm² Nafion ionomer) using an automatic ultrasonic sprayer. Carbon serpentine flow fields about 2.25 cm \((1.5 \text{ cm} \times 1.5 \text{ cm}) \) delivered humidified \( H_2 \) at 5 psig and humidified air at atmospheric pressure to the electrodes. Both gases were conditioned by bubbling the incoming gas through a bottle of room temperature deionized water. Hydrogen gas was delivered to the anode at a rate of approximately 660 mL/min using a recirculation pump, while air was delivered to the cathode at a rate of approximately 350 mL/min.

**Figure 3.** Four-point conductivity measurement apparatus.
using a flow-through setup. Nafion 212 (∼51 um thick) served as the polymer electrolyte membrane for all MEAs and electrical current was collected from the edges of the electrodes. A start-up procedure was used to ensure proper membrane hydration prior to collecting discharge performances. The start-up procedure included operating the PEMFCs at 0.2 V until 0.4 A/cm² was achieved, then holding the discharge current steady at 0.4 A/cm² for 1 h.31 Discharge polarization curves were collected in constant voltage staircase mode from open circuit voltage (OCV) to 0.2 V in increments of 50 mV. Multiple polarization curves were collected to ensure adequate membrane hydration and repeatable results. The start-up procedure proved to be adequate in fully hydrating the membrane in order to provide consistent results. EIS was completed on each fuel cell at 5 mV amplitude over a frequency range of 1 Hz to 100 kHz in order to measure the internal cell resistance.

Results and Discussion

After exposing several membranes to various heat-treatment conditions, multiple surface characterization techniques were used to validate that the exposure conditions created a durable hydrophobic or hydrophilic surface. To begin, contact angle measurements were collected by placing a water droplet on top of a flat membrane. Contact angle measurements for Nafion 115 as-received, Nafion 212 as-received, hydrophobic-treated Nafion 212, hydrophobic-treated Nafion 212 boiled for 1 h, and hydrophilic-treated Nafion 212 are shown in Figure 5. The contact angle measurements for the as-received membranes are shown for comparison purposes. Comparison of the hydrophobic-treated and hydrophilic-treated membranes enables us to determine whether or not the membrane’s surface can be engineered to be rich in Teflon or ionic groups, respectively. Comparison of the hydrophobic-treated and hydrophobic-treated boiled for 1 h determines whether the hydrophobic surface structure is durable. Boiling for 1 h is a harsher condition than a membrane is expected to encounter during operation in a PEMFC.

The initial contact angles at 0 min indicate a high contact angle for the as-received Nafion 115, as-received Nafion 212, the hydrophobic-treated Nafion 212, and hydrophobic-treated Nafion 212 boiled for 1 h membranes. The contact angles at 0 min for these membranes were measured to be ∼97 degrees. As expected, the hydrophilic-treated
Nafion 212 membrane had a lower contact angle at 0 min of ~67 degrees. Further analysis of the contact angle measurements made every 5 min over the course of 20 min, we observe that the hydrophobic-treated Nafion 212 membrane absorbs greater than 90% of the water droplet by 20 min. The hydrophilic-treated membrane absorbs greater than 90% of the water droplet more quickly, in approximately 15 min. Additionally, after the water droplet had been fully absorbed by each membrane, similar contact angles were achieved when placing a second droplet at the same location as the first droplet. These contact angle results indicate that the hydrophilic-treated membrane contains more surface ionic groups than the hydrophobic-treated membrane. The increased amount of surface ionic groups enables the hydrophilic-treated membrane to absorb the water droplet more quickly into the bulk of the membrane.

Next, the AFM was operated in tapping mode to obtain phase contrast images of the treated and untreated membranes. Phase contrast will be able to differentiate between harder Teflon domains and softer ionic domains. Figure 6 shows the phase contrast measurements obtained for the Nafion 212 as-received, hydrophilic-treated, hydrophobic-treated, and boiled hydrophobic-treated membranes. The Nafion 212 as-received membranes shows a wide distribution of phase contrast values. The intensity versus phase contrast value graph for Nafion 212 as-received shows two peaks. The lower phase contrast peak (red color/darker greyscale) correlates to Teflon domains. The higher phase contrast peak correlates to ionic domains (blue and green color/lighter greyscale).

