Iranica Journal of Energy & Environment 4 (4): 357-360, 2013
ISSN 2079-2115
IJEE an Official Peer Reviewed Journal of Babol Noshirvani University of Technology
DOI: 10.5829/idosi.ijee.2013.04.04.07

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# Construction of Composite Polymer Bipolar Plate for Pem Fuel Cell

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(Received: Jan. 13, 2013; Accepted in Revised Form: Nov. 26, 2013)

**Abstract:** Bipolar plates play the most significant role in weight, volume and corresponding costs of fuel cells. Initially, metallic and graphite materials had been used for production of bipolar plates due to their electrical conductivity characteristics. Later, these plates due to their deficiency such as corrosion, weight and production expenses were appropriately substituted by composite plates. This article presents results of a study on construction of bipolar plates using conductive polymeric composites. In the constructed composites, polypropylene was implement as polymer matrix and conductive carbon black and graphite as filler in order to supply the required electrical conductivity. The added fillers have been distributed in polypropylene by using an internal mixer. Then, bipolar plate specimens were prepared by molding of composite in hot press. The prepared specimens have been characterized to evaluate their specifications such as mechanical properties and their performance properties like thermal and electrical conductivities. The results of performed tests have shown a good performance on thermal conductivity greater than 10W/m.K, electrical conductivity higher than 50S/cm and high mechanical strength, flexural strength greater than 25MPa. The constructed composite plates were optimized and their weight in compare to similar metallic plates 80% and in contrast to graphite plates 40% were reduced. This method for production of bipolar plates is more economical as it reduces the cost of used materials and expenses of manufacturing operations.

**Key words:** Fuel cell . Bipolar plates . Composite . Polypropylene . Carbon black . Graphite

## INTRODUCTION

Bipolar plates are main parts of fuel cells including Proton Exchange Membrane (PEM) that plays several significant roles in fuel cells [1]. These cells are composed of a sequence of units which each unit is assembled from membrane and bipolar plates (Fig. 1). The main functionalities of these plates are uniform distribution of oxygen and hydrogen all over the effective surface of cell, conduction of electricity from one unit to another and transfer of produced heat from cells [2]. In hydrogen fuel cells, hydrogen and oxygen are used to produce electricity, thus the plates must be properly sealed to prevent leakage of the gases to environment. Bipolar plates are effective parts in reducing volume, weight and the most important issue that is the overall cost of a complex cell [3, 4]. Therefore, use of bipolar plates with appropriate specifications has a great influence on productivity, efficiency and final price of manufactured fuel cells.

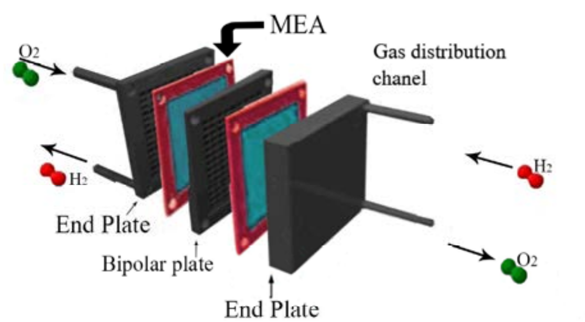


Fig. 1: Fuel Cell structure and position of bipolar plates [2]

Main duties of these plates in brief are as follows:

- Uniform distribution of oxygen and hydrogen.
- Facilitation of water management in cell.
- Conduction of produced electricity to cell's circuit terminals.
- Fuel cell heat management by removal of generated heat.

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- Providing pathways to transfer oxygen and hydrogen through cell.
- Connecting a sequence of cells to gain higher voltage.
- Arrangement of paths for flowing of cooling fluid.

Used material for construction of fuel cells' bipolar plates of must be formable to a structure and have proper properties for machinery operation to make grooves in various forms over the manufactured plates. These grooves are designed to transfer oxygen and hydrogen to the cell's membranes and uniform distribution of gases over them. In polymeric fuel cells, water is the reaction's product that must be removed from the cells through the grooves [5].

Some main specifications of these plates for supplying an appropriate cell's performance are:

- Electric conductivity: more than 10 S/cm, for optimum transferring of generated electrons to terminals.
- Thermal conductivity: more than 10 W/(m.K), for controlling cell temperature.
- Hydrogen and oxygen permeability: less than $2\times10^{-6}$ cm/s, for decreasing diffusion rates of gases from cells.
- Mechanical strength: bipolar plates should be over tensile strength of more than 25MPa and flexural strength of more than 30MPa.
- Density: used materials should be light, overall density less than 5g/cm$^3$.
- Thermal stability: bipolar plates must be stable up to temperature of 120 ºC [6,7].

