Graphite for Lead-acid Battery

‘How a carbon material helps a proven technology to improve further’

Dr. Sören Köster
Superior Graphite

Thermal Purification Plants

Located in
- Hopkinsville, Kentucky
- Sundsvall, Sweden

Superior Graphite
- Operates largest thermal purification processing capacity worldwide
- Achieves purities of beyond 99.95 % carbon
- Has capacity > 80,000 Mt/ year
Advanced Electro-Thermal Purification

**Proprietary Processing Technology**
- Continuous, high throughput process
- Efficient removal of impurities from purging, homogeneity from fluidized bed mixing
- Applicable to wide range of carbonaceous materials
- Wide temperature range ranging to above 2400°C

**Unique Structure/Properties**
- Resistively heated, local plasma conditions
- Tunable thermal shock
- Changes in crystallinity and pore structure, modifications of surface, synthesis of novel materials

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Advanced Energy Materials Products for Advanced Lead-Acid Battery Applications
World Powertrain Forecast

Source: 2013 Valeo Powertrain Forecast, D. Benchentrite, EEHE meeting, Bamberg, Germany, May 2014 (taken from Boris Monahov, ALABC, 2014)

HEV architectures
HEV/EV Incremental Cost vs Benefit

<table>
<thead>
<tr>
<th>System Metric</th>
<th>Micro Hybrid</th>
<th>Mild Hybrid</th>
<th>Full Hybrid</th>
<th>Plug-in Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>12V</td>
<td>24-130V</td>
<td>200-270V</td>
<td>300-400V</td>
</tr>
<tr>
<td>Regen. Power</td>
<td>0.5-3.0 kW</td>
<td>~10 kW</td>
<td>~20 kW</td>
<td>20 kW +</td>
</tr>
<tr>
<td>e-Drive Range</td>
<td>0</td>
<td>0</td>
<td>~2 km</td>
<td>~30 km</td>
</tr>
<tr>
<td>OEM on-cost estimate</td>
<td>$200 - $900*</td>
<td>$2,100 - $4,000*</td>
<td>$4,000 - $6,600*</td>
<td>$8,000 - $13,000*</td>
</tr>
<tr>
<td>CO₂ Benefit %</td>
<td>4 - 7%</td>
<td>8 - 15%</td>
<td>15 - 30%</td>
<td>30 % +</td>
</tr>
<tr>
<td>OEM Cost/Benefit</td>
<td>$45 - 130 per 1% CO₂ less</td>
<td>$265 - 330 per 1% CO₂ less</td>
<td>$265 - 330 per 1% CO₂ less</td>
<td>$400 - 660 per 1% CO₂ less</td>
</tr>
</tbody>
</table>

Source: ALABC, 2012
“THE PROBLEM”

Start-stop operation requires multicycle high-rate partial-state-of-charge operation (HRPSoC)
(shown: discharge 4C, charge 3C for BAE hybrid transit bus program; from: Moseley, 2006)

Main cause: accumulation of lead sulfate (passive film) on negative plate surface
(shown: results from electron micro probe analyzer EMPA after 1735 HRPSoC cycles; Moseley, 2006)

Expanded (Exfoliated) Graphite

Expanded Graphite shows excellent electric conductivity

SG Expanded Graphite Products - high performance, high purity expanded graphite products

Expanded graphite
Å FormulaBT® ABG1010
Å FormulaBT® ABG1025
Å FormulaBT® ABG1045

Super Expanded Graphite
Å FormulaBT® ABG2010
Å FormulaBT® ABG2025
Power Assist Cycle Life
End of discharge voltage and electrical resistance


Power Assist Cycle Life
- Capacity and weight evolution -

Charge Acceptance vs. SoC (8V, 5s, 25°C)

Charge acceptance improvements with additional graphite and conductive carbon (CB)


From ‘Lead-acid’ to ‘Lead-carbon Battery’

Lead-acid Battery (conventional)  ‘Lead-Carbon Battery’ for HRPSoC applications (carbon enhanced)

Lead with graphite + carbon black

FormulaBT® Benefits

- Significant Cycle Life Improvement
- Improving dynamic charge acceptance
- Chemical Stability
- Minimizing water consumption

FormulaBT® Characteristics

- Excellent Electric Conductivity
- High Purity
- Consistent particle size distribution
- Easy to process

6/17/2016
Thank You!