Effects of (in)homogeneous pressure distribution on the performance of battery materials using operando dilatometry

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Impact of increasing energy density on dilation in lithium-ion cells

Possible ways to increase energy density in lithium-ion batteries

- Optimized cell design
- New materials (e.g. silicon or lithium metal)

How does optimizing the energy density of lithium-ion cells affect their performance and dilation behavior?
Graphite (3.8 mAh/cm², 87.5 μm) vs. NCM111 (3.5 mAh/cm², 90 μm)

High initial irreversible swelling of 8.5%

Reversible swelling of 9.2% (8.1 μm)

The dilatation of NCM 111 with Δd ~ 0% - 1% is neglected
Effects of (in)homogeneous pressure distribution on the performance of battery materials using *operando* dilatometry.

**Impact of (in)homogeneous pressure distribution**

- **Homogeneous pressure distribution**: negligible mechanical stress-induced capacity reduction up to 191 N;
- **Inhomogeneous pressure distribution**: lower capacity being related to contact losses, partly delamination and localized increased tortuosity and ionic transport resistance inside the separator.
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Dilation behavior of different battery materials

State of the art materials: NCM, Graphite and LTO

- Electrodes: Graphite (~2.2 mAh/cm², ~47 μm), LTO (~2.1 mAh/cm², ~150 μm), NCM111 (~2.1 mAh/cm², ~80 μm)
- Electrolyte: LP 57 (1 M LiPF₆ in EC/EMC)
- Separator: Celgard 2500 (PP, 25 μm)
- Applied pressure: 0.05 MPa

In SoA’s lithium-ion batteries, dilation is mostly related to graphite.
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Dilation behavior of different battery materials

Next generation materials: Silicon vs. LTO

- Pressure-dependent dilation of silicon
- High porosity of the electrodes and fiber-based separator prevent significant dilation.

- Electrodes: Silicon (~2.5 mAh/cm², ~20 µm, porosity ~70%, used capacity 33%), LTO (2.1 mAh/cm², ~150 µm)
- Electrolyte: LP 57 (1 M LiPF₆ in EC/EMC) + 5 wt.% FEC
- Separator: Whatman GF/C (glass fiber, 260 µm)
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Dilation behavior of different battery materials

Next generation materials: Lithium vs. LTO

- Significant expansion of lithium metal during cycling due to lithium stripping/plating.
- Parasitic side reactions of lithium with the carbonate-based electrolyte increase the thickness change.

Electrodes: Lithium metal (~380 µm), LTO (~2.1 mAh/cm², ~150 µm)
Electrolyte: LP 57 (1 M LiPF₆ in EC/EMC)
Separator: Celgard 2500 (PP, 25 µm)
Applied pressure: 0.05 MPa
Thank you

Feel free to contact me!

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