MULTIFUNCTIONAL PERFORMANCE OF TAILOR-MADE CARBON FIBRES

An improved structural battery negative electrode

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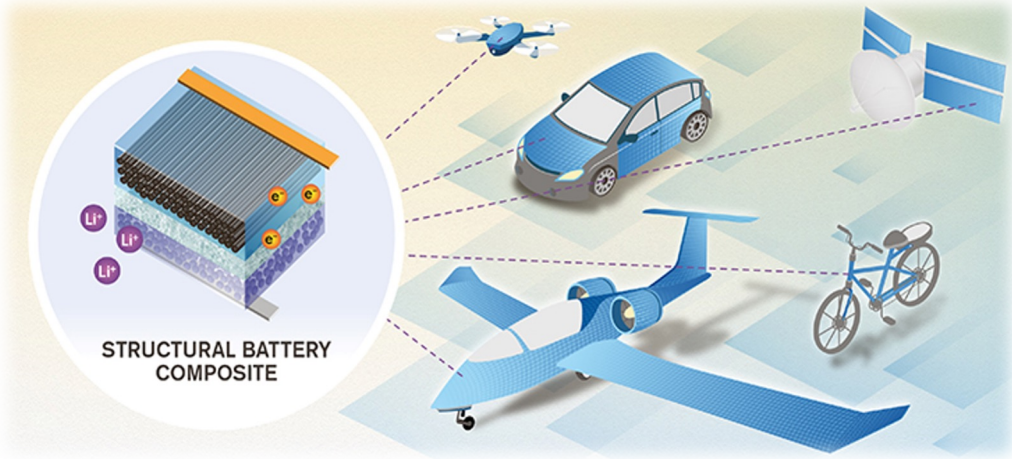
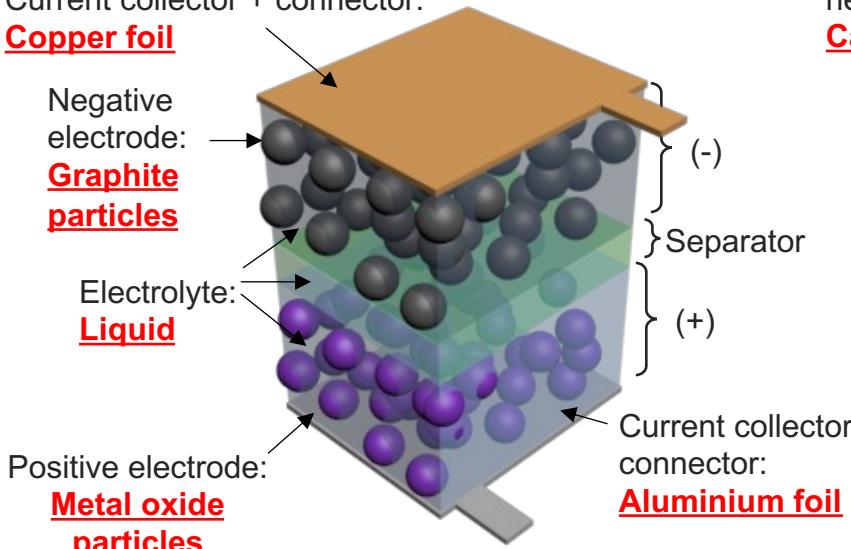
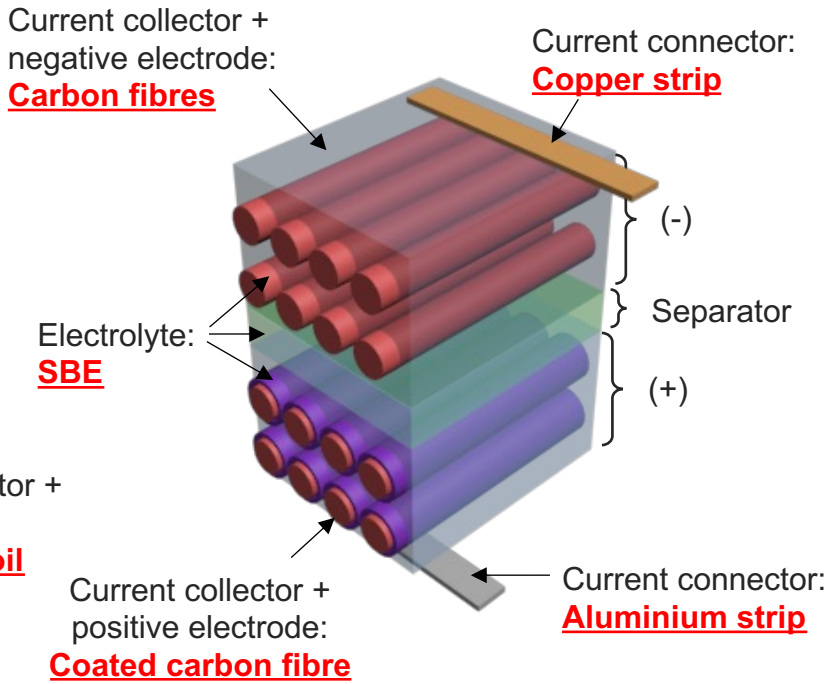
Structural batteries

