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Investigations on novel low-cost graphite composite bipolar plates

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Abstract

PEM fuel cells are viewed as one of the most environmentally friendly propulsion systems for automotive travel in the future. The PEM fuel cell is still too expensive for wide-spread commercialization. To achieve this cost target and at the same time meeting several technical requirements for mass production, a novel type of low-cost bipolar plates has been developed by SGL Technik GmbH. In this paper, test results of novel SGL bipolar plate materials concerning electrical conductivity (including material resistivity and contact resistances), corrosion, chemical compatibility, gas tightness and mechanical strength are presented. Based on the measurements of resistivity and cell performance, the investigated material appears to be a good choice for stable high performance PEMFC bipolar plates.

Keywords: Fuel cell; PEMFC; Bipolar plate

1. Introduction

PEM fuel cells are viewed as one of the most environmentally friendly propulsion systems for automotive travel in the future. However, even though this technology is being successfully tested in various demonstration cars and buses, it still remains too expensive for wide-spread commercialization. Typical stack costs range today between 2000 and 5000 $/kW, while the ultimate goal for replacing the internal combustion engine is 25-50 $/kW. To achieve this cost target and at the same time meeting technical requirements for mass production, a novel type of bipolar plate was developed by SGL Technik GmbH.

PEMFC bipolar plate technical design criteria are (i) electrical conductivity, (ii) corrosion, (iii) chemical compatibility, (iv) thermal conductivity, (v) gas tightness, (vi) mechanical strength, (vii) weight, (viii) volume and (ix) manufacturability [1].

In this paper, test results of novel graphite composite SGL bipolar plate materials (SGL 001) concerning criteria (i) to (vi) are presented, where (i) includes material resistivity and contact resistance, (ii) comprises chemical and electrochemical stability in a fuel cell environment, and (iii) defines that no emissions affecting the electrode performance as well as no plate surface degradations occur. For comparison of the presented results of graphite composite plates, data on metal-based bipolar plates are given in Ref. [2].

2. Experimental procedures

The investigated bipolar plates were assembled in a 100 cm^2 fuel cell stack comprising four cells and two cooling

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plates. The thickness of the SGL 001 bipolar plate was 1.5 mm. Metal-based bipolar plates ($d = 0.5$ mm) were used as a reference. The EME units comprised GORE MEGA 6000® MEAs with CARBEL® gas diffusion layers. Teflonized Toray paper (25 wt.% PTFE) was used as gas distribution unit. Additionally, a gas distribution mesh is used. The schematic of stack assembly is shown in Fig. 1.

To minimize the influence of the electrode kinetics and to have a potentially more aggressive environment, the stack was operated under pure H_2/O_2 atmosphere at 80°C. No external humidification was provided. To prevent dry out during O.C.V. conditions, current–voltage curves were measured at 50°C. The stack was prepared with probes individually monitoring all potentials. Current vs. voltage curves were taken before and after the 120-h test, and ohmic resistances were determined by two independent methods, the IR-correction by oscilloscopic potential monitoring of a rectangular 100 Hz current change ($\Delta I =$ 10 A), as well as the monitoring of DC-potentials during current–voltage curves.

3. Results and discussion

3.1. Current–voltage curves and endurance test

The current–voltage curves recorded at the beginning and at the end of the 120-h test are shown in Figs. 2 and 3.

In general, the current–voltage curves of the cells are comparable. Initially, reference cell 4 shows the lowest polarisation of all electrodes whereas after the test, the cell SGL 2 and reference cell 1 show the lowest polarisation.

The performance during the 120-h test showed that within the operation time, no performance losses caused

