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Battery system development based on Al-ion cell chemistry for grid stabilization applications

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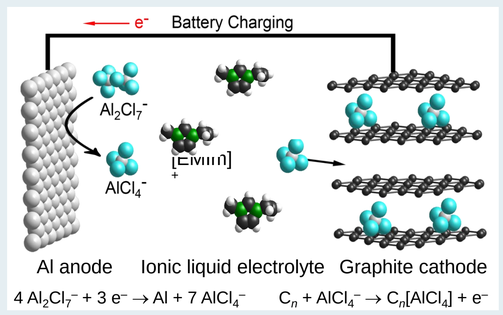
Aluminum Graphite Dual-Ion Battery

Advantages[1-3]

- Low-cost & abundant electrode materials
- High power density (9 kW/kg$_{Graphite}$)
- Long cycle life (> 20.000)



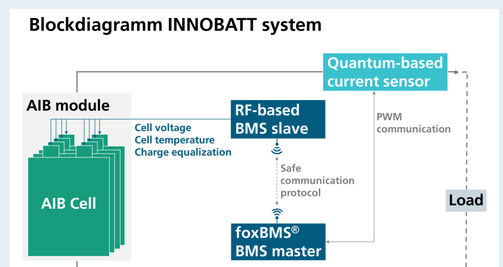
Use-case: dynamical grid stabilization

- Balance frequency fluctuations with battery micro cycles
- Requirement: High symmetrical power, medium energy, high cycling stability

Battery system design

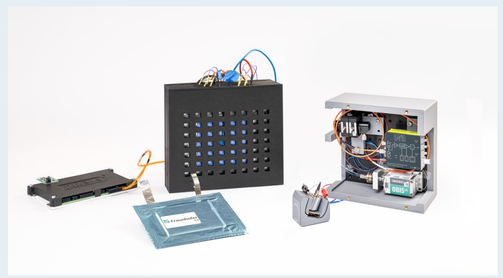
Components

- 2p4s module configuration:
- 155 mAh; 7.6 V
- BMS slave & BMS master
- Quantum based current sensor



Results

- High homogeneity of the cells
- Low gas and fold formation
- Good thermal stability



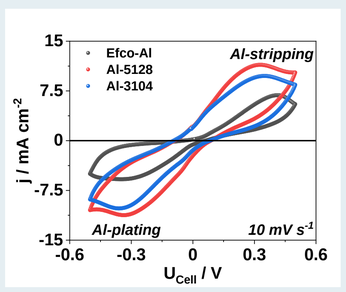
AGDIB electrochemical evaluation

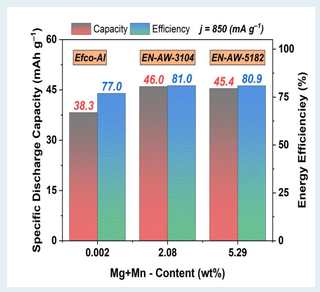
Anode kinetics

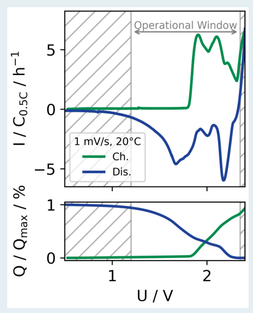
- High Mg & Mn content in Al alloys improve anode kinetics
- ➢ Improved rate capability & energy efficiency

Pouch cell evaluation

- Focus on application relevant testing
- Defining operational voltage window
- First-time empirical model parameter f(SOC,T)

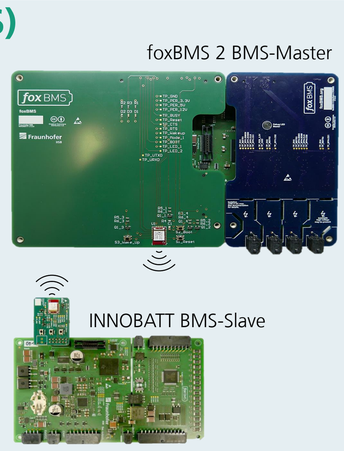






Wireless Battery Management System (BMS)

- Safe, radio frequency based wireless communication between central BMS-Master and local BMS-Slaves
- Monitoring of:
  - Cell voltage
  - Cell Temperature
  - Module Current
- Control of passive charge equalization

