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Graphite Powder Processing

A Key Element for High Performance Lithium-Ion Batteries

Bernt Ketterer, Ulrich Bosch, Oswin Öttinger, DKG-AKK Herbsttagung, 7th November 2014

Graphite Powder Processing for High Performance Lithium-Ion Batteries

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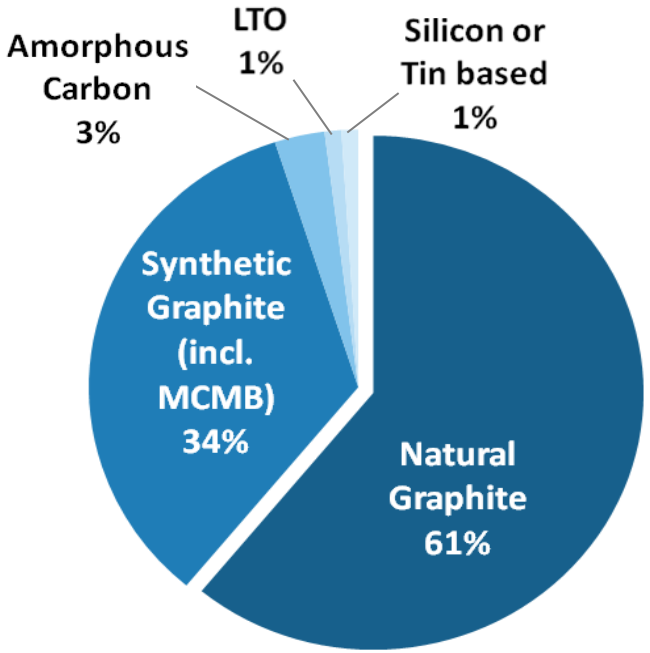
Outline

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



Total Volume in 2012: ~32000t

- **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**

Source: SGL, Avicenne, Battery Market Development 2012-2025

Graphite Anode Materials
Joint Forces for Best Solutions

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Hitachi Chemical
Working On Wonders

More than 10 Years Cooperation

World Largest Synthetic Graphite Anode Production
& Leading Edge Technology Know How

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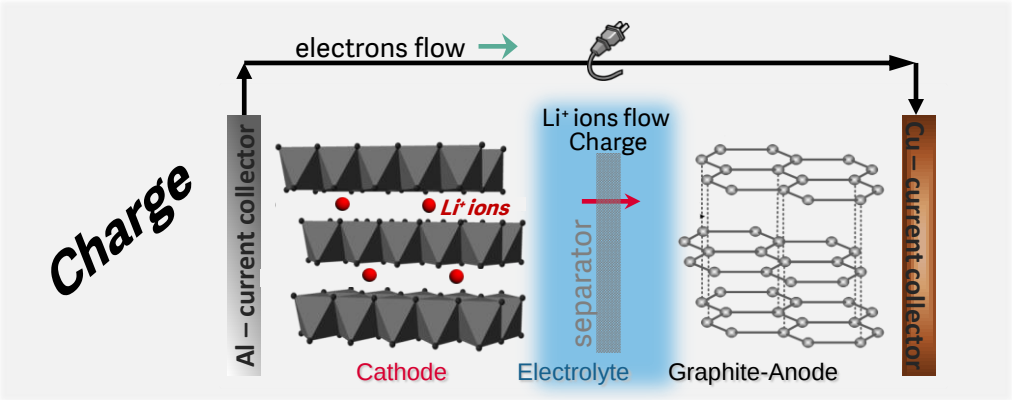
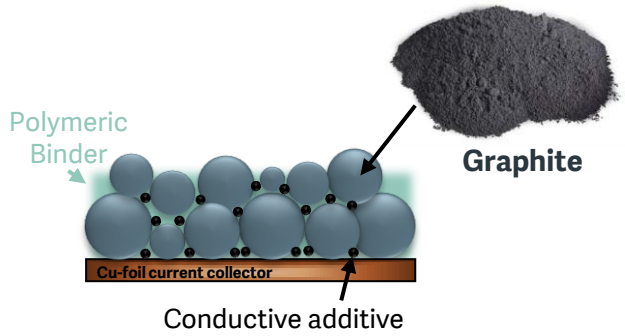
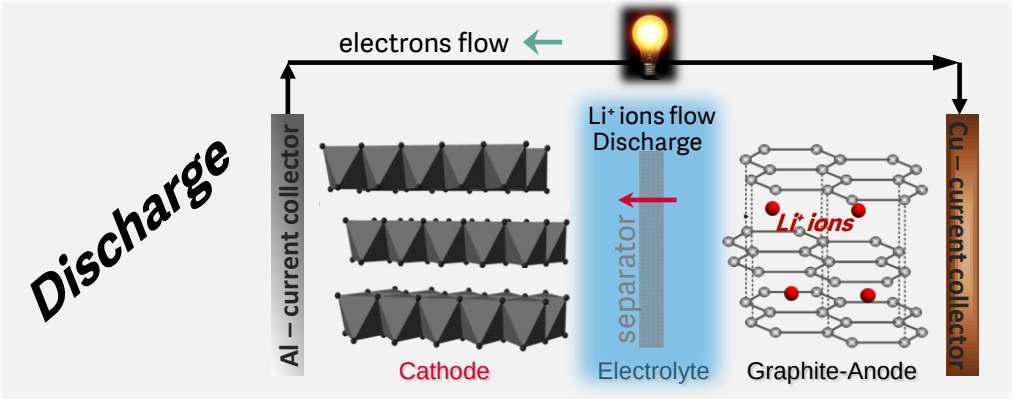
Lithium Ion Battery: Basic Working Principle