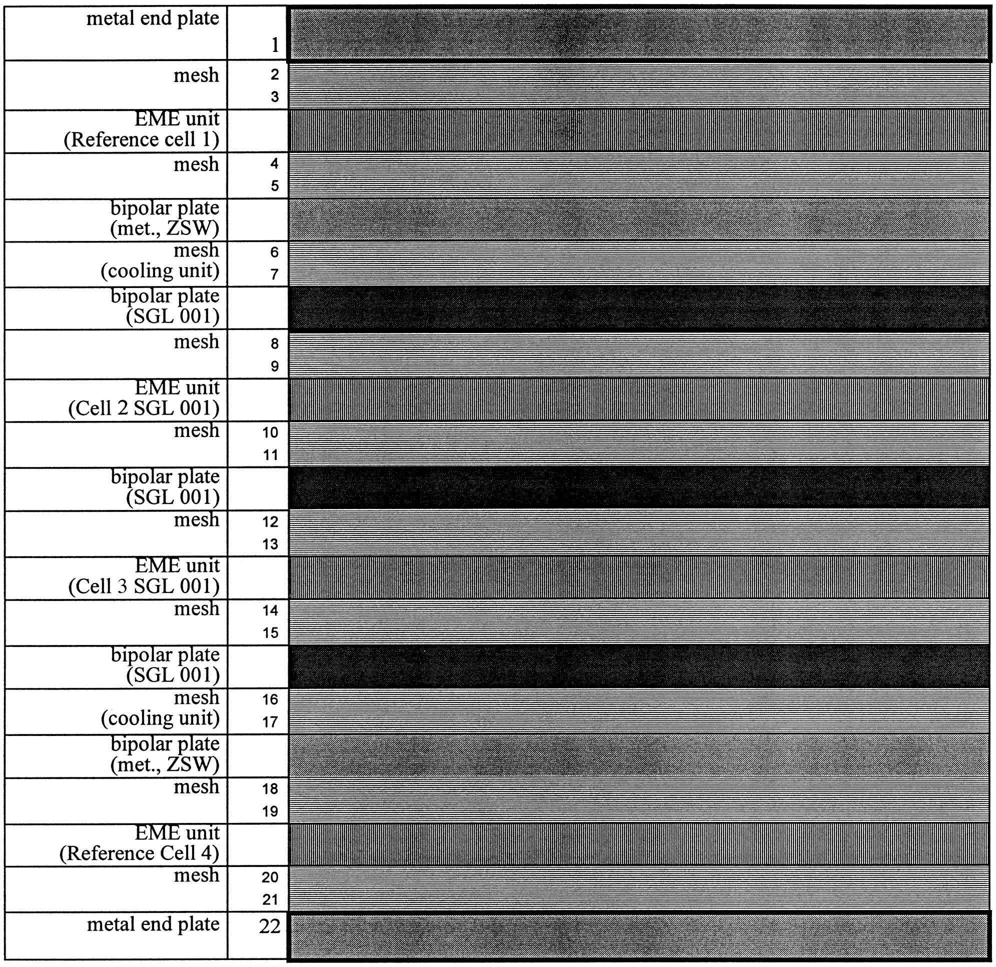

Fig. 1. Schematic of stack assembly.

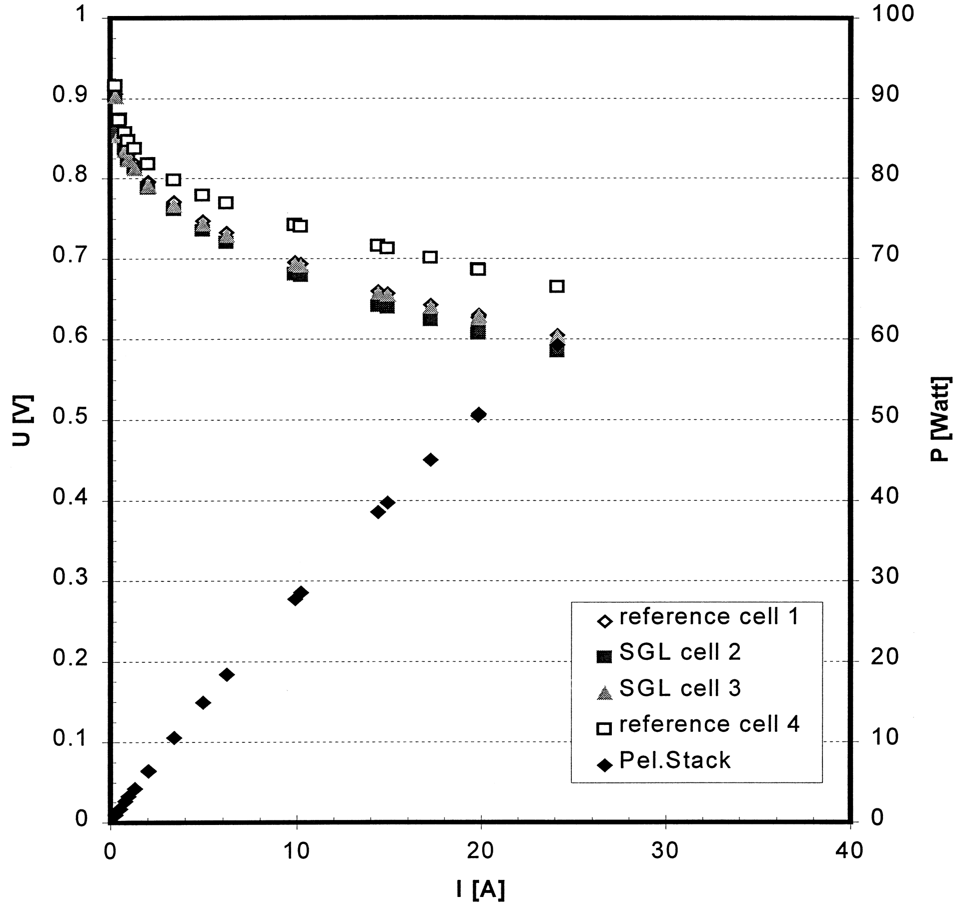

Fig. 2. Current–voltage curves before 120-h test (I), $T = 50°C$.

by leaching of the SGL 001 bipolar plate could be observed.

