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Advances in materials for HT-PEM applications

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1. Introduction

- High temperature PEM fuel cells can be operated in the temperature range between 160 – 200 °C and offer a number of potential advantages compared to low temperature PEM fuel cells, e.g. high CO tolerance, no need for humidification of reactant gases, simplified heat management of the fuel cell system.
- In the field of mass production of high temperature PEM bipolar plates, the Zentrum für Brennstoffzellen Technik gGmbH (ZBT) together with the University of Duisburg-Essen, has started the development work in 2004. A number of graphite-polymer compounds were identified that can be processed by compression moulding. Standard compound mixtures consist of a thermoplast and a graphite mixture with additional additives to increase the conductivity of the compound material, just as in the case of low temperature bipolar plates.

2. Graphite-polymer compounds for HT bipolar plates

- Experimental screening of compound mixtures based on PPO, PES, PSU, PEI, PPS took place in a kneader. During the process of compounding it has been observed, that depending on the grade of crystallinity, the thermoplastics exhibit significant differences in their quality to disperse the graphite particles.
- The characteristic of amorphous polymers, i.e. slowly softening over a large temperature range, was reflected in their behaviour of dispersing the filling particles. Bringing the filling particles into the polymer matrix during kneading turned out as very difficult to accomplish. The particles must be mixed in, step by step very carefully. Nevertheless it was possible to produce some highly filled compounds (> 80 %) based on PPO and PEI which were pressed into unstructured plates.
- Contrary to the amorphous resins, production of highly filled compounds on the basis of semi-crystalline polymers (PA, PPS) proved to be straightforward. Due to the typical behaviour of this category of polymer, the melt is of low viscosity and flows readily around the filling particles which resulted in homogenous carbon-polymer compound material.

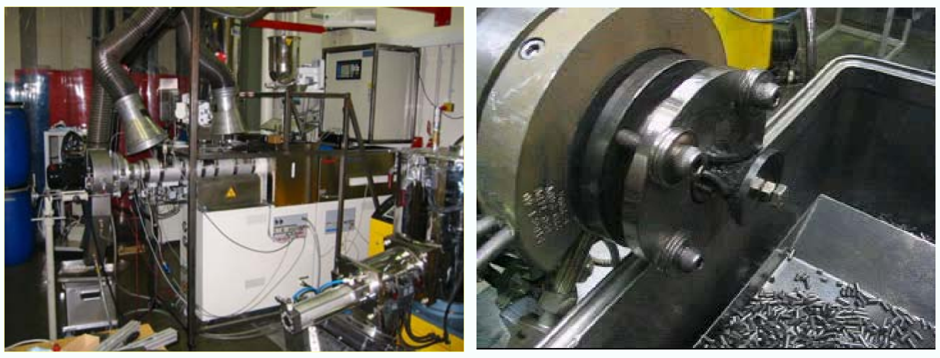

Figure 1: Compound production with the extruder

3. Characterisation of HT bipolar plates

- Plates made of amorphous thermoplastic based compounds were more brittle than plates made of semi-crystalline resins and showed lower gas tightness. Hence, the semi-crystalline materials PA and PPS were to prefer as binder for HT-materials and finally, due to the higher chemical stability, PPS has been selected. In a next step larger quantities of PPS based compound materials were processed in a twin screw extruder and afterwards successfully compression moulded into unstructured compound plates.
- With the help of a four-pole-electrode DC-measurement, bulk resistivity R_Ω, volume resistivity $R_D = R_\Omega + 2\ R_K$ and contact resistivity R_K of the bipolar plates were obtained simultaneously. During the measurements the bipolar plates are contacted in an area of 20 x 20 mm² via two Gore gas diffusion layers (ca. 300 µm) in a press with two gold-coated hobs.
- Main features of the measuring device: heatable, adjustable contacting pressure, almost no limitation in sample size.

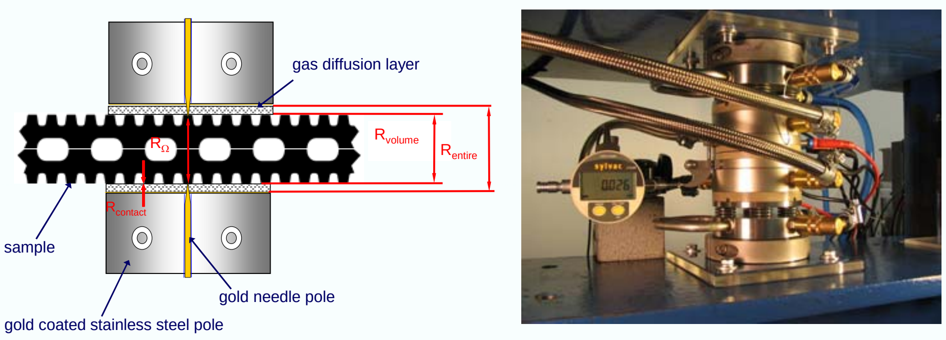

Figure 2: Resistivity measuring – schematic view of four-pole measuring device

4. Resistivity of HT bipolar plates

- Flat, unstructured plates of up to 140 x 140 mm² were manufactured by compression moulding. The flow-fields and cooling structures were milled into the blank plates. A typical resistance measurement of a compression moulded bipolar plate (graphite-PPS compound – 1,8 mm thickness per half-plate) consisting of two half-plates as a function of contacting pressure is depicted in the following figure.