- **Multifunctionality:**
  - Energy storage
  - Load carrying capabilities
- **Layered composite structure:**
  - Carbon fibre negative electrode
  - Glass fibre separator
  - Lithium-iron-phosphate (LFP) on aluminium positive electrode
  - Bi-continuous structural battery electrolyte (SBE)



Conventional and structural battery





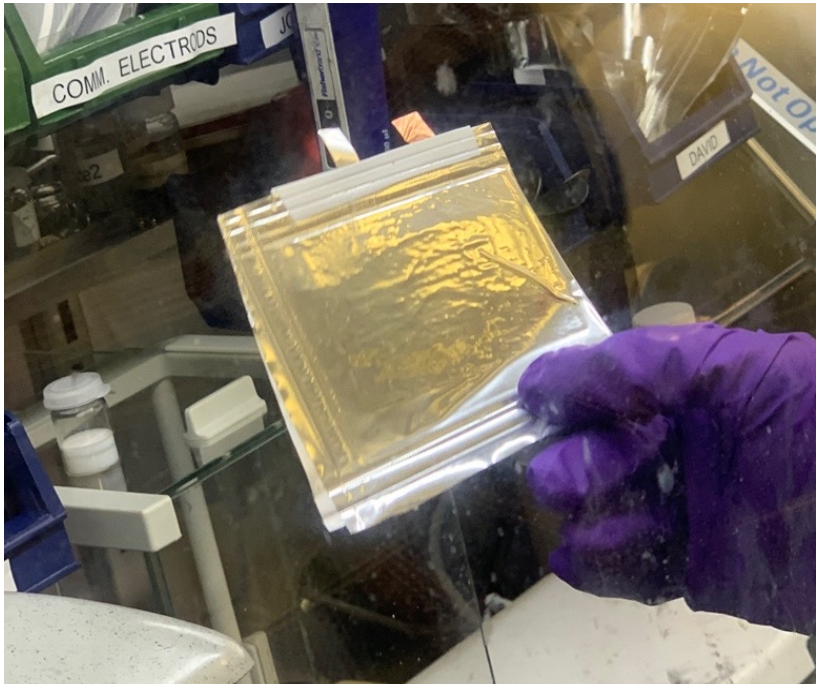
Conventional Li-ion battery

Structural battery laminate

Carlstedt et al., *"Electro-chemo-mechanically coupled computational modelling of structural batteries", Multifunctional Materials,* 2020

Pouch-bag cells

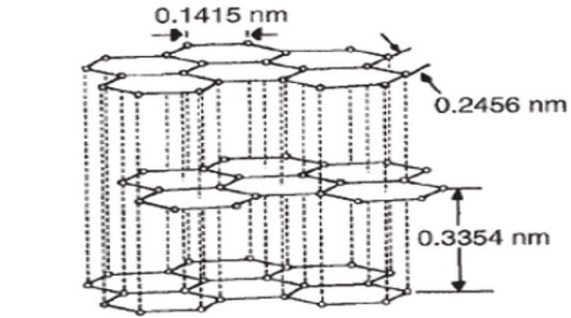
Infused and cured cell

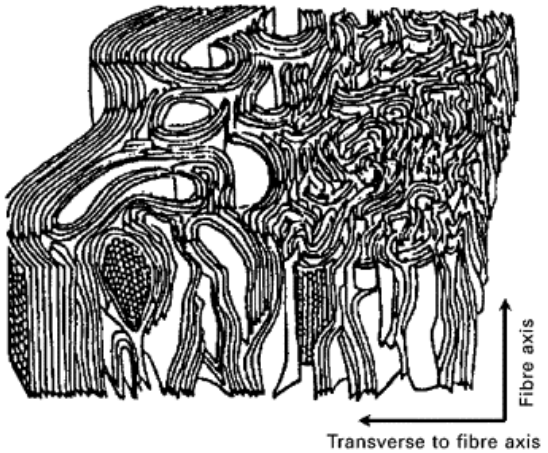


Sealed cell

Carbon fibres as negative electrodes

- Conventional batteries use graphite
- Carbon fibres are also made of carbon but with a different microstructure
- The microstructure is called turbostratic graphite
- Precursor and manufacturing process affect the microstructure
- Lithium ions are stored differently in different microstructures

