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# Carbon black / PTFE composite hydrophobic gas diffusion layers for a water-absorbing porous electrolyte electrolysis cell

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ABSTRACT

The characteristics of a water-absorbing porous electrolyte electrolysis cell, in which pressurized water is injected directly into the electrolyte layer, are investigated. High water support force is required for the gas diffusion layer (GDL) in this novel cell design, and therefore here we report a new type of hydrophobic GDL comprising an acetylene black (AB) and poly(tetrafluoroethylene) (PTFE) composite film. The method of preparation of the AB/PTFE slurry, film formation methods, and the AB/PTFE weight ratio were investigated and optimized. The ball-milling and transfer method were suitable for preparing uniform AB/PTFE slurry and successfully covering AB/PTFE film without any cracks on micro-porous layer coated carbon paper, respectively. An investigation about different PTFE weight ratios against AB from 0.1 to 6 showed a serious trade-off character between electrical resistance $R$, gas permeability $V'$, and water support force $P_{lim}$. The 1/2.5 of AB/PTFE weight ratio was most optimal, which showed to have most equivalent $R$ (2.5 Ω cm$^{-2}$), $V'$(136 mL atm$^{-1}$ cm$^{-2}$ min$^{-1}$), and $P_{lim}$ (0.25 MPa). We also confirmed that fabricated GDL with optimal condition was worked as the blocking layer against water injected through electrolyte layer and pressurized by nitrogen gas, and as gas-permeation layer for generated hydrogen gas in water electrolysis test.



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## Introduction

Hydrogen production is one of the key topics in terms of bringing about a sustainable hydrogen-based society, and ending our dependence on fossil fuels [1–3]. Over the past thirty years, water electrolysis has become attractive as a highly practical, relatively low cost, and convenient method to produce hydrogen gas [4]. Ideally, renewable electrical power generated from solar cells or wind turbines should be utilized. Eventually, the hydrogen gas produced by water electrolysis is expected to be reconverted to back electrical power by the use of fuel cells [5]. Therefore, the development of water electrolysis cells with higher performance is of crucial importance for the future.

Polymer electrolyte water electrolysis (PEWE), using Nafion membranes, is one of the most promising methods for hydrogen production [6,7]. Fig. 1 (a) shows a schematic image of conventional PEWE cell, which consist of dense polymer electrolyte (e.g. Nafion), electrocatalyst layer (e.g. Platinum or Iridium oxide inks), gas diffusion layer (e.g. carbon paper). Water is supplied from outside of anode electrode to the electrolyte layer, and then generated protons move to cathode electrode during water electrolysis. However, PEWE cells still have some practical problems, such as the poor stability of Nafion at temperatures higher than 80 °C [8]; dehydration of the electrolyte layer [9]; and decomposition of carbon supports at the oxygen-evolution electrode [10]. To resolve these issues, recently developed a novel water-absorbing porous electrolyte electrolysis cell (Fig. 1 (b) [11]). This water-absorbing electrolysis cell consists of a hydrophilic inorganic porous electrolyte, an electrocatalyst layer, and a hydrophobic gas diffusion layer (GDL). We previously reported a water-absorbing porous electrolyte electrolysis cell using sulfonated titanium oxide particles as the electrolyte layer. We obtained a cell voltage of 3.0 V at 20 mA cm$^{-2}$, and a hydrogen gas evolution rate similar to the theoretical rate calculated by Faraday's law [11].

Compared with conventional PEWE cells, this new type of cell has several advantageous points. These include: (1) direct injection of water into the porous electrolyte layer to avoid dehydration of the layer during operation of water electrolysis because of continuous supplying water through porous electrolyte; (2) use of a water tank for water electrolysis with applied pressure to produce pressurized hydrogen or oxygen gas effectively because compressed hydrogen or oxygen gas was effectively produced by controlling differential pressure between water tank and collected gas tank; and (3) a possibility to reduce concentration overvoltage in the electrode layer because electrocatalyst layer was supplied a water from porous electrolyte layer and separation of generated gas to outside of the cell in hydrophobic electrocatalyst layer. In general, the researches of high pressure PEM electrolyzer to produce purified and compressed hydrogen gas were reported [12], however these reported cells were difficult for complicated cell designs and high cost. On the other hand, there is large possibility to design simple structure in our suggested water absorbing porous electrolyte electrolysis cell, which is expected to be substitution from PEM electrolyzer cell in the

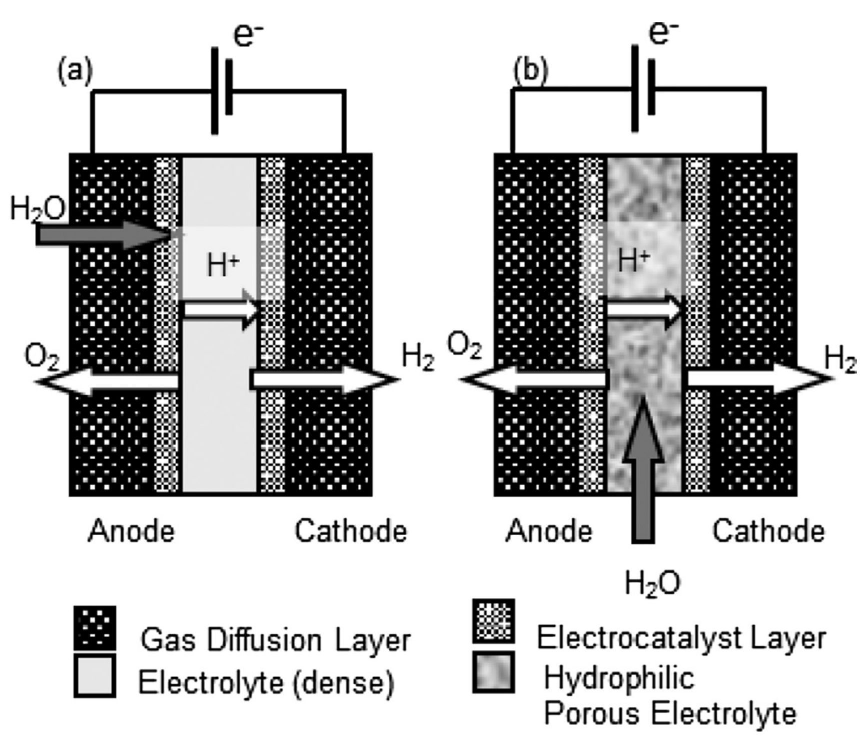


**Fig. 1 – Schematic images of different water electrolysis cells: (a) a conventional PEWE cell consist of dense polymer electrolyte layer (e.g. Nafion), electrocatalyst layer, and carbon paper type gas diffusion layer. Water was supplied from outside of anode electrocatalyst layer. (b) Water-absorbing porous electrolyte cell consist of hydrophilic porous electrolyte layer, controlled hydrophobic electrocatalyst layer, and fully hydrophobic gas diffusion layer. Water was injected for porous electrolyte layer directly.**

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