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Differences in structure and property of carbon paper and carbon cloth diffusion media and their impact on proton exchange membrane fuel cell flow field design

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ABSTRACT

Gas diffusion media (GDM) and flow fields perform the task of distributing the reactant gases uniformly over the active electrochemical area in proton exchange membrane (PEM) fuel cells. Carbon paper and carbon cloth are two commonly employed gas diffusion media in PEM fuel cells, and they differ widely in their structure and properties. Since the path of the reactant gases to the catalyst in the fuel cell electrodes involves passing through the flow fields as well as the GDM, a good design for a fuel cell requires an understanding of the interaction between these components. The focus of the present work is to study the impact of the difference in structure and properties of the diffusion media used, on the design of the PEM fuel cell flow field. Carbon paper and carbon cloth were characterized for the pressure drop they cause when used as GDMs, for channel intrusion, compressibility and electrical resistivity. Carbon cloth exhibits about 43–125% more intrusion into the channel in comparison with carbon paper for the conditions tested. This intrusion results in increased pressure drop in the flow channel especially at higher channel widths and at higher compression. Compression studies reveal that carbon cloth lacks compression rigidity and suffers considerable strain at lower stress values whereas carbon paper is relatively rigid in nature. The results indicate that the intrusion of carbon cloth into the channel, constraints the channel width in a flow field design if it were to be used with a carbon cloth GDM as opposed to a carbon paper GDM. Electrical resistivity measurements were carried out and a simple mathematical model has been developed for the potential drop in the GDM. The model indicates that even from the perspective of electrical properties, use of carbon cloth GDM constraints the channel width that is permissible in flow field design.

1. Introduction

Proton exchange membrane (PEM) fuel cells are attracting considerable attention as power sources because of their simplicity relative to other types of fuel cells, and high power density [1]. Fuel cells provide an attractive possibility that the primary exhaust from the power source is water. Further, since hydrogen is being targeted as the fuel in several types of fuel cells, there is a possibility of using a cycle of water electrolysis using solar energy, coupled with the use of hydrogen and oxygen as reactants in a fuel cell to generate energy. Such a mode of operation is similar to that used with respect to rechargeable batteries. Fuel cells, therefore, offer the highly desirable possibility of addressing the energy and environmental crisis issues simultaneously.

The potential benefits offered by fuel cells can be taken advantage of only if they are operated efficiently. One of the factors limiting the efficiency of a fuel cell is the lack of uniformity of reactant distribution across the active area of the cell, which can also lead to inefficient catalyst utilization and reduced cell life [2]. In fuel cells, flow fields play an important role in distributing the reactant gases to the electrochemically active area in the electrodes. Several flow field patterns such as parallel channel, single serpentine, multiple serpentine, interdigitated flow patterns are widely used in fuel cells [3]. In a typical PEM fuel cell, a porous gas diffusion medium (GDM) is placed in direct contact with the flow field. In conjunction with the flow field, the GDM also distributes the reactants over the active catalyst area. Carbon paper and carbon cloth are the two most commonly used gas diffusion media in PEM fuel cells. In carbon paper the carbon fibres are held together in a carburized resin matrix. In case of carbon cloth no such binder is necessary as the fibres are woven. Carbon paper and cloth differ in their structure and hence have different properties [4].

Kowal et al. [5] concluded from neutron imaging that carbon paper GDM retains more water than carbon cloth GDM in the flow field land (also referred to as rib) area and hence it is more prone to

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