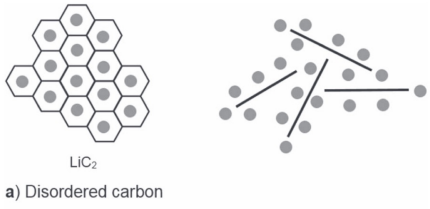


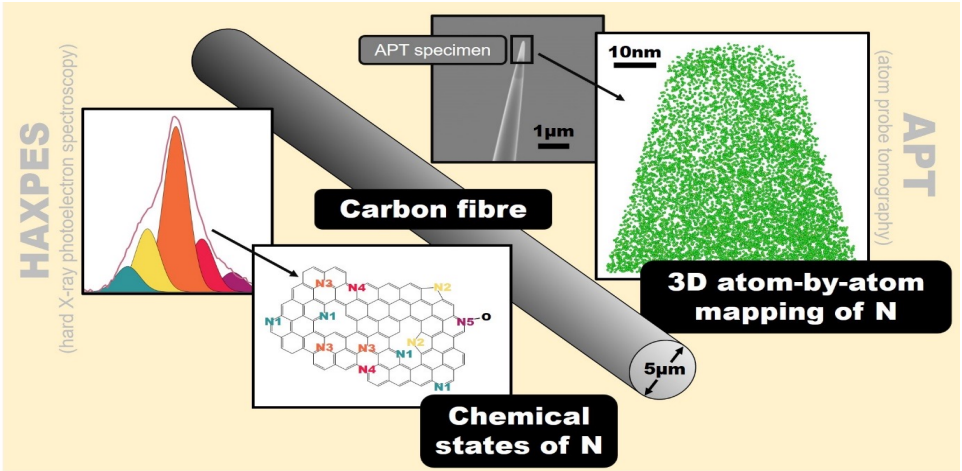


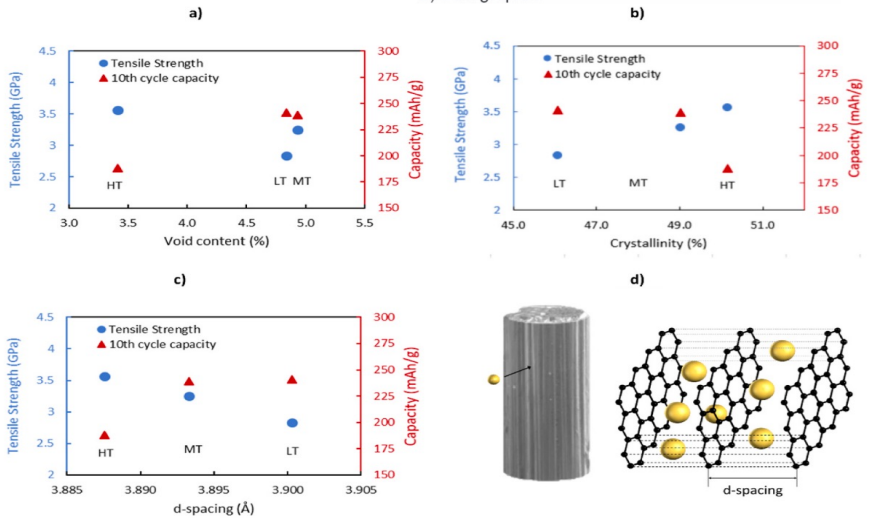
S. C. Bennett, “Strength-structure relationships in carbon fibers”, PhD thesis, University of Leeds, 1976.

Previous work

- Lithium insertion mechanism in commercial carbon fibres has been studied
- Presence of different heteroatoms has been determined
- Effect of microstructure has been identified





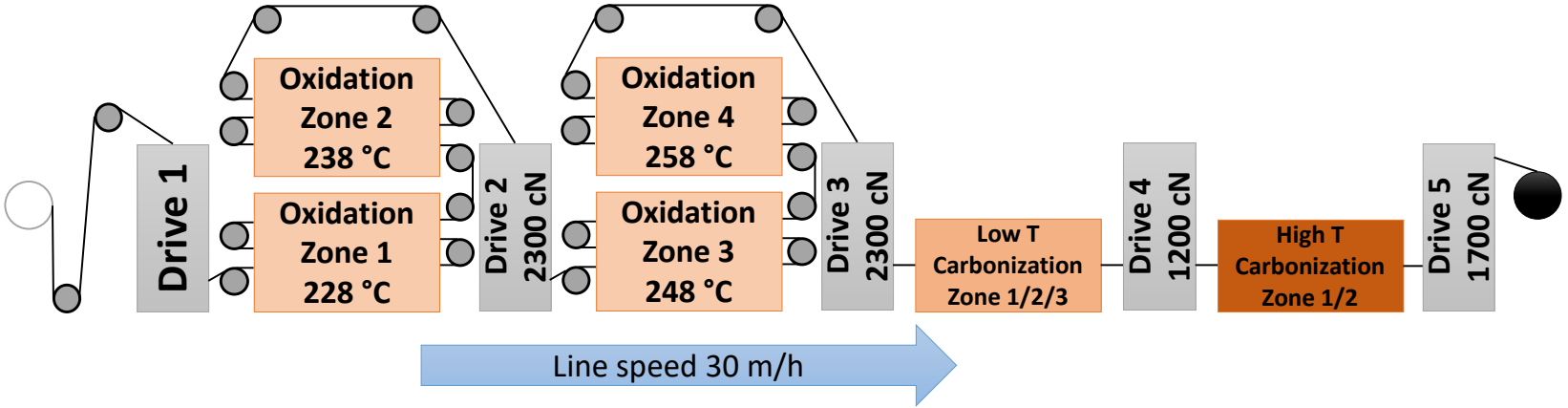


Fredi et al., “Graphitic microstructure and performance of carbon fibre Li-ion structural battery electrodes “, *Multifunctional Materials,* 2018
Johansen M et al., “Mapping nitrogen heteroatoms in carbon fibres using atom probe tomography and photoelectron spectroscopy”, *Carbon*, 2021
Xu et al., “Effect of tension during stabilization on carbon fiber multifunctionality for structural battery composites “, Carbon, 2023

