The impact of anode gas diffusion layer structure on fuel cell performance

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Abstract. The gas diffusion layer (GDL) plays an important role in the operation of fuel cells with a proton exchange membrane (PEMFC). GDL is commonly used on three possible types of carbon fiber-con backing: carbon fabric, non-woven material, carbon paper. All three types have different properties, such as gas permeability, mechanical strength, electrical resistance, hydrophilicity and price. Paper is much cheaper than non-woven material, and replacing even one electrode could make a fuel cell cheaper. But replacement makes sense only if the same efficiency is maintained. In this work, two types of GDL as an anode in PEMFC were compared. As a result of the comparison, current-voltage and power characteristics were obtained.

1. Introduction
Fuel cells with a proton exchange membrane (PEMFC) have the potential to meet the challenges of the future energy industry. A key element in these devices is the gas diffusion layer (GDL). GDL has several characteristic functions: ensuring the permeability of the reagents to the active sites of the catalyst, removing the formed water during the reaction, ensuring electronic conductivity. The main structural differences in different type of GDL are described in the literature [1,2]. Due to the different structure of the GDL also behave differently. Studying the behaviour of a given GDL during work is a difficult task, since a large number of external factors affect the work [3,4]. Typically, a GDL consist of a substrate based on carbonized and teflonized fibers. A microporous layer is applied to one side of the GDL, it improves the removal of reaction products and reduces contact resistances. The most common structures of GDL: woven carbon materials, non-woven carbon materials, as well as carbon cardboard. In [5,6] it was shown that woven and non-woven carbon GDLs have higher specific characteristics than other structures and are most effective at high humidity[7]. At the same times, carbon cardboard is cheaper than other structures, as well as more rigid, which in turn facilitates the design of flow fields in bipolar plates.

This paper presents a comparison of membrane electrode assemblies (MEA) with different structures of GDL, namely, a comparison of carbon non-woven material and carbon cardboard as an anode.

2. Sample preparation and measurement methodology
To test various types of GDL, a measuring cell was designed and made. As a source of hydrogen, a laboratory commercial electrolyzer «GVCH-12» of the company «Chem element electronics» was used. Moistening of the samples was achieved by passing the cathode gas through water.
The working areas of the fabricated MEAs are 5 cm². In this work used graphite bipolar plates with direct channels of flow fields along the cathode and anode, while the gas flows were directed towards each other.

The cathode parameters for the gas diffusion layer were constant in all measurements. The catalyst loading was 0.2 mg cm⁻² from the cathode side. The catalytic ink based on commercial «JM HySPEC 13100 Pt/C», catalyst was applied manually on a GDL by airbrushing. The catalyst loading at the anode was 0.1 mg cm⁻². An «MF4-SK» membrane was used as a solid – polymer proton exchange electrolyte. The membrane electrode assemblies underwent a hot pressing procedure at the temperature 140 °C and a pressing force of 750 kg. Only non-woven cathode and anode had a microporous layer. In this work, the following anode materials are presented:

- Freudenberg H24C5 (Carbon non-woven material)
- Toray HCP030N (Carbon cardboard)

The parameters and characteristics on the studied gas diffusion electrodes are shown below in table 1.

| Structure       | Freudenberg H24C5 | Toray HCP030N |
|-----------------|-------------------|---------------|
| Thickness       | 0.27 mm           | 0.3 mm        |
| Resistivity     | 9 mOhm cm⁻²       | 3 mOhm cm⁻²   |
| Price           | 0.085 $ cm⁻²      | 0.078 $ cm⁻²  |
| Microporous layer | +                 | -             |

After assembling the MEA, it must be activated. Activation was carried out in accordance with the recommendations of the international electrochemical commission [9]. Samples were tested under the same conditions:

- Hydrogen consumption: 12 liters per minute
- Air consumption: 30 liters per minute
- Reagent supply pressure: 1 bar
- Measurement cell temperature: 50 °C
- Data logging speed: 1 second

After the activation procedure of the MEA, three current-voltage characteristics were taken to confirm the coincidence of the results, with the coincidence of the three current-voltage characteristics, the fourth went to the final report.

3. Results and discussions
The results obtained by comparing the two structures were analyzed. It is important to note that the results discussed in this article are based on testing under certain operating conditions, which are presented above. The behavior of the test samples can change dramatically depending on the operating conditions.

The material structure on the gas diffusion layer largely determines the characteristics of the fuel cell. A change in the operating efficiency of a MEA with different structures of the GDL cannot be explained solely by a change in structure, but studies of this kind are necessary to understand the nature of the change in other properties of the fuel cell.

From table 1 it is seen that GDL based on non-woven material is slightly thinner than the carbon cardboard-based sample, although it has a microporous layer. At the same time, the electrical resistivity of the studied object based on carbon cardboard is three times lower than another sample. Figure 1 show that, with equal activation and diffusion losses, the resistive losses on the carbon cardboard-based sample are lower. Despite all this, fuel cell manufactures prefer to work with non-woven based GDL, the most famous manufactures of these types of GDL are Freudenberg and
Sigracet, non-woven material is more expensive due to more complex production technology. It should be noted that the anode reaction of the fuel cell is simpler than cathode one, therefore, in this article, the replacement of the gas diffusion layer on the anode is considered.

![Graph showing current-voltage characteristics](image1)

**Figure 1.** Current-voltage characteristics of the test samples.

The sample based on Toray HCP030N at the maximum power point had 167 mW cm$^2$, while the MEA with Freudenberg H24C5 had 157 mW cm$^2$. Power characteristics of the studied samples are presented in Figure 2.

![Graph showing power characteristics](image2)

**Figure 2.** Power characteristics of the test samples.

4. Conclusion
Selected samples of commercial gas diffusion layers were tested as an anode of a proton exchange membrane fuel cell. The main criteria for evaluating the operation of the MEA, which includes a gas diffusion layer, is the maximum power density at the peak, as well as the magnitude of the losses in the sections of the current-voltage characteristic. The research showed that the samples have approximately the same activation and diffusion losses, but the resistive losses of the carbon cardboard-based sample are smaller. At the same time, a sample based on non-woven material is more expensive, and the use of a GDL based on carbon cardboard as an anode fuel cell can make the final product cheaper, without any efficiency losses.

5. References
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