After the 120-h test, the gas leakage rate of the bipolar plate materials was tested by the voltage decay measurement leaving the cell under O.C.V. conditions with no gas flow. No significant difference between the SGL 001 and reference cell voltage decay was observed. Thus, it is confirmed that the SGL 001 bipolar plates have a sufficient gas tightness for PEMFC operation.

3.2. Contact and materials resistances

The total resistivity measured at the bipolar plates consists of contact and materials resistance. They are measured after start of operation (I), after 2 h operation time

Table 1
Total resistivity in Ω cm^2 (A = AC-current, B = slope of the I–U curve)

Measuring object	Probe number (Fig. 1)	R (Ω cm^2)					
		(I)		(II)		(III)	
		A	B	A	B	A	B
Reference cell 1	4, 3	0.292	–	0.150	–	0.270	–
Bipolar plate (met., ZSW)	6, 5	0.000	0.000	0.000	0.001	0.000	–
Bipolar plate SGL 001	8, 7	0.079	0.088	0.089	0.092	0.064	0.059
Cell 2 SGL 001	10, 9	0.354	–	0.143	–	0.229	–
Bipolar plate SGL 001	12, 11	(0.298)	0.053	0.059	0.056	0.037	0.032
Cell 3 SGL 001	14, 13	0.300	–	0.151	–	0.282	–
Bipolar plate SGL 001	16, 15	0.090	0.091	0.098	0.099	0.058	0.054
mesh (met., ZSW)	17, 16	0.092	0.002	0.000	–	0.000	–
Bipolar plate (met., ZSW)	18, 17	0.008	0.008	0.000	0.000	0.000	–
Reference cell 4	20, 19	0.180	–	0.180	–	0.190	–

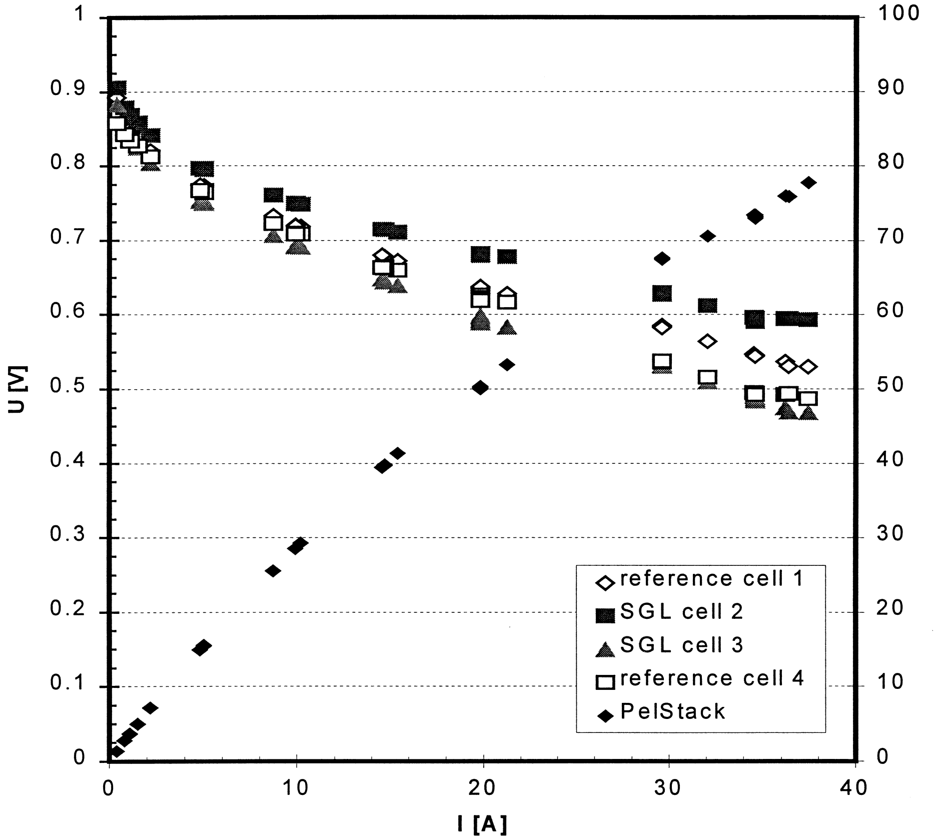

Fig. 3. Current–voltage curves after 120-h test (III), $T = 50°C$.

(II) and after 120 h of operation (III). The results are shown in Table 1.

The resistivities determined from both methods are in good agreement. The resistivities measured at the start of the stack test (I) are partially enhanced compared with the corresponding values (II) and (III). This is presumably caused by a diminished contact pressure of the meshes at the start of the experiment.

The averaged total resistivity of the SGL 001 bipolar plates was 0.087 Ω cm^2 at the start of the experiment and shifted to 0.051 Ω cm^2 at the end.

4. Conclusion

The presented results show that the investigated material SGL 001 is a promising candidate for PEMFC bipolar plates. Though extended life tests are still to be performed and a further reduction of materials resistance could enhance cell performance, the material investigated appears to be a good choice for high performance and cost efficient PEMFC bipolar plates.

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