Next, XRD was used to probe the surface of the as-received and heat treated membranes. Figure 7 shows the wide angle XRD results using an incident beam angle of 3°. The wide angle XRD spectrum for each membrane type contains both a low angle ∼1.5–3.0° and wide angle ∼17.5° peak. In order to qualitatively compare each membrane, a peak intensity ratio was calculated by dividing the maximum counts per second (CPS) for the low angle peak by the maximum CPS of the wide angle peak. In Figure 7A, we observe a low angle to broad amorphous peak intensity ratio of ∼2 for the as-received Nafion 212. A low angle to broad amorphous peak intensity ratio of ∼2.75 is observed in Figure 7B for as-received Nafion 115. Nafion 115 has a hydrophobic Teflon skin due to the thermal extrusion process. We will use this fact to analyze the next set of XRD scans for the hydrophilic and hydrophobic-treated membranes. As shown in Figure 7C and Figure 7D, the peak intensity ratio of the hydrophilic-treated membrane resembles the as-received Nafion 212 membrane. The hydrophobic-treated membrane resembles the as-received Nafion 115 membrane. These XRD results confirm our hypothesis that specific heat-treatment conditions can create a hydrophobic or hydrophilic skin on a biphasic membrane.

Next, XRD scans were collected in the Bragg-Brentano theta-2theta configuration in order to conduct deconvolution of the broad amorphous peak centered at about 8–22° and the sharp crystalline peak centered at about 17.5°. Since the Bragg-Brentano theta-2theta configuration is representative of the entire sample, it only allows us to estimate percent crystallinity of the membrane’s bulk. Even though it is not a surface characterization technique, percent crystallinity calculations using the Bragg-Brentano theta-2theta configuration reveals major differences between the as-received and heat-treated membranes. Figure 8 shows an example of how deconvolution is completed on the original XRD scan. Table II provides the results of the crystallinity calculation using the deconvolution method for the as-received and heat-treated membranes. As expected, the hydrophobic-treatment resulted in a higher percent crystallinity than the hydrophilic-treatment due to the larger fraction of crystalline Teflon domains near the membrane’s surface. The higher fraction of amorphous ionic domains near the hydrophilic-treated membrane’s surface results in a lower measured percent crystallinity.

Next, angle-resolved XPS was used to measure the atomic concentration of sulfur and carbon at the membrane’s surface. The
Figure 7. Grazing incidence XRD with incident beam set at 3.0 degrees for (A) Nafion 212 as-received, (B) Nafion 115 as-received, (C) Hydrophilic-treated Nafion 212, and (D) Hydrophobic-treated Nafion 212 membranes.

Figure 8. Deconvolution of XRD profile for hydrophobic-treated Nafion 212.

take-off angle was varied from 20° to 70° in 5° increments. Figure 9 shows the sulfur to carbon atomic concentration ratio for Nafion 212 as-received, Nafion 115 as-received, hydrophobic-treated Nafion 212, boiled hydrophobic-treated Nafion 212, and hydrophilic-treated Nafion 212. The theoretical sulfur to carbon atomic concentration ratio of 5% for Nafion 212 is included on the graph as a dotted gray line. As expected, the thermally-extruded Nafion 115 as-received membrane has a lower sulfur to carbon atomic concentration ratio (~3.5%) at low take-off angles. As we penetrated deeper into the membrane at higher take-off angles, the Nafion 115 as-received membrane’s sulfur to carbon atomic concentration ratio increases up toward the 5% theoretical bulk sulfur to carbon atomic concentration ratio. The hydrophobic-treated Nafion 212 membrane’s sulfur to carbon atomic concentration ratio is about 2% at low take-off angles and trends upwards to the 5% theoretical bulk at higher take-off angles. Finally, the boiled hydrophobic-treated Nafion 212 membrane’s sulfur to carbon atomic concentration ratio mirrors the hydrophobic-treated membrane. These XPS

| Membrane Type                | Percent Crystallinity Range |
|------------------------------|-----------------------------|
| Nafion 115 as-received       | 26.8%                       |
| Nafion 212 as-received       | 24.2%                       |
| Hydrophobic-treated Nafion 212 | 36.7%                       |
| Hydrophilic-treated Nafion 212 | 19.1%                       |

Table II. XRD deconvolution to calculate percent crystallinity.