**Plate's Materials:** There are various materials for production of bipolar plates. Usage of these materials such as metals, demonstrate different sets of advantages and disadvantages. Although application of coated metallic materials in bipolar plates were satisfactory in laboratory scale, but the governing production cost at industrial scale and their high density, has been concluded to proper candidates, conductive polymeric composites.

Polymeric composites are light materials that can be casted in different structures, shapes and sizes for application in fuel cells. For enhancing the electric conductivity of polymeric composites, additives such as carbonic composites including carbon fibers, conductive carbon black, graphite and coke; or metallic particles can be used. Bipolar plates were previously made from carbonic materials such as graphite which provide necessary properties of bipolar plates. But due to some improper properties of graphite such as low mechanical resistance and fragility, it was gradually substituted by other materials. The substituted materials can be classified into two groups of coated metallic alloys and polymeric composite materials. While the metallic alloys benefits the advantages of high mechanical resistance and proper electric and thermal conductivities, some of involved disadvantages are corrosion under acidic condition of fuel cells, heavy weight and inappropriate surface connections between the cell's parts. The main advantages of polymeric composites are high resistance against corrosion and light weight, while their corresponding disadvantages are low electrical and thermal conductivities. However this shortcoming can be removed by adding conductive particles. Electrical conductivity of polymers can be enhanced by adding conductive compounds such as metallic particles, conductive graphite, carbon black and carbon fibers. Resulted composite from polymer carbon black compounds are used in some industrial applications in which metals or graphite were the only options.

By increasing the trend on usage of fuel cell for supplying energy and their mass manufacturing scale application of appropriate bipolar plate have a great influence on weight and cost of manufactured cells.

In some cases that usage of graphite plates can be costly, or their fragility may be an inappropriate property for performing some operations such as lathing of graphite surface, polymeric composites could be an appropriate substitute [8]. By addition of a proper amount of conductive particles to base polymers, suitable composites with exclusive properties and controllable electric conductivity can be developed.

A variety of mechanisms for describing the conductivity of conductive composites have been offered. A set of researches on designing of a proper formulation for having a specific thermal and electric conductivities are performing in both academia and industry. Conductive composites are based on two groups of (i) thermoplastic resins such as polypropylene and polyethylene; and engineering polymers such as poly amides and poly carbonates; and (ii) thermoset resins including phenol and epoxy, ester compounds. Carbon fiber can be used in composites to increase their firmness [9, 10].

## RESULTS

In this project, for achieving to the desired electrical conductivity, it was estimated to add graphite and carbon black to composites more than 70% by weight. Thus, for reaching to this range of filers' content, simultaneous addition of carbon black and graphite was arranged. While carbon black increases electric conductivity, graphite assists carbon black to increase electric conductivity and control melted viscosity during mixing process.

Polypropylene has been used as a matrix base in order to reduce the weight and the fragility of produced plate. For production of the composite, initially polypropylene granules were melted in an internal mixer. Then graphite was gradually added and the materials were completely mixed to make a uniform mixture. In the next step, conductive carbon black was added to the melted consistent mixture. The molten mixture was casted and placed in hot press. The variation of electrical conductivity of produced bipolar plates with ingredients content of produced composites are shown is Table 1.

Electrical conductivity of the produced composites varies with percentages of carbon black and graphite as conductive contents (Fig. 2). Thermal conductivity of the produced composites varies with percentages of carbon black and graphite as conductive contents (Fig. 3). Furthermore, variations of flexural strength of the produced composites were measured for various amounts of both carbon black and graphite as conducting particles (Fig. 4).

Table 1: Variation of electrical conductivity of the produced composites with ingredients contents

| Polypropylene (wt%) | Graphite (wt%) | Carbon Black (wt%) | Conductivity (S/cm) |
|---|---|---|---|
| 50 | 50 | 0 | 0.01 |
| 50 | 45 | 5 | 0.05 |
| 50 | 35 | 15 | 0.1 |
| 40 | 60 | 0 | 0.5 |
| 40 | 50 | 10 | 0.8 |
| 40 | 45 | 15 | 1 |
| 30 | 70 | 0 | 2 |
| 30 | 60 | 10 | 8 |
| 30 | 55 | 15 | 10 |
| 30 | 50 | 20 | 20 |
| 20 | 70 | 10 | 30 |
| 20 | 65 | 15 | 50 |
| 20 | 60 | 20 | 100 |

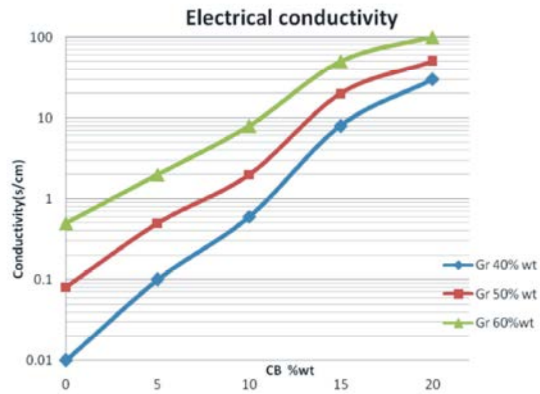


Fig. 2: Variation of electrical conductivity of the produced composites with Carbon Black (CB) and Graphite (Gr) contents.