Carbon fibres manufacturing

- Historically, the focus has been on mechanical properties
- This work is a collaboration between Chalmers University of Technology and Deakin University:
  - Carbon fibres were manufactured at Carbon Nexus on a state-of-the-art research line from a 24k tow of polyacrylonitrile (PAN) precursor
  - Different process parameters were used to produce 3 different types of fibres
  - The focus was on making carbon fibres with an optimal microstructure to be used in structural batteries

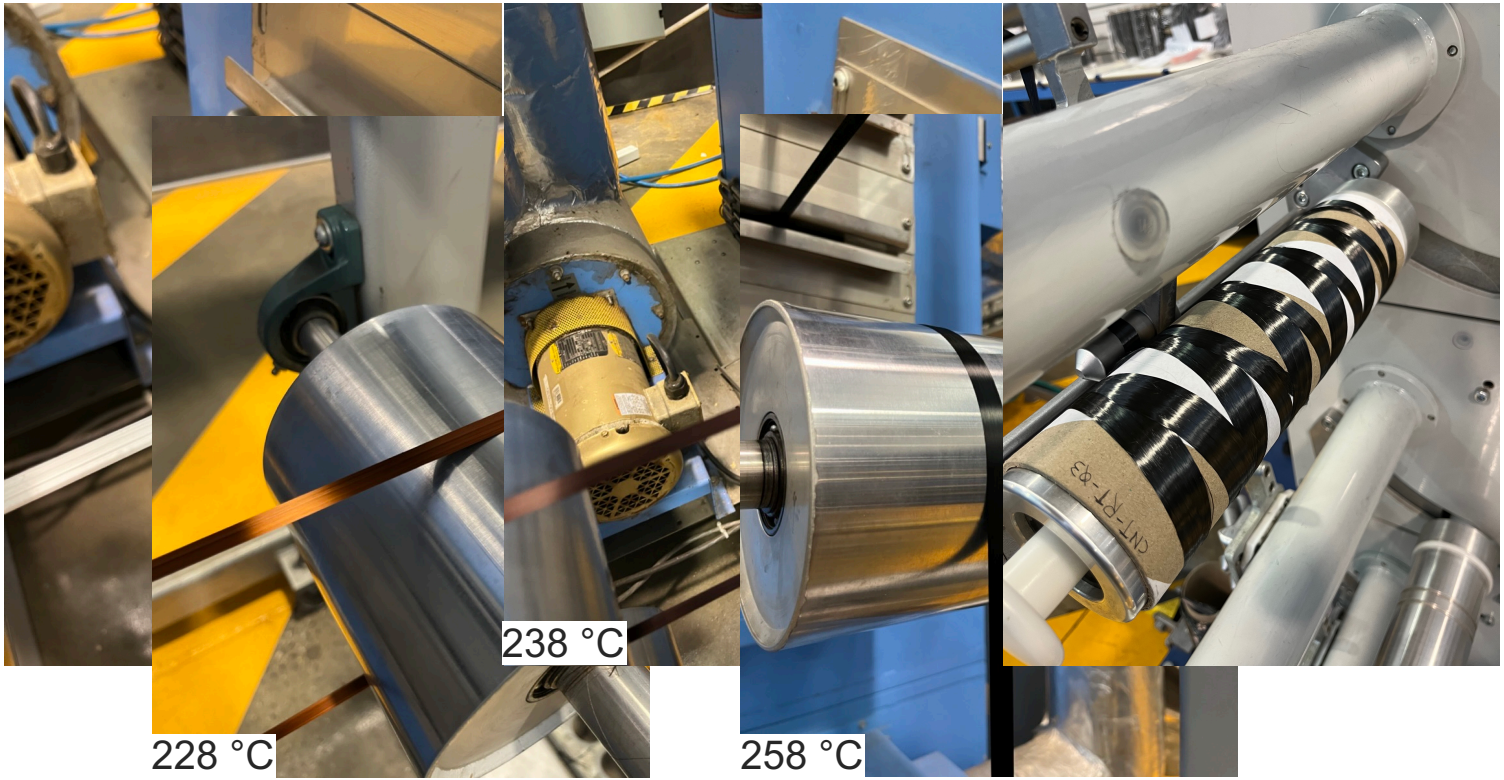
Details about manufacturing



- Different temperature profiles for the LT (3 zones) and HT (2 zones) carbonization steps:

