

**Graphite for
Lead-acid Battery**


**AKK, Meitingen
26.04.2016**

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

**Dr. Sören Köster
Superior Graphite**

Science · Synergy · Solutions · Service · Since 1917

Approved for publication 2016-06-16



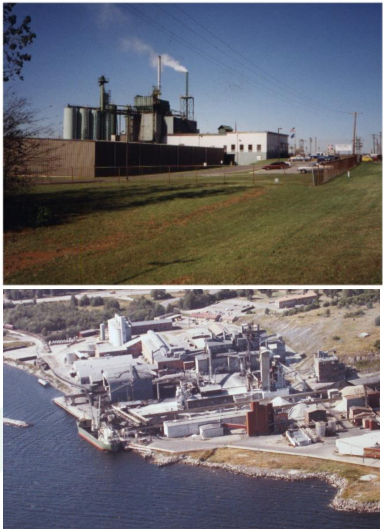
Thermal Purification Plants


Located in

- Hopkinsville, Kentucky
- Sundsvall, Sweden

Superior Graphite

- Operates largest thermal purification processing capacity worldwide
- Achieves purities of beyond 99.95 % carbon
- Has capacity > 80000 Mt/ year



SUPERIOR  GRAPHITE

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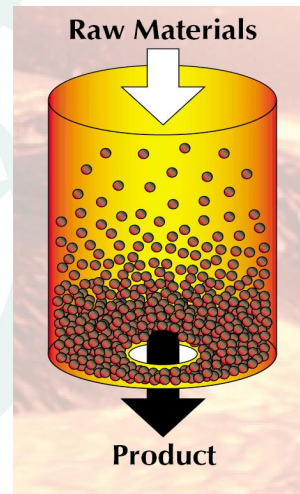
Advanced Electro-Thermal Purification

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 2400C

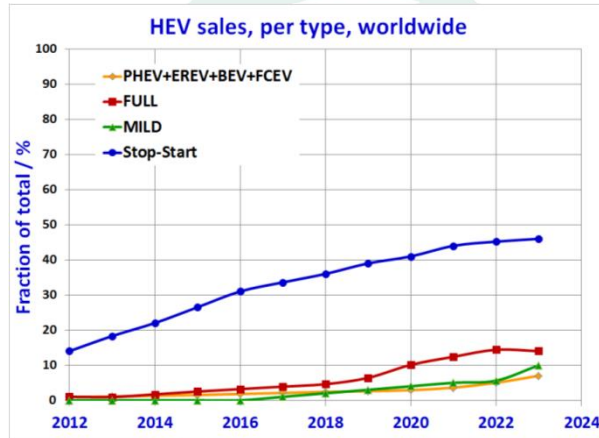
Unique Structure/Properties

- ❑ Resistively heated, local plasma conditions
- ❑ Tunable thermal shock
- ❑ Changes in crystallinity and pore structure, modifications of surface, synthesis of novel materials



The advertisement features a large lead-acid battery in the foreground, with three cars (orange, silver, and gold) in the background. The text 'Advanced Energy Materials Products for Advanced Lead-Acid Battery Applications' is overlaid on the image.

World Powertrain Forecast



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

HEV architectures

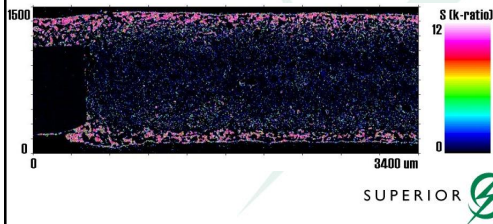
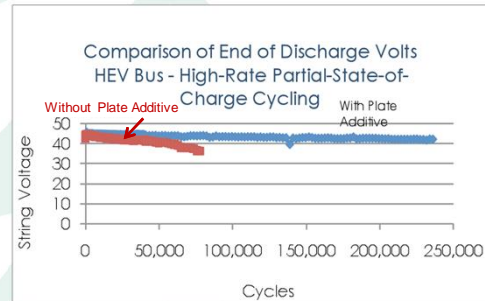
HEV/EV Incremental Cost vs Benefit