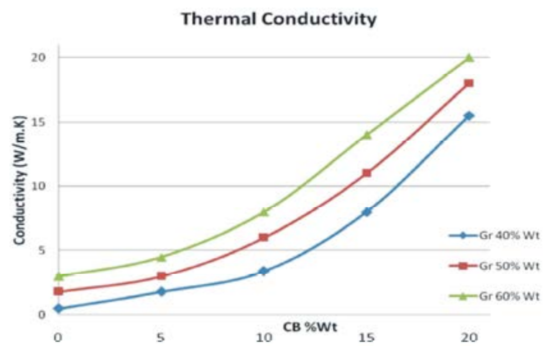


Fig. 3: Variation of Thermal conductivity of the produced composites with Carbon Black (CB) and Graphite (Gr) contents.

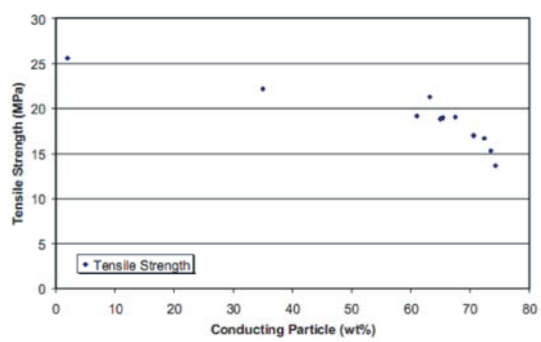


Fig. 4: Variation of Tensile strength of the produced composites with overall conducting particles contents.

## CONCLUSION

Experimental results revealed that a stable molten mixture of polypropylene containing 20% carbon black and 50% graphite have electrical resistance of 0.02 Ω/cm. As a part of this research, polymeric composite with mechanical resistance of 25 MPa and electrical conductivity of 10k was produced. This result shows that the produced composites are well-suited for application as bipolar plate in fuel cells.

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## Persian Abstract

DOI: 10.5829/idosi.ijee.2013.04.04.07


چکیده

صفحات دو قطبی پیل‌های سوختی تاثیر قابل توجهی در وزن، حجم و هزینه های اقتصادی آن دارند. صفحات گرافیتی یا فلزی مشکلاتی را به لحاظ خوردگی، شکنندگی، وزن زیاد و هزینه های بالای تولید دارند. در این پژوهش، ساخت صفحات دوقطبی توسط کامپوزیت های پلیمری رسانا مورد ارزیابی قرار گرفت. بر اساس مطالعات انجام شده، از پلی پروپیلن بعنوان ماتریس و از گرافیت و سه گونه کربن سیاه هادی بعنوان پرکننده برای تامین رسانایی گرمایی و الکتریکی استفاده شد. کامپوزیت‌های حاوی ۵۵ تا ۶۰ درصد گرافیت، ۱۵ تا ۱۸ درصد کربن سیاه و ۲۰ تا ۲۵ درصد پلی‌پروپیلن، بهترین گزینه‌ها برای تولید صفحات پیل سوختی هیدروژنی می‌باشند. صفحات کامپوزیتی ساخته شده با چگالی حدود ۱/۱ در مقایسه با صفحات فلزی با چگالی ۵ الی ۸ $g/cm^3$ برای کاربرد مورد بحث، از لحاظ سبکی نیز گزینه برتری می‌باشند. در بین کامپوزیت‌های تولیدی، نمونه‌هایی با ویژگی‌های مطلوب صفحات دو قطبی در پیل سوختی با هدایت الکتریکی بیش از ۵۰ S/cm، استحکام فشاری افزون بر ۲۵ MPa و ضریب هدایت گرمایی بالاتر از ۱۰W/(m.K) وجود دارند. صفحات کامپوزیتی ساخته شده چگالی حدود ۱/۱ دارند که وزن این صفحات در مقایسه با نمونه های مشابه فلزی ۸۰ درصد، و نسبت به نمونه‌های مشابه گرافیتی ۴۰ درصد کمتر می‌باشد. و نیز مشکل خوردگی صفحات فلزی و شکنندگی صفحات گرافیتی را ندارند. کامپوزیت‌های ساخته شده از کربن سیاه نوع XE-CB و نوع HI-CB-40B به ترتیب دارای بیشترین و کمترین هدایت حرارتی، هدایت الکتریکی و مقاومت مکانیکی بودند.