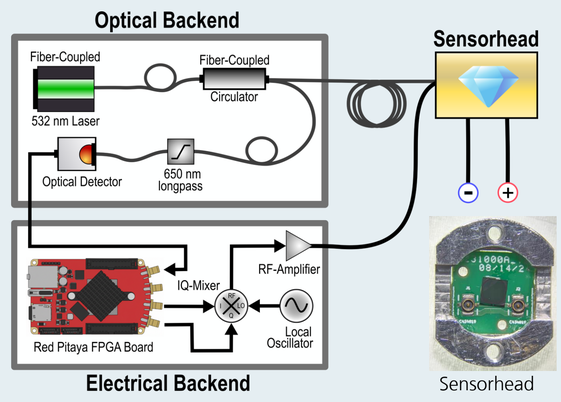


Quantum based current sensor

- Sensor based on NV-centers in diamond[4]
- Current measurement based on high-precision magnetic field measurements
- Focus on miniaturization & high resolution to detect dynamical currents
- signal processing & measurements are FPGA-controlled for high-speed sensing

Results

- Sensitivities
  - in lab: 900 pT/$\sqrt{\text{Hz}}$ & 16 μA/$\sqrt{\text{Hz}}$
  - portable setup: 50 nT/$\sqrt{\text{Hz}}$ & 320 μA/$\sqrt{\text{Hz}}$
- Dynamic range of 5 A explored, ~100 A feasible



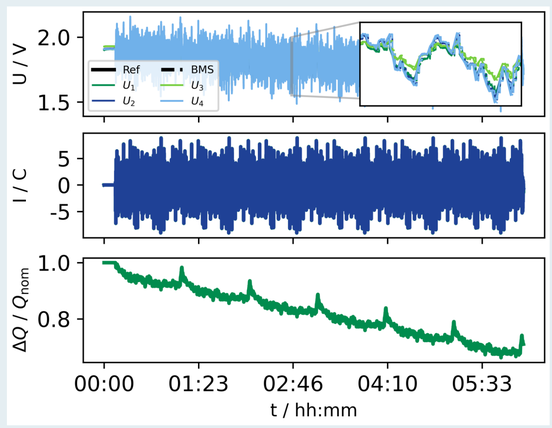
Suitable Application: Instantaneous Reserve (grid service)

Load profile

- Derived from real frequency data[5]
- 95-Percentile scaled to 5C (I_{max} = 9C)

Characteristic

- Many, high-power but low-energy charge-discharge cycles
- No rest-periods, small net-charge turnover

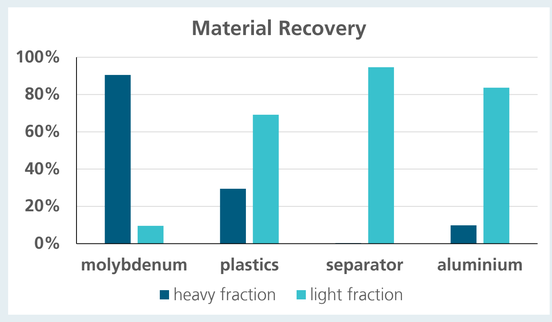


Results

- Successful validation of components during dynamical load
- Good agreement between BMS and potentiostat measurements
- Low thermal losses confirm AIB's high power capabilities

Recycling examination of module & cells

- Dismantling-friendly guidelines defined within design phase of module
- Water-based shredding process
- Sucessful physical separation of cell components



Summary

- Worldwide first Al graphite dual-ion cell chemistry battery system
- Implementation of wireless BMS & quantum sensor
- AGDIB cells prove stable performance even with dynamic high current loads at 10C over long time periods in cell-level & module tests

1 G.A. Elia et al., *J. Power Sources* **2021**, *481*, 22887.
2 F. Jach et al., *ChemElectroChem* **2021**, *8*, 1988.
3 U. Wunderwald et al., *Nachr. Chem.* **2023**, *71*, 38.
4 L. Rondin et al., *Rep. Prog. Phys.* **2014**, *77*, 056503.
5 J. Klink et al., *Energy Reports* **2025**, *13*, 3096.

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