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

Source: ALABC, 2012

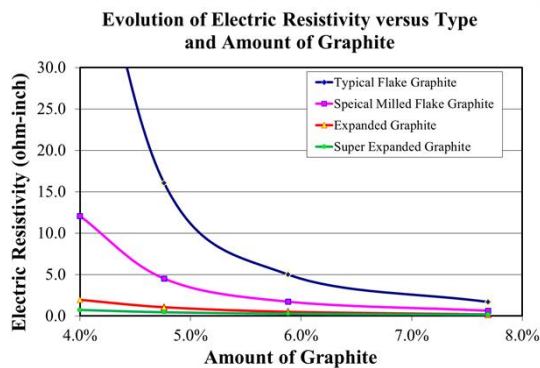
“THE PROBLEM”

Start-stop operation requires multicycle \pm High-rate partial-state-of-charge operation (HRPSoC)q (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

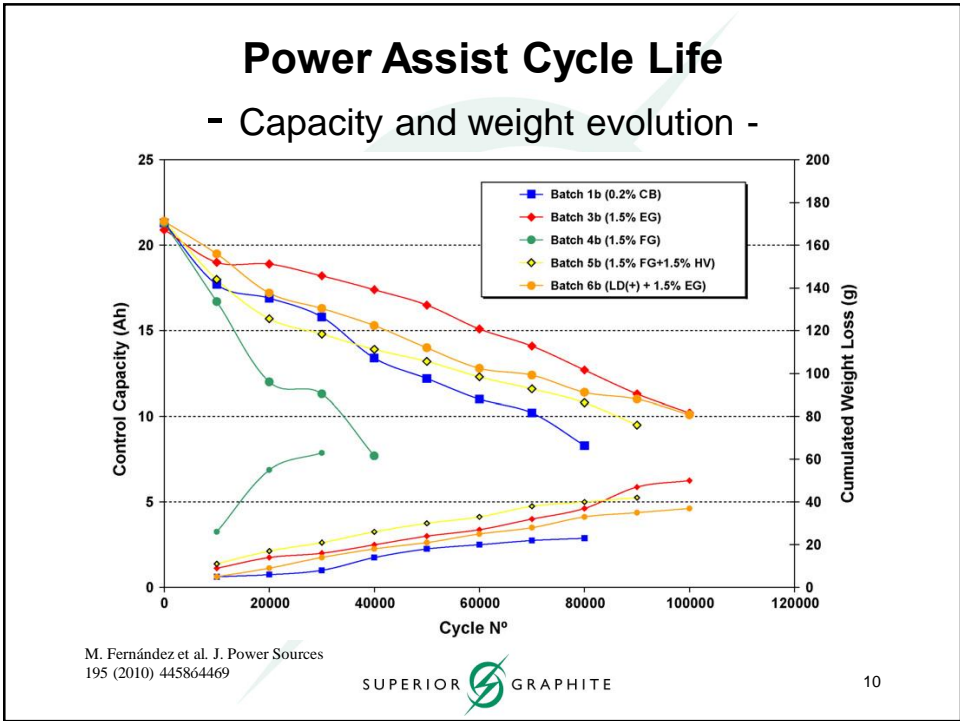
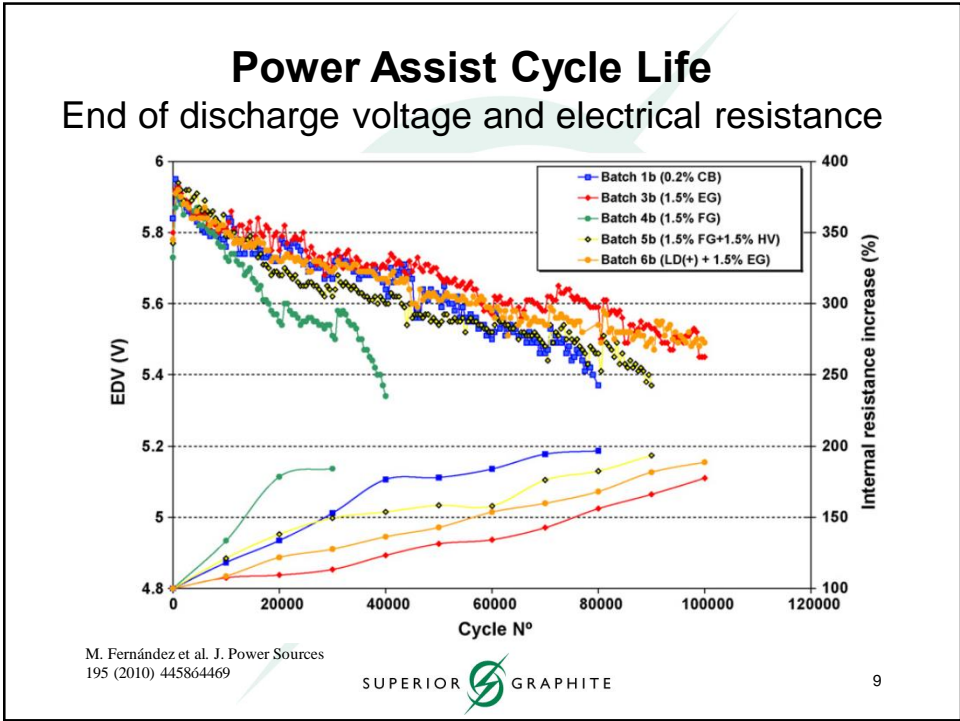
SG Expanded Graphite Products - high performance, high purity expanded graphite products