Li-Ion Battery - Graphite as Anode Material
Solid Electrolyte Interface - SEI

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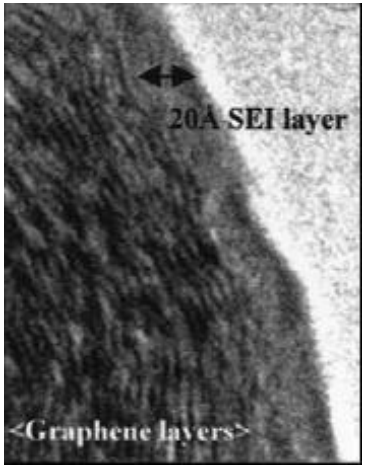
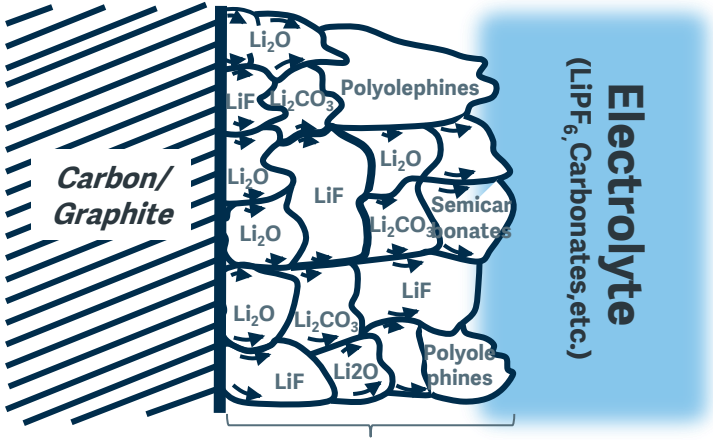
First Cycle: Carbon/graphite + Electrolyte → Solid Electrolyte Interphase

TEM of Solid Electrolyte Interphase



Schematic drawing of the composition of the SEI



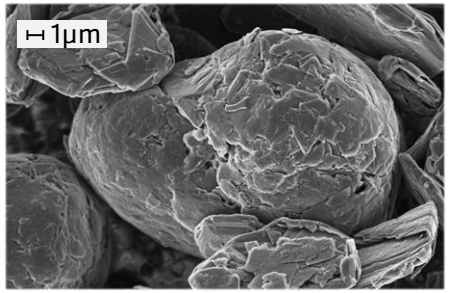
Solid Electrolyte Interphase (SEI)

