CHARACTERIZATION OF COMPOSITE AND METALLIC BIPOLAR PLATES

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ZBT Zentrum für BrennstoffzellenTechnik is

- Independent R&D service provider
- Dedicated to hydrogen and fuel cell technology
- ~ 100 full time employes
- Focussing on applied technologies

Core technologies and services

- Bipolar plates
- Fuel cell stacks < 3 kW
- Fuel reforming
- Fuel cell system technologies (H₂, reformate)
- Production technologies
- Testing for certificates (accredited testing lab)
Types of bipolar plates – ZBT technologies

Graphite Compound hot pressed & milled

Graphite Compound injection moulded

metallic BPP (screen printing)

metallic BPP (structured foils)
### Table 1 Performance requirements for PEM fuel cell bipolar plates.

<table>
<thead>
<tr>
<th>Property</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength – ASTM D638</td>
<td>MPa</td>
<td>&gt;41</td>
</tr>
<tr>
<td>Flexural strength – ASTM D790</td>
<td>MPa</td>
<td>&gt;59</td>
</tr>
<tr>
<td>Electrical conductivity</td>
<td>S cm(^{-1})</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Corrosion rate</td>
<td>mA cm(^{-2})</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Contact resistance</td>
<td>m(\Omega) cm(^{-2})</td>
<td>&lt;20</td>
</tr>
<tr>
<td>Hydrogen permeability</td>
<td>cm(^3) (cm(^2) s)(^{-1})</td>
<td>&lt;2.10(^{-6})</td>
</tr>
<tr>
<td>Mass</td>
<td>kg/kW</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Density – ASTM D792</td>
<td>g cm(^{-3})</td>
<td>&lt;5</td>
</tr>
<tr>
<td>Thermal conductivity</td>
<td>W (m K)(^{-1})</td>
<td>&gt;10</td>
</tr>
<tr>
<td>Impact resistance (unnotched)</td>
<td>J m(^{-1})</td>
<td>&gt;40,5</td>
</tr>
</tbody>
</table>

Determination of mechanical characters:
- Three-point bending test for flexural strength
- Tensile test for tensile strength is being established

3-point bending test of ZBT injection molded material for LT application

Flexural strength ~ 43 MPa
measured resistance:
\[ R_{\text{total}} = 2 R_{GDL}^+ + 2 R_{\text{contact}} + R_{\text{bulk}} \]
\[ R_{\text{bulk}} + (R_{GDL} \text{ determined prior to measurement}) \]

calculated resistance
\[ R_{\text{forward}} = R_{\text{total}} - 2 R_{GDL} \]
\[ R_{\text{contact}} = R_{\text{forward}} - R_{\text{bulk}} \]
Abstract of results of ZBT resistance benchmark at Hanover Fair 2009 compared at 21 bar pressure

- Total resistance
- 2 side contact resistance
- Bulk conductivity

DOE target conductivity

DOE target contact resistance

<table>
<thead>
<tr>
<th>Sample Type</th>
<th>Area Specific Resistance [mΩ cm²]</th>
<th>Bulk Conductivity [S/cm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphitic Single-part</td>
<td>140</td>
<td>60</td>
</tr>
<tr>
<td>Graphitic Single-part</td>
<td>182</td>
<td>60</td>
</tr>
<tr>
<td>Graphitic Material</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>Graphitic Material</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>Metallic Two-part</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td>Graphitic Two-part</td>
<td>60</td>
<td>60</td>
</tr>
</tbody>
</table>

Characterization of bipolar plates - www.zbt-duisburg.de
**area specific resistances at 21 bar pressure**

uncoated and coated metal samples

<table>
<thead>
<tr>
<th>Material</th>
<th>Uncoated</th>
<th>Coated</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td></td>
<td></td>
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<tr>
<td>D</td>
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<td>E</td>
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<td>F</td>
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<td>G</td>
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<td>H</td>
<td></td>
<td></td>
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<tr>
<td>I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G-1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G-2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>G-3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**DOE target contact resistance**

Characterization of bipolar plates - www.zbt-duisburg.de
Immersion test – method of measurement

Accelerated ageing of PEMFC components (bipolar plates, gaskets) in fuel cell simulating environment.

- dest water / sulphuric acid / phosphoric acid
- temperature 40 – 80°C
- gas purge (air, hydrogen)

Ageing characteristics of samples:
- sample mass
- sample thickness
- roughness / waviness
- modulus of elasticity
- nano structure (REM)

Ageing characteristics of soaking liquid:
- conductometry

"Potentiostatic and potentiodynamic voltammetry is being established for determination of corrosion resistance."
Immersion test – results

Mass loss of uncoated and coated sheet metal (0.1 mm)
4 weeks in 1.0 M H₂SO₄ at 80°C and O₂ purge

![Bar chart showing mass loss in mg/cm² for different materials](chart.png)
**Immersion test – results**

**Conductivity of immersion liquid**

3 elastomeric gasket materials in distilled water for 500 hours at 80°C

- **Material A**
- **Material B**
- **Material C**
Density - method of measurement

Determination of density:

- Gas Pycnometry (Quantachrome, Ultrapycnometer 1000)
- Measurement referring to Boyle-Mariotte
- Using He as displacement gas
- Dimension of measuring chamber Ø 49 mm x 75 mm
- Measuring at standard temperature (25°C)
- Averaging 5 measurements

„Used as quality assurance tool for compound material development.“
Thermal Conductivity - method of measurement

Is being established

- Determination of thermal conductivity
  “Measurement of through plane- and in plane thermal conductivity of anisotropic materials.”

- Determination of heat capacity
- Determination of temperature conductivity

„To be used as quality assurance tool for compound material development.“

„Hot disk“- thermal conductivity measuring device
Additional measurements

3D-Scan (FRT, MicroProof-TTV)

- Determination of topographical deviation

Measurement setup

Sheet metal bipolar plate

Screen printed sealing on compound bipolar plate

Raised illustration of topography

Contact angle measurement

<table>
<thead>
<tr>
<th>Material</th>
<th>Surface Preparation</th>
<th>Laplace - Young</th>
<th>Tangential</th>
</tr>
</thead>
<tbody>
<tr>
<td>104 St</td>
<td>untreated</td>
<td>108,7°</td>
<td>114,8°</td>
</tr>
<tr>
<td>104 St</td>
<td>treated</td>
<td>117,4°</td>
<td>124,7°</td>
</tr>
</tbody>
</table>

Method
The test rig consists of three identical testing places. It is designed to compare small differences between the three setups respective stack components or operating conditions.

Testing goals: Qualification and comparison of
- stack components (gaskets, bpp materials etc.)
- media supply, control strategies, BOP components

Test setup (standard setup)
- 3 short stacks (5 cells) in parallel
- H₂ recirculation, (no) cathode humidification
Summary

- ZBT has developed graphite based and metallic bipolar plate technologies since ~ 2002
- A large bandwidth of qualification procedures and technologies have been established for bipolar plates and materials
- Services are being offered for industry and science
Thanks for supporting:

- State of Northrhine Westfalia and European Union for supporting
  - ZBT and the initial R&D regarding bipolar plates
  - Project “NETZ”
  - Project “HiperLoco”
- Bundesministerium für Wirtschaft supporting
  - Lebensdauerprognose 03ET2006A
  - Projects of Industrial Gemeinschaftsforschung regarding bipolar plates
- Bundesministerium für Bildung und Forschung
  - Project CarboPlate
  - Project MetallBip
- Our R&D partners
- The team at ZBT (Thorsten Derieth, Lars Kühnemann, Claus Irsa, Sebastian Brokamp and many others)