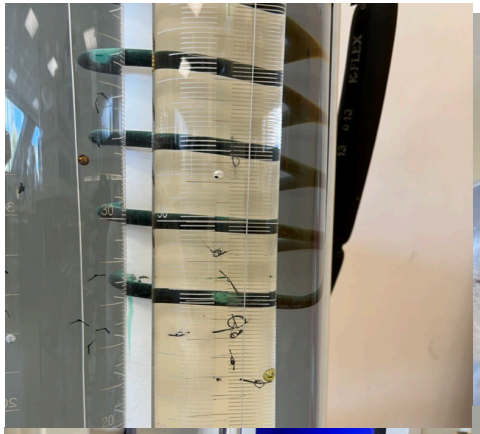
Trial	LT-furnace zone 1 (°C)	LT-furnace zone 2 (°C)	LT-furnace zone 3 (°C)	HT-furnace zone 1 (°C)	HT-furnace zone 2 (°C)
Trial 1	284	450	600	1000	1300
Trial 2	350	550	700	1100	1400
Trial 3	450	650	800	1200	1500

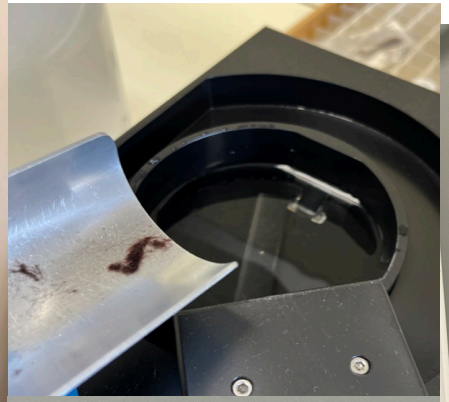
Manufacturing process

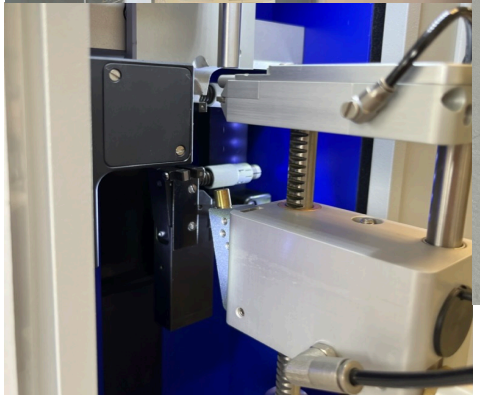


Physical and mechanical characterization

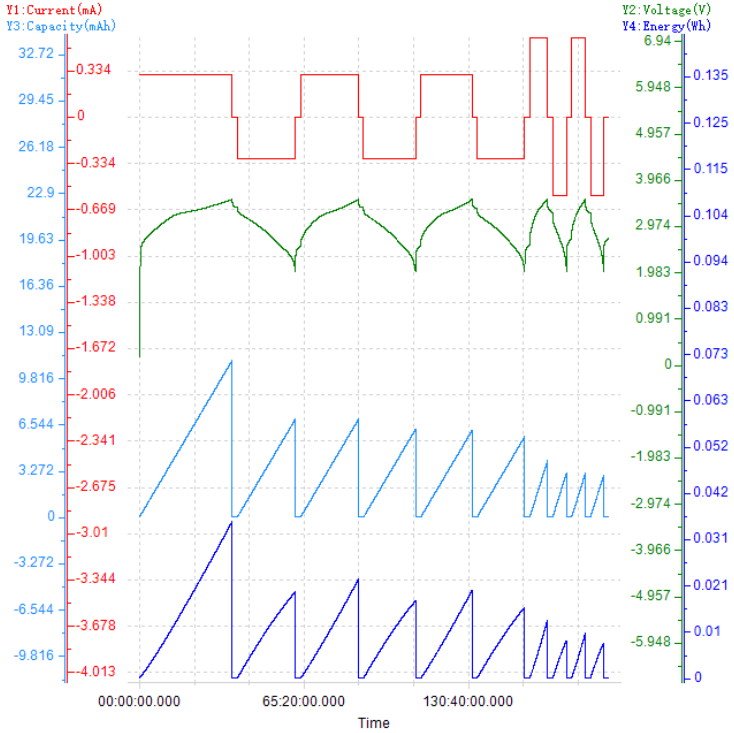
- Density measurements
- Diameter measurements
- Surface area measurements
- Conductivity measurements
- Single fibre tensile tests