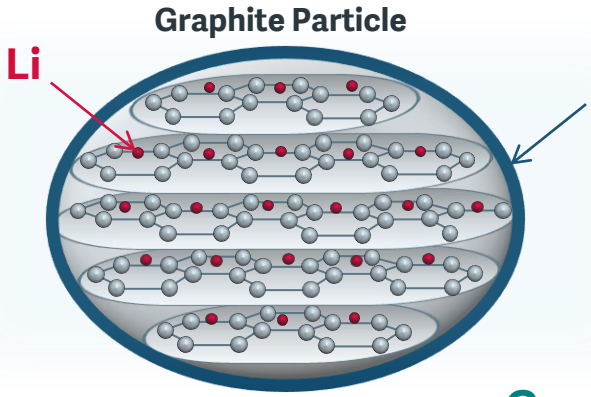
SEI formation consumes Lithium!

The SEI protects the graphite from solvent co-intercalation → Graphite would not work without SEI

Source: TEM: F. Orsini, L. Dupont, B. Beaudoin, S. Grugeon, J.-M. Tarascon, Int. J. Inorg. Mater. 2 (2000), 701 AND E. Peled, D. Golodnitsky and G. Ardel, J. Electrochem. Soc. 144 (1997), L208.

Key Parameters of Electrode Materials: Capacity and Efficiency





Surface –Electrolyte Interphase Layer (*‚SEI'*):

Passivating layer formed on the graphite particle surface

Capacity:

How much lithium is intercalated in graphite? Depending on:

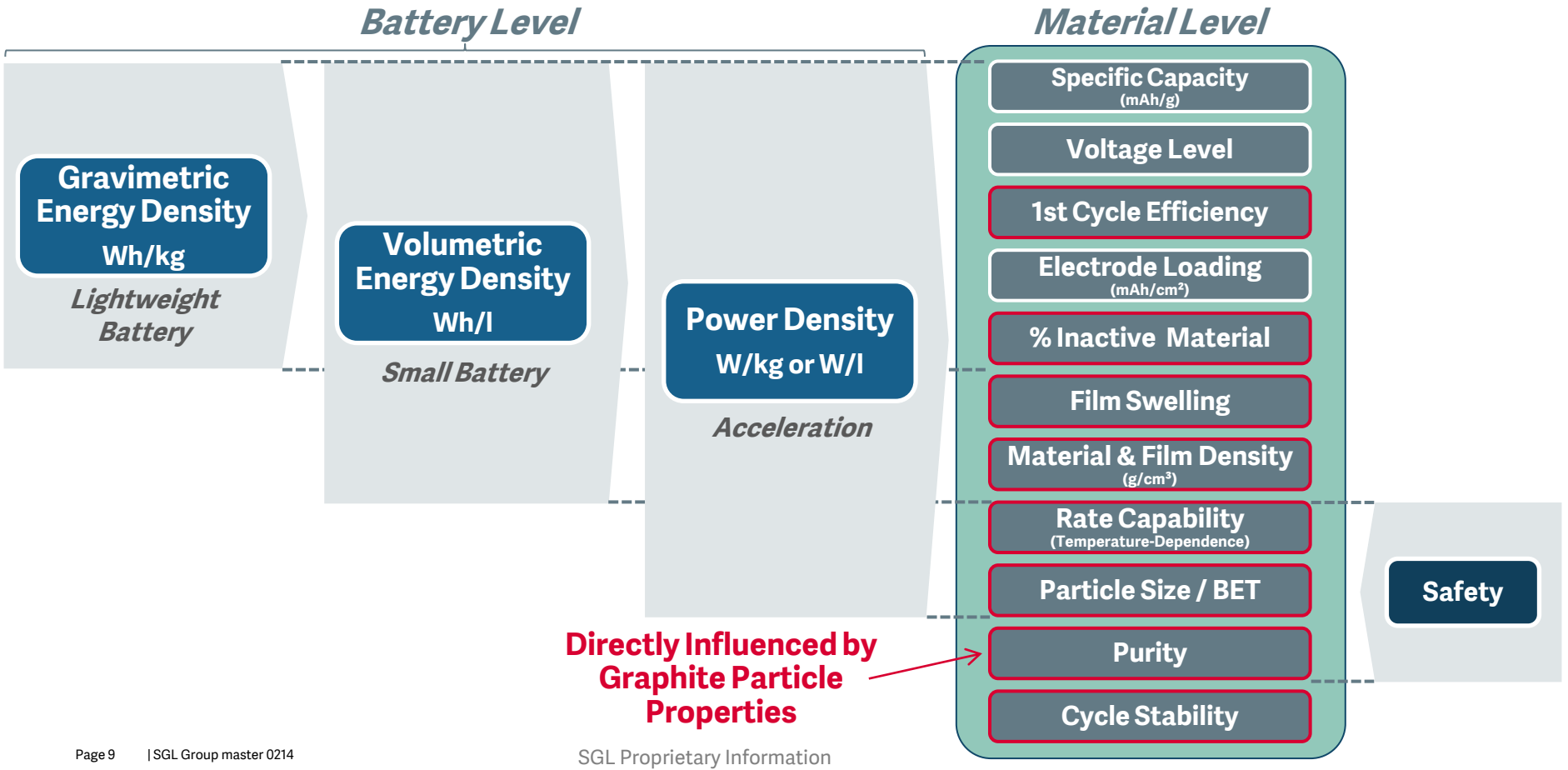
- How many defects are in the graphite?
- Degree of graphitization