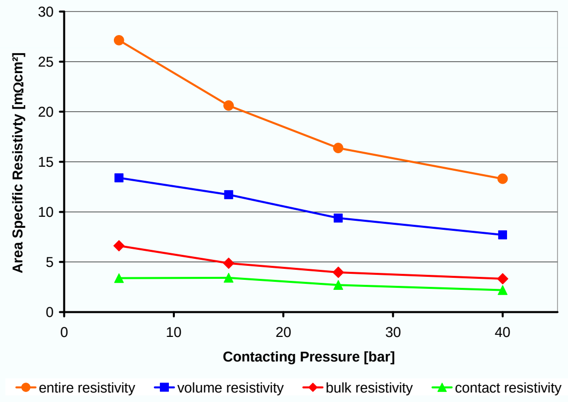

Figure 3: Area specific resistivities of a 3,6 mm ZBT PPS-based bipolar plate (140 x 60 mm²) as a function of contacting pressure. The sample is a hot pressed bipolar plate, consisting of two halfplates including flowfields

- The results show that the highly filled PPS bipolar plate possesses very low contact and bulk resistivities (bulk conductivity ca. 110 S/cm.). The total resistivity of the bipolar plate / GDL sandwich is clearly dominated by the resistivity of the two Gore gas diffusion layers over a large range of contacting pressures.

5. HT PEM fuel cell stack operation

- In-cell testing of moulded compound bipolar plates of 140 x 60 mm² was carried out in single cells at 170°C with commercially available high temperature membrane-electrode-units. Moreover, HT-PEM stacks for portable applications with moulded bipolar plates and electrical power outputs between 100 W and 180 W have been constructed and successfully operated, for instance 5-days operation at 170 °C during the Hannover Fair 2006. The concept of the HT-PEM stack is based on two monopolar (half-)plates, connected by gastight sealings. The heat is removed by air-cooling through open channels integrated into one of the plates.
- In Figure 4 the performance of a 12 cell fuel cell stack operated with hydrogen and air is shown. The stack is air cooled, possesses an active area of 50 cm², the temperature is T = 180°C (H_2/air: 1.2/2.0).

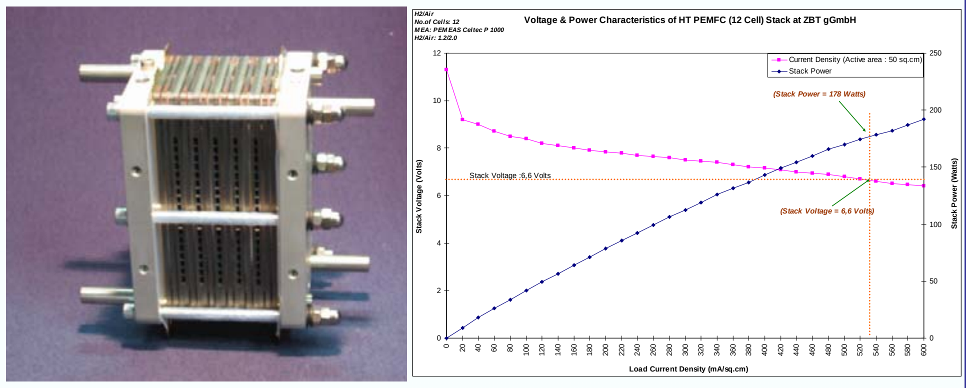

Figure 4: ZBT`s 12 cell HT PEM stack with a nominal power of 180 Watt (left) and performance curve with pure hydrogen and air at 180°C

6. Conclusion and outlook

- HT PEMFC technology is a promising technology offering significant benefits in terms of system optimization when compared to the existing LT PEMFC technology.
- Extensive material research was performed ending up with operating high temperature bipolar plate materials optimized for a challenging environment such as the one in an operating HT PEMFC. It is ZBT's aim to make the graphite based bipolar plates to be commercially viable in the near future.
- Short and long term single cell characterisation was performed, with a closer understanding of the processes involved in optimized HT PEMFC.
- HT PEMFC`s tolerance to impurities such as CO etc. in under investigation.
- Future development of cell and stack design will also extend to liquid cooled HT PEM stacks. All these developments at the time being focus on low cost fuel cell stacks for APU applications both using hydrogen and reformate gas as fuel.

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