Graphite Powder Processing

A Key Element for High Performance Lithium-Ion Batteries

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Graphite Powder Processing for High Performance Lithium-Ion Batteries

Outline

1. Graphite Anode Materials: Position of SGL & Market Perspectives

2. Anode Materials for Lithium Batteries: Basic Requirements

3. Powder Design for High Performance Graphite Anodes, Influences of:
   - BET Surface Area
   - Particle Size
   - Particle Shape

4. Summary
LIB Anode Materials Overview
Material Share – Status 2012

- Artificial and natural graphite biggest share (total >90%)
- Next generation high capacity materials (silicon and tin based) enter the market
- Fast growing market for graphite anodes in 3C and electromobility

Total Volume in 2012: ~32000t

Source: SGL, Avicenne, Battery Market Development 2012-2025
Graphite Anode Materials
Joint Forces for Best Solutions

More than 10 Years Cooperation

World Largest Synthetic Graphite Anode Production
& Leading Edge Technology Know How
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Lithium Ion Battery: Basic Working Principle

**Charge**
- Al – current collector
- Graphite
- Anode
- Li⁺ ions flow
- Charge
- Electrolyte
- Graphite-Anode
- Cu – current collector

**Discharge**
- Al – current collector
- Graphite
- Anode
- Li⁺ ions flow
- Discharge
Li-Ion Battery - Graphite as Anode Material
Solid Electrolyte Interface - SEI

**First Cycle: Carbon/graphite + Electrolyte \(\rightarrow\) Solid Electrolyte Interphase**

TEM of Solid Electrolyte Interphase
Schematic drawing of the composition of the SEI

The SEI protects the graphite from solvent co-intercalation \(\rightarrow\) Graphite would not work without SEI


SEI formation consumes Lithium!
Key Parameters of Electrode Materials: Capacity and Efficiency

Capacity:
How much lithium is intercalated in graphite? Depending on:
• How many defects are in the graphite?
• Degree of graphitization

Capacity loss (1st Cycle Efficiency):
How much lithium contributes to SEI-formation? Depending on:
• specific surface (e.g. BET)
• particle size and shape
Graphite Anode Materials: Basic Requirements

**Battery Level**

- **Gravimetric Energy Density**: Wh/kg
  - Lightweight Battery

- **Volumetric Energy Density**: Wh/l
  - Small Battery

- **Power Density**: W/kg or W/l
  - Acceleration

**Material Level**

- Specific Capacity (mAh/g)
- Voltage Level
- 1st Cycle Efficiency
- Electrode Loading (mAh/cm²)
- % Inactive Material
- Film Swelling
- Material & Film Density (g/cm³)
- Rate Capability (Temperature-Dependence)
- Particle Size / BET
- Purity
- Cycle Stability

Directly Influenced by Graphite Particle Properties

SGL Proprietary Information
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A low BET surface is crucial for:

• 1st cycle Efficiency (low Li losses)
• Energy density
• Safety
• Cycle life
• Binder demand

...
Lower the BET Surface Area: Influence of the milling device

Milling type & milling & spheroidisation equipment configuration influence significantly the particle shape / BET and therefore also the battery performance.

- Additionally milling & rounding yield is the key element for commercial success.
Lower the BET Surface Area: Influence of rounding and the coating

Graphite powder → Engineered anode material

Rounding → Coating

Lower BET Surface
Quicker Charge/Discharge: Influence of the Particle Size

Graphite with medium particle size

Graphite with very small particle size

Particle size distribution and shape
- \(d_{50}\) between 10 and 30 \(\mu m\)
- \(d_{90}< 70 \mu m\)
- Low amount of fine particle fraction

Smaller anode particle size distribution is beneficial for quicker LIB charging. However... Formation of higher surface area
Quicker Charge/Discharge: Influence of the Particle Shape

How fast is lithium intercalated in graphite? Depending on particle orientation in the electrode.
High Film Density for Improved Energy Density: Influence of Particle Shape & Particle Size Distribution

“Potato shape” particle generates higher film packing density at lower compaction pressures.

Bimodal / “broader” particle size distribution can generate higher film packing densities. However, BET need to be kept low, otherwise efficiency loss.
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Graphite Powder Processing for High Performance Lithium-Ion Batteries Key Elements - Summary

- Energy Density
- 1st Cycle Efficiency
- Quick Charge Cycle Life
- Particle Size Distribution
- Particle Size
- Particle Shape (BET)
- Yield Costs
- Particle Surface (coating)

SGL Proprietary Information
Thank you for your attention!
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