Figure 9. Angle-resolved XPS for as-received and heat-treated membranes.
measurements support the claim that a membrane’s surface can be heat treated to create a durable hydrophobic surface.

In order to verify that the heat-treatment conditions did not negatively affect the membrane’s internal conductivity, 4-point conductivity measurements were collected. The resistivity of a solution-cast membrane (95.7 ± 7.5 ohm-cm) mirrored the resistivity of a heat-treated film (92.4 ± 4.0 ohm-cm). Therefore, we don’t expect the hydrophobic heat-treatment process to have an effect on the polymer’s internal conductivity and the internal surface area of the membrane. These results indicated that the heat-treatment process would not affect the bulk and internal interfacial conductivity of the polymer phase in the fuel cell catalyst layer.

Finally, discharge polarization curves were collected for both a conventionally-prepared MEA and a MEA prepared under hydrophobic heat-treatment conditions using the porous metal disk. As shown in Figure 10, the discharge polarization curve using the porous metal disk MEA method shows improved performance at high current densities when compared to the conventional MEA. Figure 10 overlays the power density curves for both cases, showing more than a 33% increase in peak power density for the porous metal disk MEA method. The internal cell resistance for each fuel cell was measured using EIS to calculate the iR-corrected polarization and power density curves (included in Figure 10). Due to testing the fuel cells at room temperature, the polarization curves are substandard relative to state-of-the-art fuel cell performance. As previously stated, testing was completed at room temperature in order to ensure the cathodes are subjected to flooding conditions during high current density operations. Performance at higher temperatures will be included in future studies. The increase in performance at high current density for the porous disk method is suspected to be due to improved mass transport effect, an increase in the effective proton conductivity in the cathode, or a combination of both phenomena. 32,33

Summary

In summary, we used a new heat-treatment process to create a durable hydrophobic surface for a biphasic perfluorosulfonic acid membrane. Multiple surface characterization techniques were used to verify the membrane’s surface structure prior to and after heat-treatment. Contact angle, AFM, XRD, and XPS measurements of the membrane’s surface confirm our hypothesis that specific heat-treatment conditions can create a durable hydrophobic or hydrophilic surface. Four-point conductivity measurements verified the membrane’s bulk and internal interfacial conductivity was not negatively impacted by the hydrophobic heat-treatment process.

Finally, the new heat-treatment method was incorporated into the cathode catalyst layer by adding a porous metal disk to the MEA fabrication process to allow steam to escape during heat pressing. Discharge performance curves for a H2-Air PEMFC using the newly designed catalyst layer showed remarkable performance compared to the conventionally-prepared MEA. This increase in fuel cell performance is credited to improved mass transport effect, an increase in the effective proton conductivity in the cathode, or a combination of both manifestations. The improved performance for the new MEA process is evident by the extension of the ohmic region into high overpotentials (i.e. more linear polarization curve). The superior performance at high current densities enabled the newly-designed PEMFC to achieve more than 33% higher peak power density.

We expect that the hydrophobic polymer-gas interface will enable oxygen to more easily diffuse to the catalyst reaction site and aid in proper water removal from the CL. Since the CL oxygen flow channel is approximately 20–100 nm in diameter, we don’t expect the polymer-gas interface to be completely void of water. However, we do expect higher channel wall surface area for oxygen transport directly into the hydrophobic membrane-gas interface. Our proposed hydrophobic channel wall structure and contact with water is shown in Figure 11B. This is compared to a water-flooded channel in Figure 11A and a hydrophilic membrane-gas interface in Figure 11B.

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