Expanded graphite

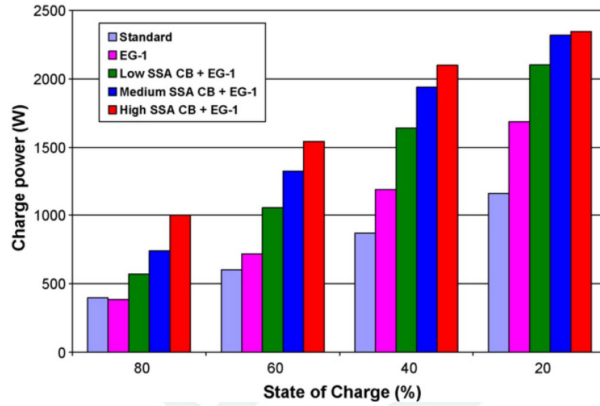
- ~ FormulaBT® ABG1010
- ~ FormulaBT® ABG1025
- ~ FormulaBT® ABG1045

Super Expanded Graphite

- ~ FormulaBT® ABG2010
- ~ FormulaBT® ABG2025



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



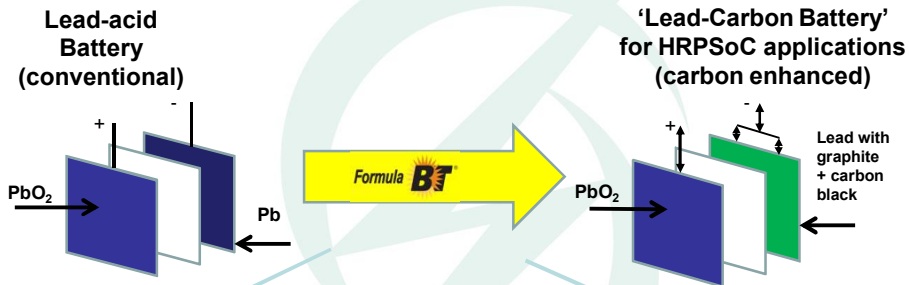
Charge acceptance improvements with additional graphite and conductive carbon (CB)

M. Fernández et al. J. Power Sources
195 (2010) 445864469



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From 'Lead-acid' to 'Lead-carbon Battery'



FormulaBT® Characteristics

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

FormulaBT® Benefits

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



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