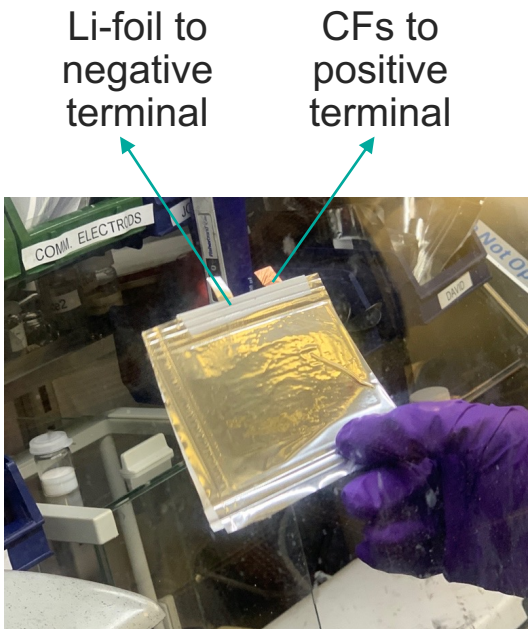




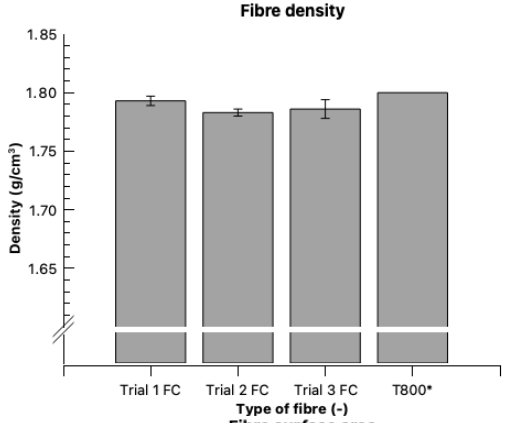


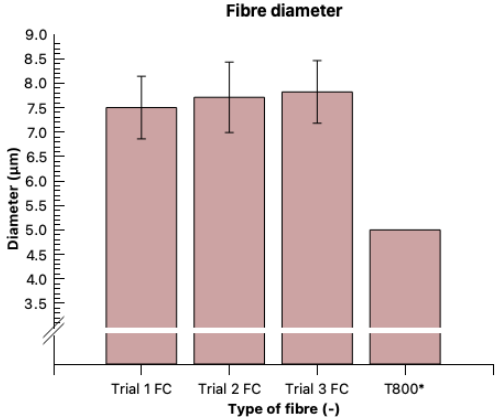
Electrochemical characterization

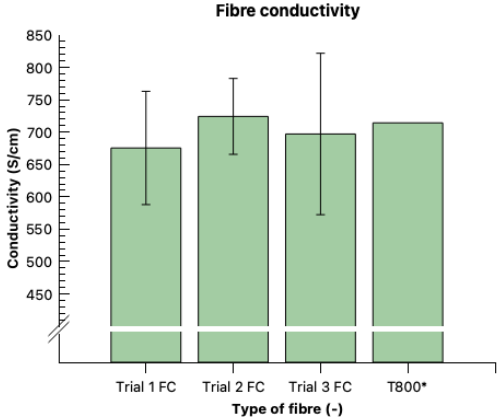


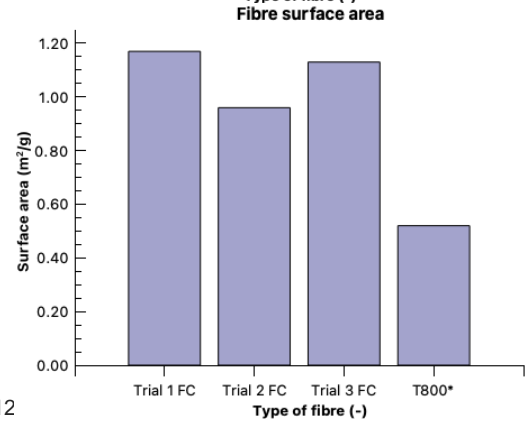


Characterization results (1)