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



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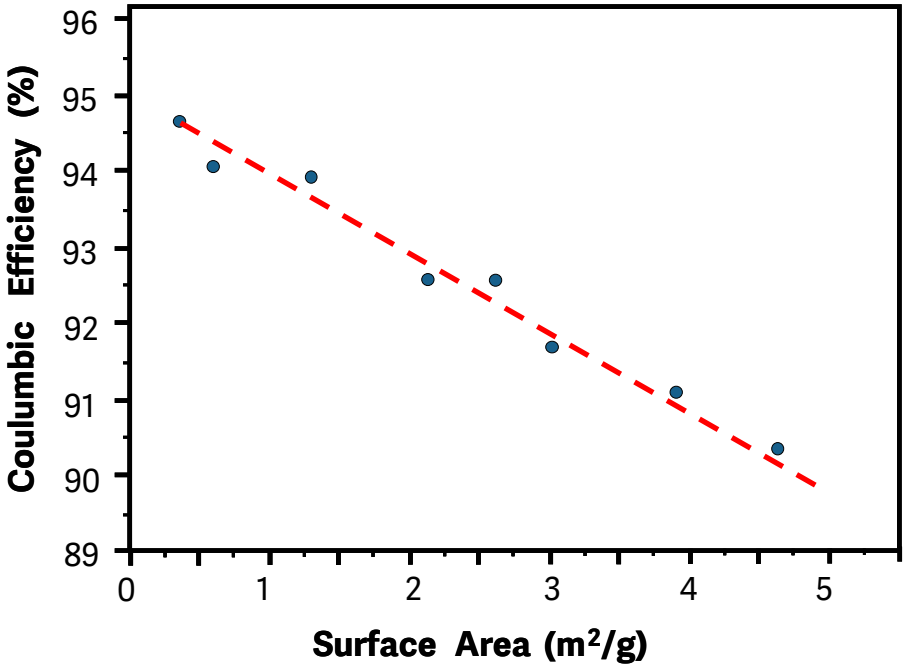
Lower BET Surface Area: Optimized Battery 1st Cycle Efficiency

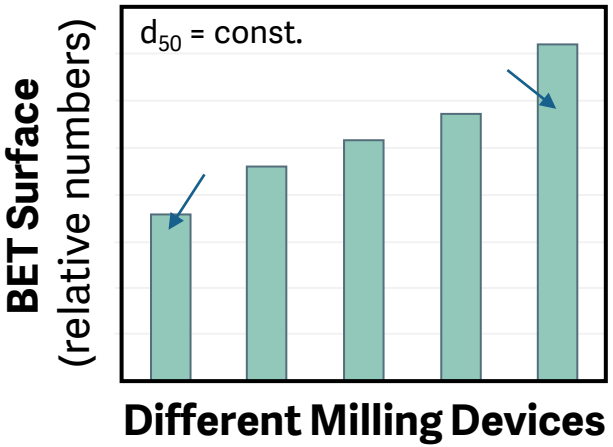


A low BET surface is crucial for:

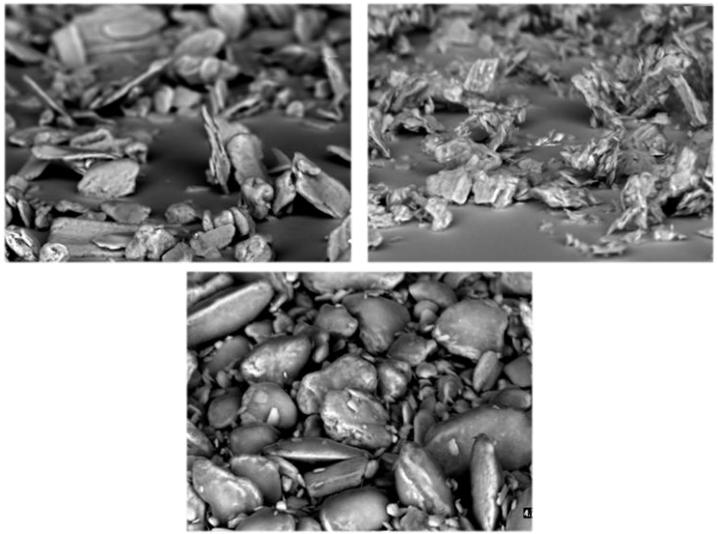
- 1st cycle Efficiency (low Li losses)
- Energy density
- Safety
- Cycle life
- Binder demand

...

