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Thermal conductivity of a graphite bipolar plate (BPP) and its thermal contact resistance with fuel cell gas diffusion layers: Effect of compression, PTFE, micro porous layer (MPL), BPP out-of-flatness and cyclic load

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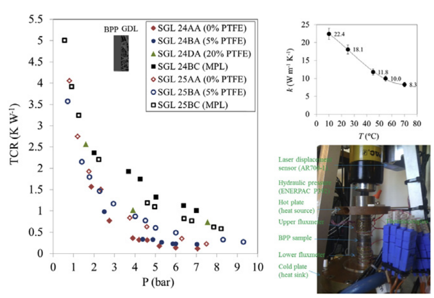
HIGHLIGHTS

- Thermal conductivity of graphite bipolar plates (BPP) decreases with temperature.
- Thermal Contact resistance (TCR) between BPP and GDLs decreases with compression.
- GDL-BPP TCR increases with MPL and PTFE, regardless of the PTFE loading.
- High PTFE loading, MPL, and BPP out-of-flatness increase the TCR dramatically.
- The graphite BPP-GDL TCR is a dominant resistance in a BPP-GDL assembly.

GRAPHICAL ABSTRACT



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ABSTRACT

This paper reports on measurements of thermal conductivity of a graphite bipolar plate (BPP) as a function of temperature and its thermal contact resistance (TCR) with treated and untreated gas diffusion layers (GDLs). The thermal conductivity of the BPP decreases with temperature and its thermal contact resistance with GDLs, which has been overlooked in the literature, is found to be dominant over a relatively wide range of compression. The effects of PTFE loading, micro porous layer (MPL), compression, and BPP out-of-flatness are also investigated experimentally. It is found that high PTFE loadings, MPL and even small BPP out-of-flatness increase the BPP-GDL thermal contact resistance dramatically. The paper also presents the effect of cyclic load on the total resistance of a GDL-BPP assembly, which sheds light on the behavior of these materials under operating conditions in polymer electrolyte membrane fuel cells.

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1. Introduction

The required power output of proton exchange membrane fuel cells (PEMFCs) for specific applications is achieved by stacking individual cells or membrane electrode assemblies (MEAs), each separated by a bipolar plate (BPP). Fig. 1 illustrates the components of a PEMFC, including the BPPs and their adjacent GDLs, and all the main thermal resistances within the cell.

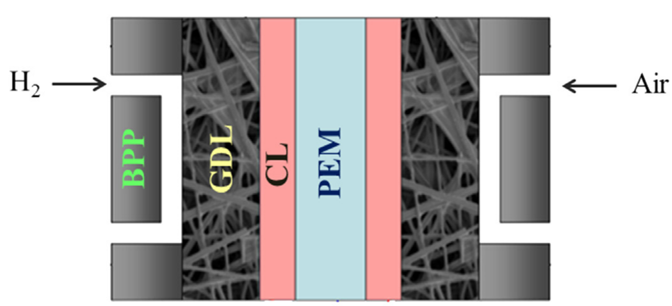
The adequate thermal and associated water management of fuel cells requires knowledge of the thermal bulk and contact resistances of all involved components [1,2]. However, due to experimental difficulties, no measurements have been reported to date on the thermal contact resistance (TCR) between GDLs and graphite BPP [3–6]. Consequently, this contact resistance has either been neglected or roughly estimated in modeling studies [7–10]. The brittle, porous anisotropic nature of most fuel cell components together with their small thicknesses have made it challenging to measure their thermal resistances, e.g. see Refs. [6,11–16].

The only attempt to estimate the thermal contact resistance between BPP and GDLs to date is due to Nitta et al. [17], which was based on simulations using Fluent, with an unverified assumption of 128 W m^{-1} K^{-1} for the thermal conductivity of the graphite BPP. The reported thermal conductivity of the GDL was several times higher than typical values found in the literature and was also independent of compression. These results are inconsistent with physical observations [18–25] and with several experimental studies showing significant dependency of GDL thermal conductivity on compression [11–15,19–21].

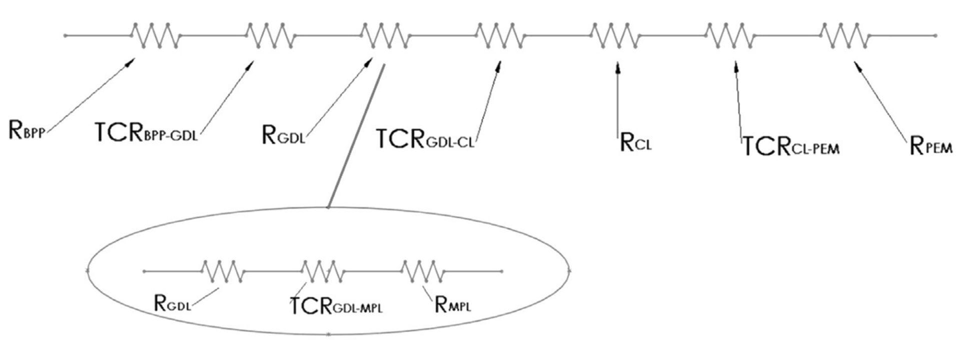
The main purpose of the present study is to measure and analyze the behavior of thermal conductivity of the graphite BPP in terms of temperature and its thermal contact resistance with different untreated and treated GDLs over a range of compression. This work provides some key data and insights on the effect of Polytetrafluoroethylene (PTFE), micro porous layer (MPL), BPP out-of-flatness and cyclic loading on the GDL-BPP TCR.

2. Experimental setup

To measure the thermal conductivity of the graphite bipolar plates and their contact resistance with different GDLs, the thermal contact resistance (TCR) apparatus described in Ref. [6] was employed. The design of this apparatus, also called TCR machine, is based on the guarded heat flux meter device as recommended by the ASTM Standard C-177 [26]. The testbed of the TCR machine, shown in Fig. 2, is comprised of two cylindrical Armco-iron heat fluxmeters, in between which the sample is located. A temperature gradient is induced across the sample using a heat source (the hot plate) and a heat sink (the cold plate). The temperatures are measured using 12 T-type thermocouples placed inside the two fluxmeters. The heat transfer is limited to one-dimensional conduction by creating a high vacuum condition inside the test chamber. The control of the compression pressure applied on the sample is performed using a hydraulic pressure device (ENERPAC P392). The measurement and monitoring of the changes in the thickness of the compressed sample is carried out with a laser displacement sensor (AR700-1). Knowing the thermal conductivity of the fluxmeters and the measured temperature profile along them, the heat transferred through the sample and the temperature drop across it can be obtained, which yields the total thermal resistance. More details of the apparatus, the experimental testbed, and the methodology used in measuring the thermal resistances with this machine can be found elsewhere [6]. The focus here will be on the experimental procedure utilized in conducting the tests to de-convolute the contact resistance between GDLs and BPP from the other present resistances, especially for the case of GDLs containing MPL.



(a)



(b)

Fig. 1. (a) Main components of a PEMFC and (b) all the main thermal resistances inside a cell.