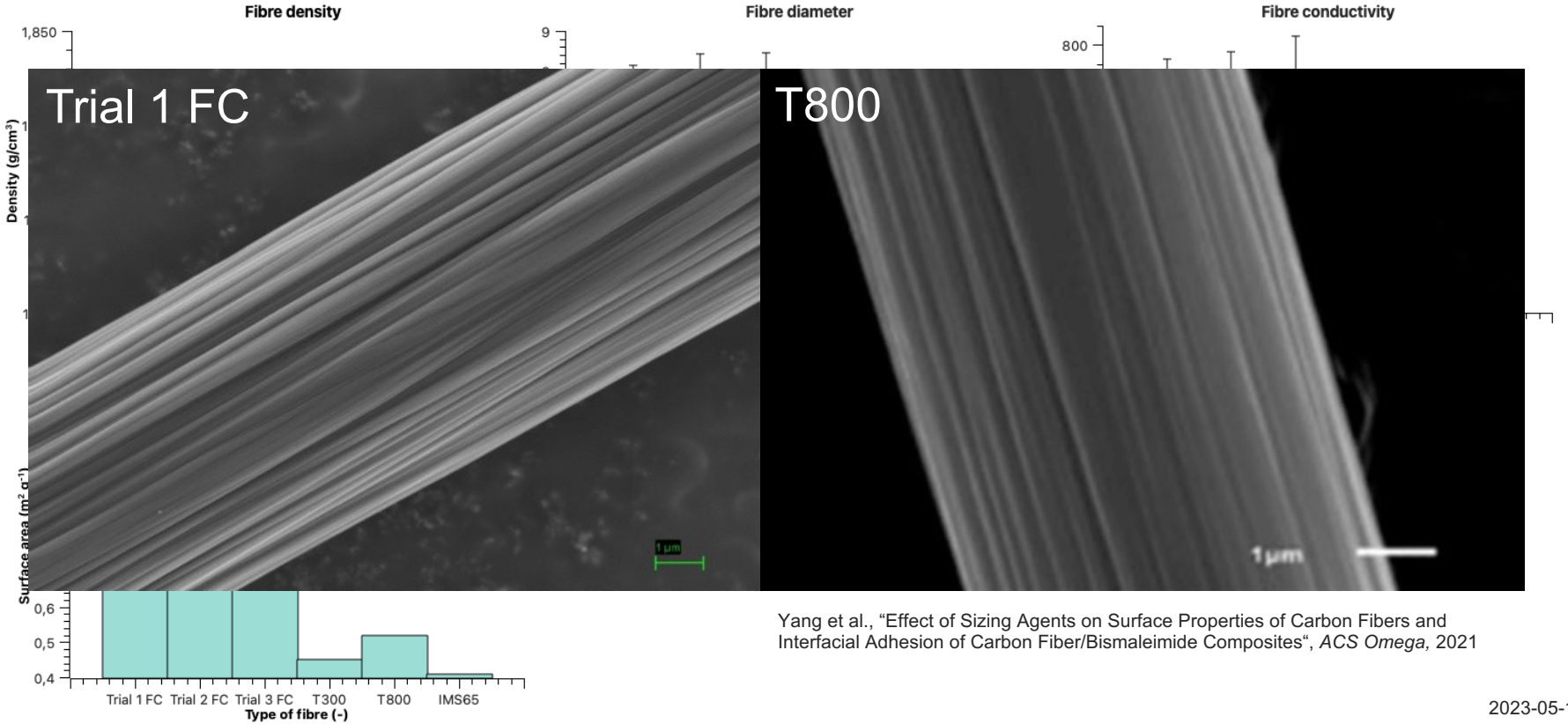






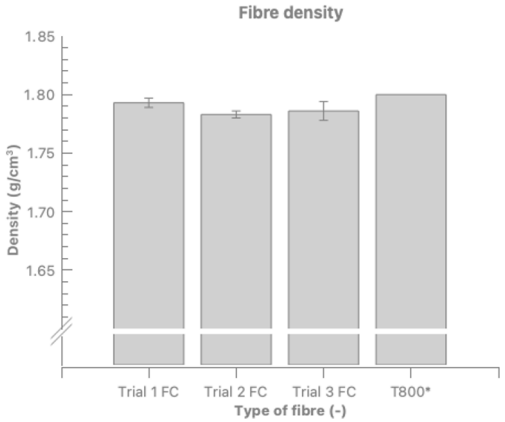
*Data for T800 CFs from manufacturer data sheet

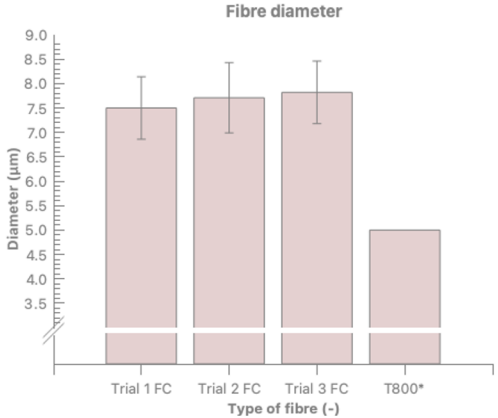
Characterization results (1)

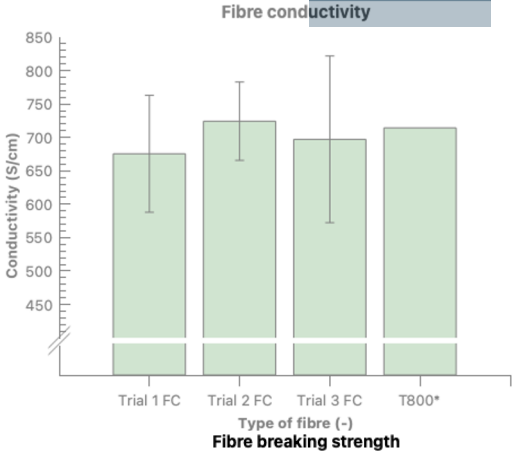


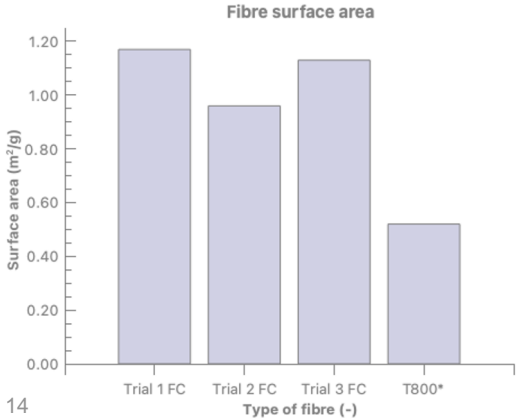
Yang et al., “Effect of Sizing Agents on Surface Properties of Carbon Fibers and Interfacial Adhesion of Carbon Fiber/Bismaleimide Composites“, *ACS Omega,* 2021