Lower the BET Surface Area: Influence of the milling device

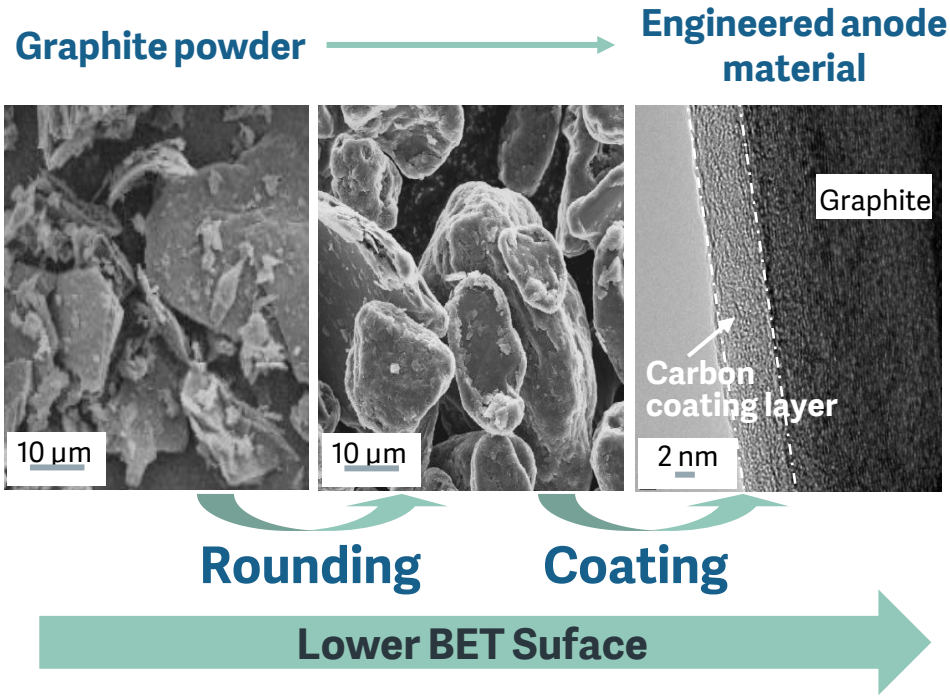


Examples from Different Milling Devices

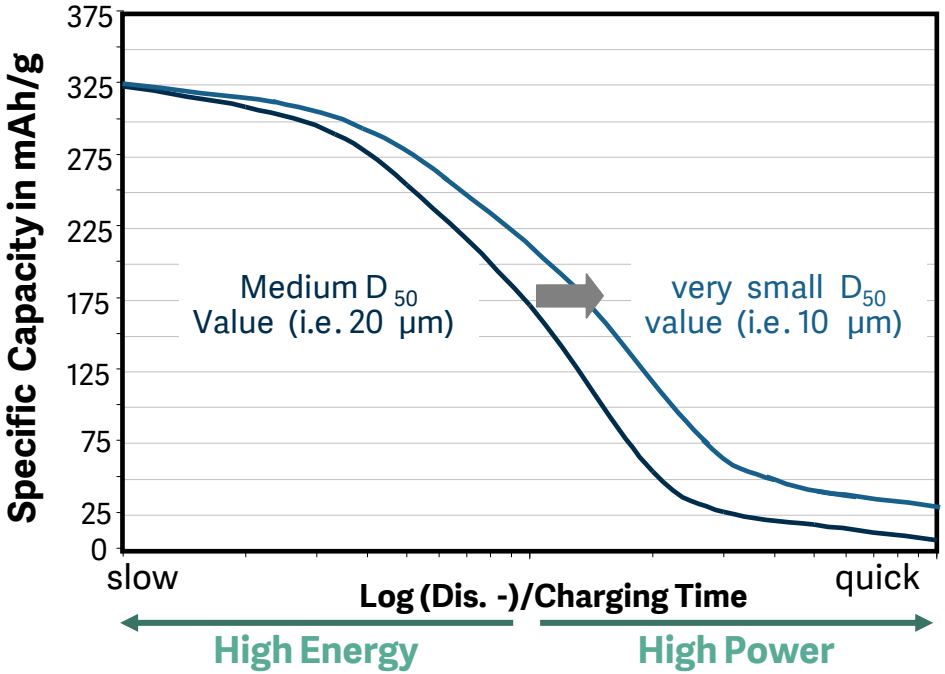


- **Milling type & milling & spheroidisation equipment configuration influence significantly the particle shape / BET and therefore also the battery performance**
- **Additionally milling & rounding yield is the key element for commercial success**

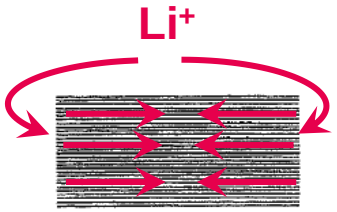
Lower the BET Surface Area: Influence of rounding and the coating



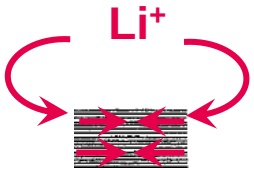
Quicker Charge/Discharge: Influence of the Particle Size



Graphite with medium particle size



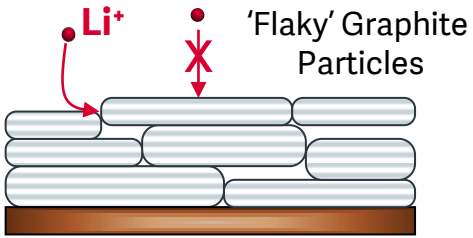
Graphite with very small particle size



Smaller anode particle size distribution is beneficial for quicker LIB charging. However… Formation of higher surface area

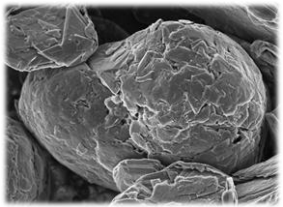
Particle size distribution and shape
d_{50} between 10 and 30 µm d_{90}< 70 µm Low amount of fine particle fraction

