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Effect of carbon nanotubes loading in multifiller polymer composite as bipolar plate for PEM fuel cell

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Abstract

In this study, bipolar plates for Proton Exchange Membrane Fuel Cell (PEMFC) were developed by compression molding technique using Polypropylene (PP) as a polymer matrix and Graphite (G), Carbon Black (CB) and Carbon Nanotube (CNTs) as reinforcements. United Stated Department of Energy (US DOE) target values were taken as the benchmark for the development and investigation of the bipolar plate properties. The effects of CNTs loading on the electrical and mechanical properties of G/CB/PP composite were investigated. By adding small amount of CNTs such as 1, 2, 3, 4, 5, 6, 7, 8, 9 and 10 wt% into G/CB/PP composite thus will give synergy effects on electrical conductivity and mechanical properties. It was found that, using CNTs as a third filler at a loading of 6 wt% in a G/CB/PP composite, shown the higher result of in-plane electrical conductivity is 158.32 S/cm, the density and shore hardness 1.64 g/cm^3 and 81.5 (SH) respectively. Meanwhile, the optimum value of flexural strength obtained was 29.86 MPa at 5 wt% of CNTs.

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Keywords: nanomaterial fillers; electrical conductive polymer composite; carbon nanotube.

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1. Introduction

Proton exchange membrane fuel cells (PEMFCs) is a good contender for portable and automotive propulsion applications because of their advantages of high power density, solid state construction, high efficiency of conversion of chemical to electrical energy, near zero environmental emissions and low temperature operation[1]. The bipolar plate is a main component of PEMFCs stack, which takes a large portion of stack cost[2,3]. They can contribute 70-80% of the stack weight and up to 45% of the costs[4]. Thus, the investigation on cost/performance materials of bipolar plates has become a critical research issue. Bipolar plates can be made from many different materials, such as pure graphite, metal or polymer composites with carbon or metal conductive as a main filler. Pure graphite is one of the more traditional materials used to produce bipolar plates due to their advantages of good thermal and electrical conductivity, excellent chemical compatibility and good corrosion resistant. However, some problems with pure graphite is during fabrication process is too costly and time consuming, especially the machining process of gas flow channels into the plate surface and yet graphite has low mechanical strength properties[5-7].

Although there were many researches about Conductive Polymer Composite (CPCs) as bipolar plates for PEMFCs, only few of them focused on CNTs as reinforced filler. So it is necessary to do deep research on the combinations of multi fillers bipolar plate materials to obtain the better electrical conductivity of the composite[8-10]. Therefore, some conductive fillers like carbon black, graphite, carbon nanotubes and carbon fiber are commonly used as reinforced filler to enhance overall performance of CPCs as bipolar plates[11,12]. The interaction between fillers and polymer chains are the most important aspect need to be improved in CPCs as bipolar plates by conventional polymer processing technique[13,14].

Since Carbon nanotubes (CNTs) have good electrical and mechanical properties due to its high aspect ratio [15], the idea of using them as reinforcing fibers in composite materials has been a great potential for composite design [14,16]. However, the dispersion of CNTs in the polymer matrix is a challenging operation since they tend to agglomerate due to their high surface energy, thus impeding the formation of conductive paths that allow for the buildup of enhanced conductivity[17]. One of the most widely used methods to prevent the agglomeration of CNT in polymer matrix is melt mixing via internal mixer technique[18]. CNTs is a good candidate to produce nanocomposite with polymers due to its high Young‘s modulus, aspect ratio and electrical properties[19]. It is assumed that composites reinforced with carbon nanotubes could be stronger and lighter than reinforced with carbon black, metallic powders and glass fibers with metal coatings[11,20,21].

The aim of the present work is to investigate the effects of CNTs loading in multi filler G/CB/CNTs/PP composite for bipolar plate PEMFC. The paper also explores the electrical and mechanical properties of using more than one conducting fillers in CPCs. To achieve the requirements stated by the U.S. DOE for bipolar plate, materials/composite properties of the CPCs must be considered for achievable design for a fuel cell application, specifically, electrical and thermal conductivity, gas permeability, mechanical strength, corrosion resistance and low weight[10]. The properties requirements shown in Table 1 should be satisfied for the fabrication of a bipolar plate.

Table 1 Requirement properties for the bipolar plate (DOE target)[10,16,22]

Property	Value
Electrical conductivity	> 100 [Scm^{-1}]
Thermal conductivity	> 10 [$W(mK)^{1}$]
Flexural strength	> 25 [MPa]
Shore hardness	>50
Bulk Density	<5 [g/cm^{3}]