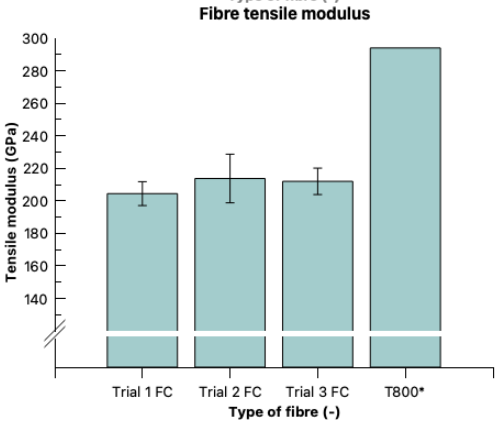
Characterization results (1)

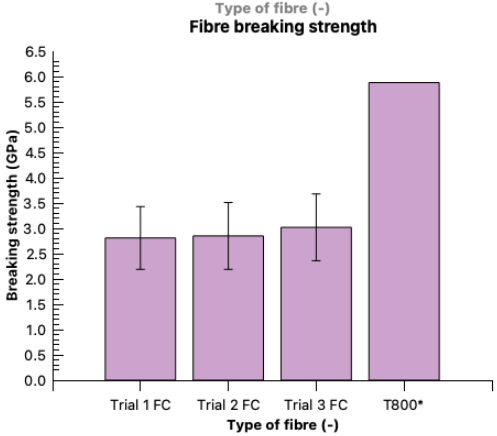








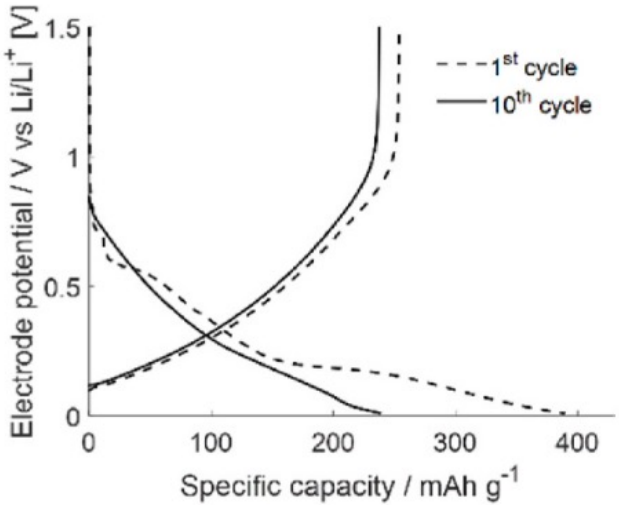


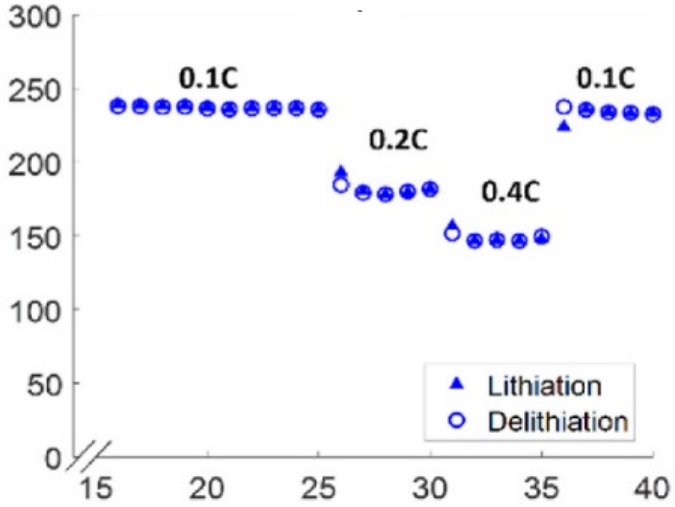


*Data for T800 CFs from manufacturer data sheet

Characterization results (2)

- Previous study has shown:



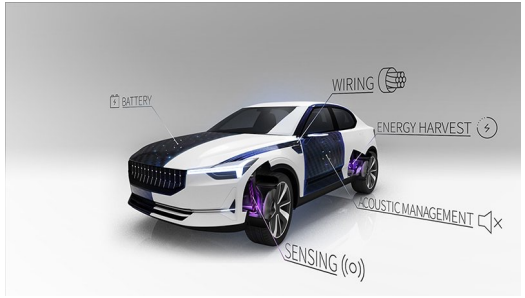


- Similar results are expected also for these carbon fibres based on preliminary results (cycling of the half-cells is still not finished)

Xu et al., “Effect of tension during stabilization on carbon fiber multifunctionality for structural battery composites “, Carbon, 2023

Summary

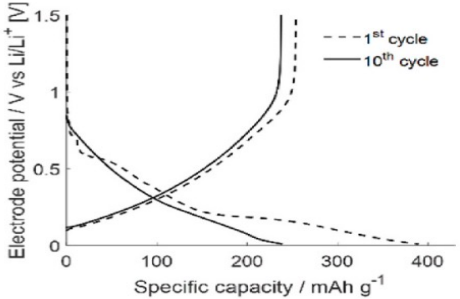
Structural batteries



Tailor-made carbon fibres

Physical and mechanical characterization

Electrochemical characterization



Further analyses

- Microstructure determination:
  - SAXS/WAXS
  - HR-TEM
- Low-temperature extracted CFs characterization

Further optimizations

Aknowledgements

- Co-autors:
  - Prof. Leif E. Asp
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