Quicker Charge/Discharge: Influence of the Particle Shape



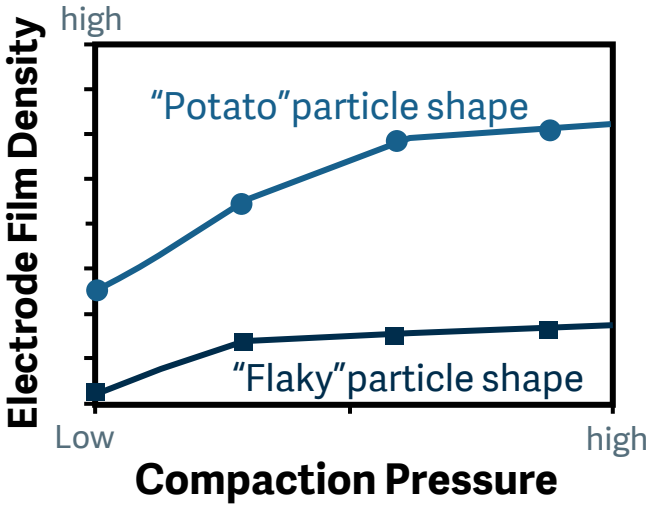
Flaky

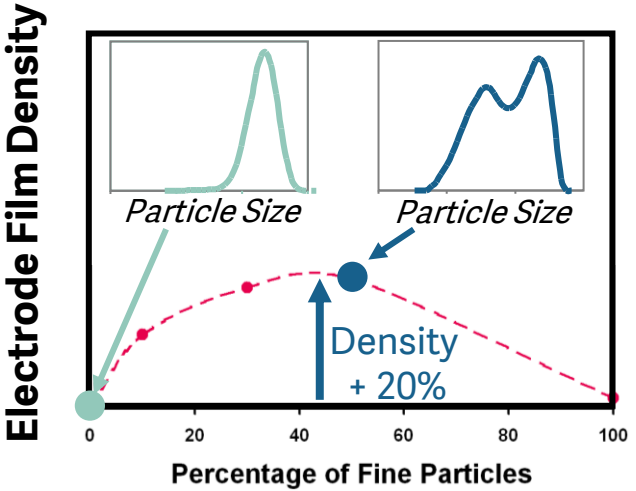
Potato



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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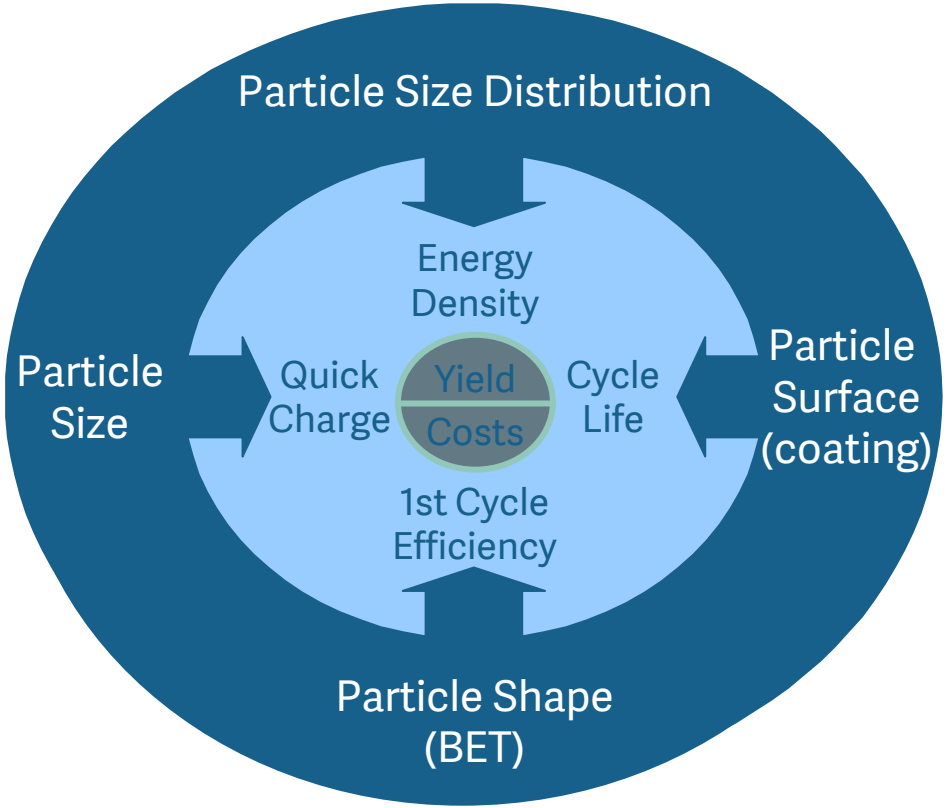
Graphite Powder Processing for High Performance Lithium-Ion Batteries Key Elements - Summary



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