

Thermogravimetric Analysis

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Quality Control of Polymer Electrolyte Membrane Fuel Cells by Thermogravimetric Analysis

Introduction

Fuel cells are electrochemical devices that convert chemical energy into electricity. They offer cleaner and more-efficient energy than the internal-combustion engine. They have been used to power vehicles, for stationary power generation and portable applications. Hydrogen or hydrogen-rich gas (such as natural gas) or liquid methanol can be used as fuels depending on the fuel-cell type. Many types

of fuel cells are now available based on the electrolyte used, including polymer electrolyte membrane fuel cells (PEMFC), direct methanol fuel cells (DMFC), solid oxide fuel cells (SOFC), molten carbonate fuel cells (MCFC) and alkaline fuel cells (AFC). Each has its own electrolyte, cathode and anode as well as fuel type, typically operates in different temperature ranges and caters to different applications – among these, the polymer electrolyte membrane fuel cell is the most widely used.

Polymer electrolyte membrane fuel cells (PEMFC), also known as proton exchange membrane fuel cells, give very high power density. They have the advantage of low weight and volume, compared with other fuel cells. As shown in Figure 1 (Page 2), polymer electrolyte membrane fuel cells use a solid polymer membrane as an electrolyte and porous carbon electrodes coated with a platinum catalyst. They need only hydrogen, oxygen from the air and water to operate and do not require corrosive fluids like some other fuel-cell types (e.g. PAFCs, phosphoric acid fuel cells). Pure hydrogen or hydrogen-rich gas supplied from storage tanks or on-board reformers can be used as fuel for PEMFC.

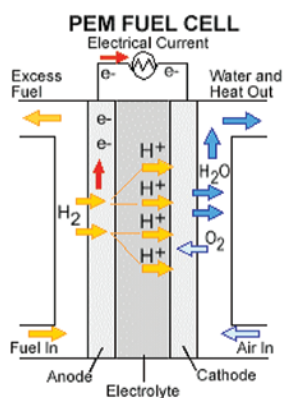


Figure 1. Schematic of a polymer electrolyte membrane fuel cell (PEMFC).¹

Polymer electrolyte membrane fuel cells (PEMFC) operate generally at relatively low temperatures, around 80 °C (176 °F), although some new types of PEMFC can operate at high temperatures as well. Low-temperature operation allows them to start quickly (less warm-up time), resulting in less wear on system components increasing lifetime of the system; however, they require a noble-metal catalyst (typically platinum) to catalyze the reaction of hydrogen with oxygen. The platinum catalyst is also extremely sensitive to CO poisoning, so it may be necessary to use an additional reactor to reduce CO in the fuel gas if the hydrogen is derived from an alcohol or hydrocarbon fuel. Different catalyst systems or different operating conditions have been developed to increase the system's resistance to CO. PEMFC are used primarily for transportation applications and some stationary applications. Due to their fast startup time and favorable power-to-weight ratio, PEMFC are suitable for use in passenger vehicles, such as cars and buses.

During the manufacturing of polymer electrolyte membrane fuel cells, one of the most important parts is the membrane electrode assembly (MEA). The MEA consists of a proton exchange membrane, catalyst layers and gas diffusion layers (GDL). One method to make an MEA is to print the catalyst-containing ink over the gas diffusion layers – for example, carbon cloth. The carbon cloth is treated to remove solvent, which results in the gas diffusion electrode (GDE). The GDE is then hot pressed with the proton-exchange membrane to form an MEA. During this process, thermogravimetric analysis (TGA) can be used to check the ink formulation for quality-control purposes and also to study the heat-treatment process of carbon cloth.

Experimental

This analysis was run on the PerkinElmer® Pyris™ 1 TGA, temperature calibrated with alumel, perkalloy and iron. The Pyris 1 TGA offers precise temperature control and accurate weight measurements. It is easy to operate, and has the flexibility to also be connected to another instrument for hyphenated applications.

For this work, the sample is an ink printed on the carbon cloth. The formulation usually contains a commercial platinum catalyst, water, Nafion™ and other solvents.

Results

During the TGA run, multiple weight losses occur which correspond to different components in the formulation. Figure 2 is the TGA run on the Pyris 1 TGA. As can be seen, three weight losses occurred during heating, which corresponded to three different components. The information from TGA can therefore help to study the formulation in more detail and understand the heat-treatment process of carbon cloth.

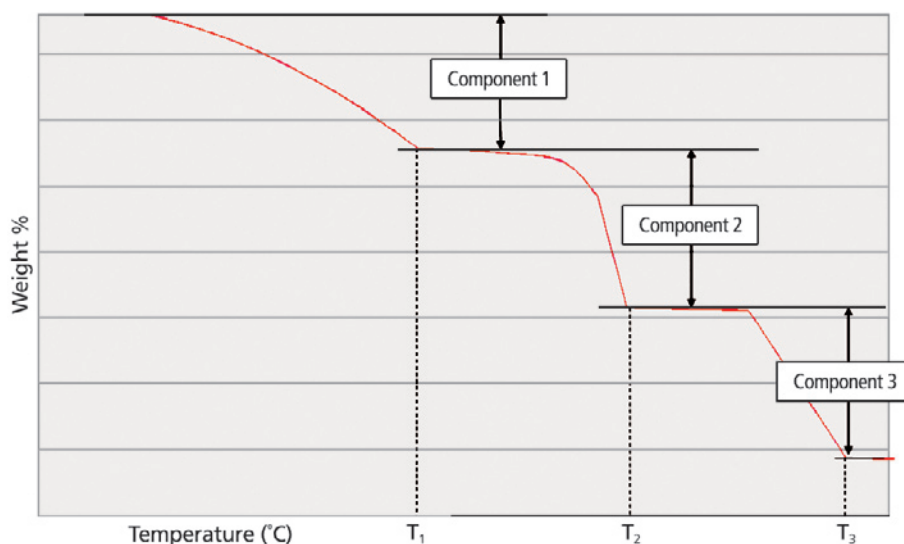


Figure 2. TGA data of ink formulation of decomposition, showing three components.

Conclusion

Fuel cells are one of the cleaner energy forms. Among all the different types of fuel cells, the polymer electrolyte membrane fuel cell (PEMFC) is the most widely used. The membrane electrode assembly (MEA) is the core of PEMFC. Formulations containing platinum as a catalyst can be printed onto a carbon cloth to make the gas diffusion electrode (GDE). TGA has been shown to be an important tool in the study of the formulation for QC or research purposes. In order to know what is coming off the sample, further instrumentation such as thermogravimetric analysis coupled with mass spectrometry (TG-MS) needs to be used to characterize the off gas from the TGA.

References

1. EERE (U.S. Department of Energy's Energy Efficiency and Renewable Energy) is the source for the image displayed as Figure 1 in this application brief (http://www1.eere.energy.gov/hydrogenandfuelcells/fuelcells/fc_types.html)