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Development of a lateral PEM fuel cell

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Abstract

A novel lateral PEM fuel cell was developed. The anodes and cathodes are situated nearby each other on a polymer electrolyte membrane. The transport of the protons takes place in a lateral way in the membrane. All manufacturing steps of the lateral PEM fuel cell were designed to meet the requirements of mass production. The base plate being the central part was made by means of polymer micro injection moulding.

Keywords: Lateral polymer electrolyte membrane fuel cell; Lateral conductivity; Micro channels; Mass production; Micro injection moulding

1. Introduction

Mass production of PEM fuel cells, respectively their components, is a precondition for a widespread economical use of this technology. Especially technology concerning the mass production of bipolar plates is one of the main goals of international fuel cell research activities [1]. From an economical point of view, injection moulding of bipolar plates would be the favoured process. The main obstacle of producing the bipolar components with this technology is the rather poor electrical conductivity in through plane direction, of the known highly filled thermoplastic/graphite compounds. Conductivities of 17 S/cm were reported [2], whereas 100 S/cm should be the target value [3]. As we have observed earlier, applying classical polymer working techniques, the highly filled compounds (>70% graphite or carbon content) can lead to severe rheological problems during the injection process with common injection moulding machines using moderate injection pressures.

One goal of this work was therefore the use of the injection moulding technique at moderate injection pressures for producing the base plate. Therefore, a novel lateral fuel cell had to be constructed.

Different concepts for lateral fuel cells have been described in the literature recently [4–9]. Although most of the cells described are rather miniaturized bipolar fuel cells than lateral cells, they offer principal advantages beyond the production process. They could exceed volumetric power densities of known bipolar fuel cells in the future, due to their unique construction features.

1.1. Principle

The recently developed lateral fuel cell is made of an insulating base plate (1) including micro-structured channels for the flow reactants hydrogen (6) and oxygen (5).

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Anodes (4) and cathodes (3) are situated nearby each other on the same side of the proton conducting polymer electrolyte membrane (2), separated by the micro-structured channel walls [8] (see Fig. 1).

To establish a small ohmic loss, the lateral distance of proton transport has got to be as short as possible. Therefore a micro-structured channel geometry, comprising channel wall thicknesses at the top in the range of 100 μm, had to be manufactured with injection moulding technology.

Although a lot of different channel geometry patterns are possible, we chose a simple parallel pattern where all anodes are connected by a single connecting channel. The channels for the oxygen delivery are open on one side, to establish an unimpeded air transport, and offer enough space for cathodic product water removal. The usual base plate geometry was 150 mm^2 with a thickness of 0.8 mm (see Fig. 2).

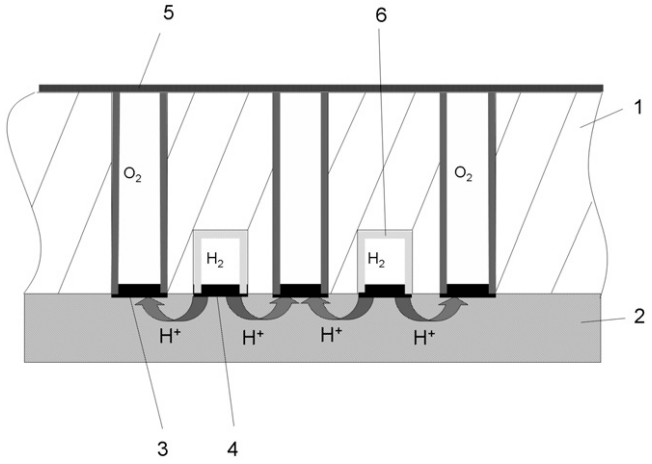

Fig. 1. Operating principle of the lateral PEM fuel cell. An insulating base plate (1) comprising channels for the mass transport of the reactants to the anode (4) and the cathode (3) is covered by a proton conducting polymer electrolyte membrane (2). To achieve electrical contact to the electrodes, the base plate is partially covered with a sputtered gold layer (5, 6).

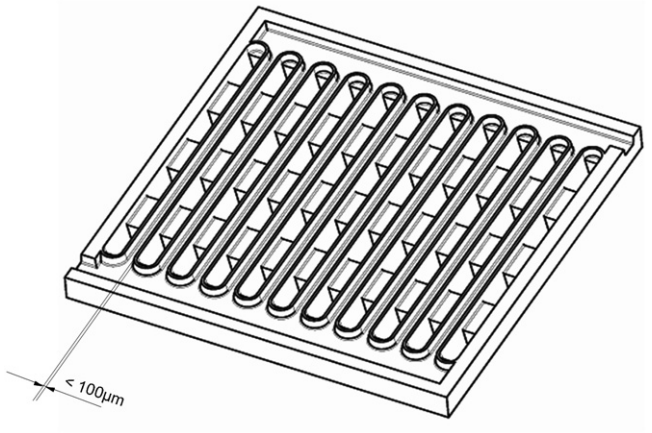

Fig. 2. The base plate of the lateral PEM fuel cell is made of an insulating thermoplastic or ceramic material by injection moulding process. The cathode channels are open to ensure removal of product water.

2. Experimental section

2.1. Manufacturing of the base plate

The insulating base plate was usually made of a thermoplastic material (see Table 1) by means of injection moulding. The manufacturing of the base plate with the PIM process (powder injection moulding), with use of ceramic feedstock, and a subsequent sintering process was also demonstrated [9].

The micro-structured injection moulding tool was made with micro electrical discharge machining by the Austrian company HTP, and utilized in an injection moulding machine (Battenfeld Microsystem 50), to produce base plates for the lateral PEM fuel cell [10].

To ensure a complete filling of the micro-structured channel geometry, every selected base material was first tested with the computer aided 3-D injection simulation tool "Sigma" [11].

After manufacturing, the base plates had to be selectively covered with a conductive, corrosion resistant electrical contact. This was established by sputtering a gold layer on both sides of the plate, and subsequent removing of the gold layer from the top of the channel walls, to electrically isolate the anode and cathode chambers. Usually, the gold layer was removed mechanically between the anodes and cathodes, resulting in a parallel switching of all anodes and all cathodes. With higher sophisticated techniques, for instance selectively masking the channels during the sputtering process, it is also possible to isolate single anode, respectively cathode chambers from each other. This leads to a series connection of anodes, respectively cathodes.

2.2. Membrane electrode formation

The development of the electrode formation process (Fig. 3) was also influenced by mass production requirements. Although the process was only performed on a laboratory scale, we feel that there are no principle restrictions for a scale-up.

The first step was filling up the channels of the base plate with an inert spacer material, and compressing the spacer. We used water soluble Na_2SO_4 as spacer and compressed it with a rubber roll. In a second step the procedure was repeated with electrocatalytically active electrode precursor material, which was made of a mixture of platinum sup-

Table 1
Selection of the used thermoplastic compounds for the production of the base plate by means of micro injection moulding

Thermoplastic compound	Type
PES	Radel AG-320 NT
PCT	Durastar DS 1110 UVI
PETG	Skygreen JN 100
PPSU	Radel R-5000 NT
PEEK	Victrex 450 G