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CNT-Compounds for Injection Molded Bipolar Plates in High Temperature PEM Fuel Cells

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Introduction

The Centre for Fuel Cell Technology (ZBT) is working in the field of PEM fuel cell stacks research and development since 2001. Using standard mass production techniques for the fabrication of fuel cell components, such as bipolar plates, is a main issue for the commercialization of fuel cell systems. Therefore high temperature fuel cell stacks based on injection molded polymeric bipolar plates (BPP) have been developed. In order to achieve adequate conductivities, the BPP generally consists of a polymer, which functions as a binding matrix, and a high content of carbon as conductive filler materials. Injection molding of BPP for high temperature PEM fuel cells, which are operated between 150 – 200 °C, is challenging. The outstanding chemical stability and the excellent mechanical properties under continuous operating conditions made the linear polyphenylene sulfide (PPS) the first choice as polymeric matrix.
Furthermore the interactions between different carbon filling materials (graphite, carbon black, carbon fibres and carbon nanotubes (CNT)) in compound based BPP and especially the potential of CNTs are investigated.

Compounding of highly filled materials

The production of highly filled PPS-compound-materials takes place in a twin-screw-extruder or a ring-extruder. Both are equipped with gravimetrical metering units for the thermoplastics, the carbon fillers and further special processing aids. Compounding conditions were systematically varied and a number of linear PPS-grades investigated. The optimization of the polymeric matrix, the carbon content and carbon filler mixture significantly decreases the torque and consequently the specific energy input during extrusion, which is an indicator for a better processability.

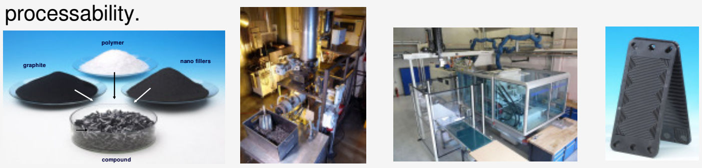

Fig. 1: Feedstock for bipolar plates, compounding, injection molding, bipolar plates (from left to right)

Injection molding of high temperature BPP

Compound materials with an optimized carbon content and composition show a reduced thermal conductivity by remaining good electrical properties which extends the time of solidification during injection operation. In consequence this fact enabled production of PPS-based IM high temperature BPP with a cycle time of below 16 seconds for two bipolar half plates. Fig. 2 shows a filling study during BPP production. The influence of different carbon mixtures at constant filler content on the IM parameters (e.g. maximum injection pressure) is shown in fig.3.

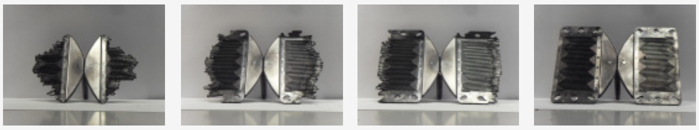

Fig. 2: Filling study of PPS based BPP with a new two cavity mold

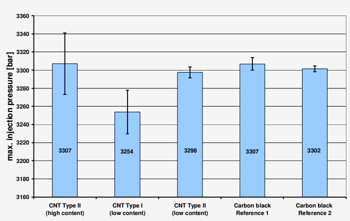

Fig. 3: Maximum injection pressure

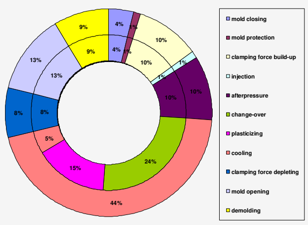

Fig. 4: Structure of injection molding cycle time

Analysis of internal material structures

The addition of the nanometer sized carbon blacks or CNTs forms further conductive bridges through the insulating polymer matrix between the micro sized graphite flakes. Fig. 5 shows schematically the differences between binary compounds (graphite + polymer) and hybrid compounds (graphite + carbon black or CNTs + polymer).
This assumption is approved by images from scanning electron microscope which give an idea about the internal structure and dispersion of nano particles between graphite flakes inside the injection molded compound materials (fig. 6).

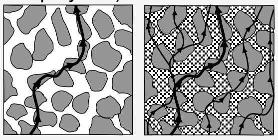

Fig. 5: Binary (left) & hybrid compound (right)

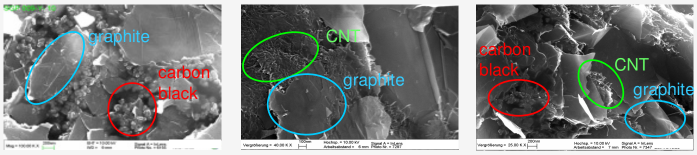

Fig. 6: SEM images of highly filled compounds with different carbon filler mixtures

Measurement of electrical conductivity

A four pole measurement device is used for determining through plane electrical conductivity. The measurements were performed under pressure and as a sandwich between GDL´s to simulate the operating conditions of a PEM fuel cell. The combination of graphite with carbon blacks or CNTs exhibits a positive effect and leads to lower volume resistivities than binary compounds. Differences in electrical conductivity between carbon black and CNT filled BPP are measured.

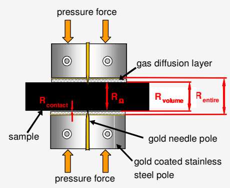

Fig. 7: Four pole measurement (schematic)

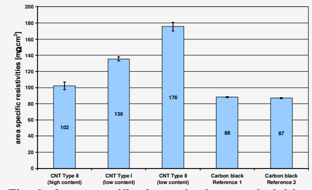

Fig. 8: Area specific through plane resistivities

Performance and long term test of HT-PEM-FC

A single cell stack and a 7-cell-stack with IM high temperature BPP have been assembled and the performance has been tested with a constant load over a period of more than 900 hours. The comparison with a stack consisting of commercial available hotpressed phenolic-bounded BPP has shown no significant difference as depict in fig. 10.

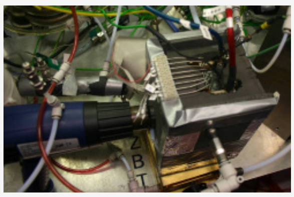

Fig. 9: Test of the 7-cell HT-PEM stack

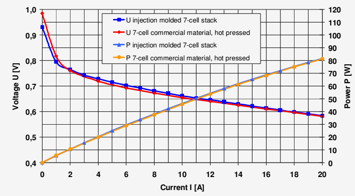

Fig. 10: Comparison of stack performances, 50 cm² active area

Conclusion

- New highly filled PPS-based Compounds developed
  - Positive effects by combination of nano particles and graphite
- First time injection molded PPS bipolar plates produced at ZBT
  - Mass production successfully demonstrated (8 seconds per plate)
- HT-single cell and 7-cell-stack with IM-BPP (without CNT) tested
  - Comparable results between IM BPP and a commercial material
  - 900 h cell operation without significant degradation
- HT fuel cell stack with CNT-based BPP is actually tested

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