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The effect of mold pressing pressure and composition on properties of nanocomposite bipolar plate for proton exchange membrane fuel cell

Reza Taherian [a,1], Ahmad Nozad Golikand [b,*], Mohammad Jaffar Hadianfard [a,1]

[a] Material Engineering Department, Shiraz University, P.O. Box 71946-85115, Shiraz, Iran
[b] Corrosion Lab. & Material Research Institute, P.O. Box 14395-836, Tehran, Iran

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ABSTRACT

This paper is an attempt to introduce a suitable composite to be used in the bipolar plate of proton exchange membrane fuel cell (PEMFC). At first the effect of the mold pressing pressure and graphite content on the through-plane and in-plane electrical conductivities, flexural strength, hardness, density, porosity and water absorption of phenolic resin/graphite composite was investigated. The two mold pressing pressures, 15 and 740 bar were applied in 20, 30, 40, 50, 60, 70 and 80 wt.% graphite contents. The characterization was also conducted by an optical microscope, a stereoscope and the scanning electron microscopy. The results showed that the pressure considerably affects all properties and can dramatically change the porosity percentage of the composite. To improve conductivity and strength, the composite composition was modified by the nanosheet expanded graphite and carbon fiber. In an optimum composition, the in-plane and through-plane electrical conductivity and flexural strength reached 1518, 76 S/cm and 84 MPa, respectively. In this study, the contact resistance between the bipolar plate and carbon paper (as a gas diffusion layer) was also determined by changing the clamping pressure.

1. Introduction

The bipolar plate is a multi-functional component in a PEMFC stack. It provides the electrical connection from cell to cell and separates the reactive gases. Eighty percent of the fuel cell stack weight is related to the bipolar plate weight [1,2]. In addition, the bipolar plate serves the following functions: (i) it facilitates water management within the cell; (ii) it enables heat transfer; (iii) it supports thin membranes and electrodes; (iv) it withstands the clamping forces of the stack assembly. The material requirements mentioned in Table 1 should be satisfied for the fabricating of a bipolar plate [1].

Graphite (G) is the most commonly used material for a bipolar plate. G has good electrical conductivity and excellent corrosion resistance with a low density of about 2 g/cm^3. However, the poor mechanical strength and ductility of G limit the minimum plate thickness to about 5–6 mm and machining is usually employed to fabricate the flow channels in the bipolar plate. The machining of G into the often complex designs employed in bipolar plates is prohibitively expensive and time-consuming and is not suited to the levels of the mass production required for the full scale commercialization of fuel cells. Metal is also a good material for the bipolar plate. It offers good electrical conductivity, excellent mechanical properties and ease of fabrication; however, it is unable to resist corrosion in fuel cells. The corrosion of a metal bipolar plate leads to the release of multivalent cations, which can lead to an increase in the membrane resistance and the poisoning of the electrode catalyst [3–5]. The assembly G composite bipolar plates are an attractive option for PEMFC. Not simply do they offer the advantage of lower cost, lower weight and greater ease of manufacture than traditional G but their properties can also be tailored by using different reinforcements and resin systems [6].

The effect of pressure in hot compaction is significant because the increasing of mold pressing pressure leads to reducing the gap between particles, thereby increasing in electrical conductivity [7]. This pressure can be induced either by injection (extrusion) or compression [8–10]. By lowering the pressure, the porosity increases. This is due to the escaped gases and free spaces between G layers. The G has a layer-to-layer shape. During polymerization the polymer branches flow into these layers and may lead to the delaminating of these layers and the increasing of volume. This phenomenon has been reported on polymer/clay composites [11].

Thus far, some authors have investigated the polymer/graphite composite (P/G) in order to be used in the bipolar plate composite [12–15]. Cunningham [12] mixed the polyphenylene sulfide and polyethylene terephtalate with G using the wet-lay method. In 80 wt.% G, in-plane electrical conductivity reached 250 S/cm; however, the formability and the through–plane electrical conductivity needed improvement. Due [13] used the expanded graphite (EG)

* Corresponding author. Tel./fax: +98 2182063112.
E-mail addresses: rtaherian@shirazu.ac.ir (R. Taherian), anozad@aeoi.org.ir (A.N. Golikand), hadianfa@shirazu.ac.ir (M.J. Hadianfard).
[1] Tel./fax: +98 711 2307293.

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