FORENSIC ANALYSIS OF LITHIUM BATTERIES FOR EARLY FAILURE MODES (FAB-FM)

Lithium Iron Phosphate Reference Electrodes for 3-Electrode Pouch Cells

Yazmin Monaghan Veronika Majherova, Andrei-Mircea Top, Maria Balart-Murria, Puritut Nakhanivej, Melanie Loveridge

1. ABSTRACT

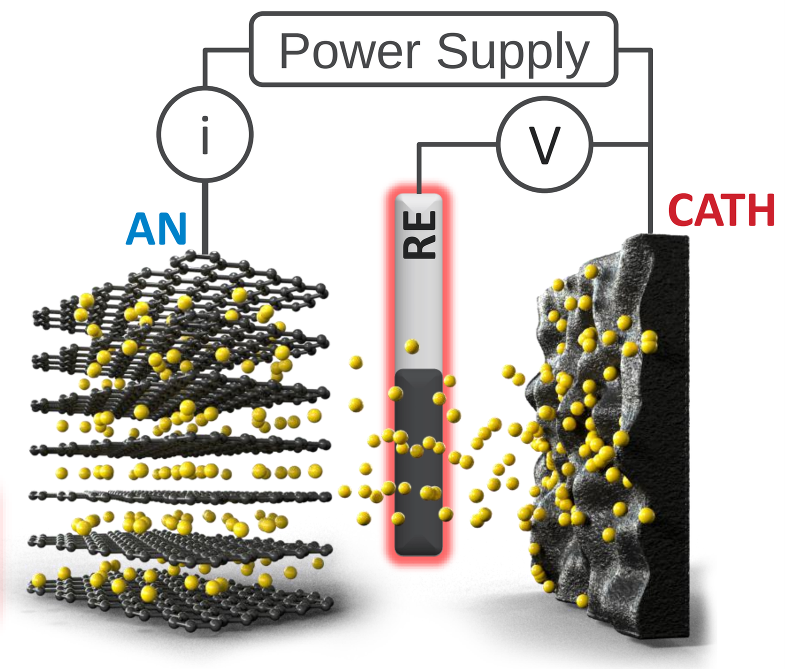
Understanding the fundamental degradation mechanism is crucial for the development of next generation Li-ion batteries (LIBs) especially for use in electric vehicles. This also highlights the need of efficient sensors to detect the early signature failure modes within the cells. **The implementation of reference electrode (RE) in the cells is very promising way as it can differentiate electrochemical phenomena of cathode and anode.** Ideally, the RE materials should be stable and operational within specific parameter range. The most frequently used RE is metallic Li, yet its ambient condition instability and the solid electrolyte interphase (SEI) formation can result in unstable potential. Herein, **we demonstrate the intercalation oxide of lithium iron phosphate (LFP) as RE in 3-electrode (3E) pouch cells**. LFP exhibits a constant potential over the large state of charge range, hence the ideal candidate for RE. The LFP electrode thickness was optimized and inserted into A7 pouch cells comprising Ni-rich oxide (NMC811) cathode and graphite anode. The 3E pouch cell configuration was optimized, demonstrating the suitability of LFP as RE in LIB cells.

2. MOTIVATION

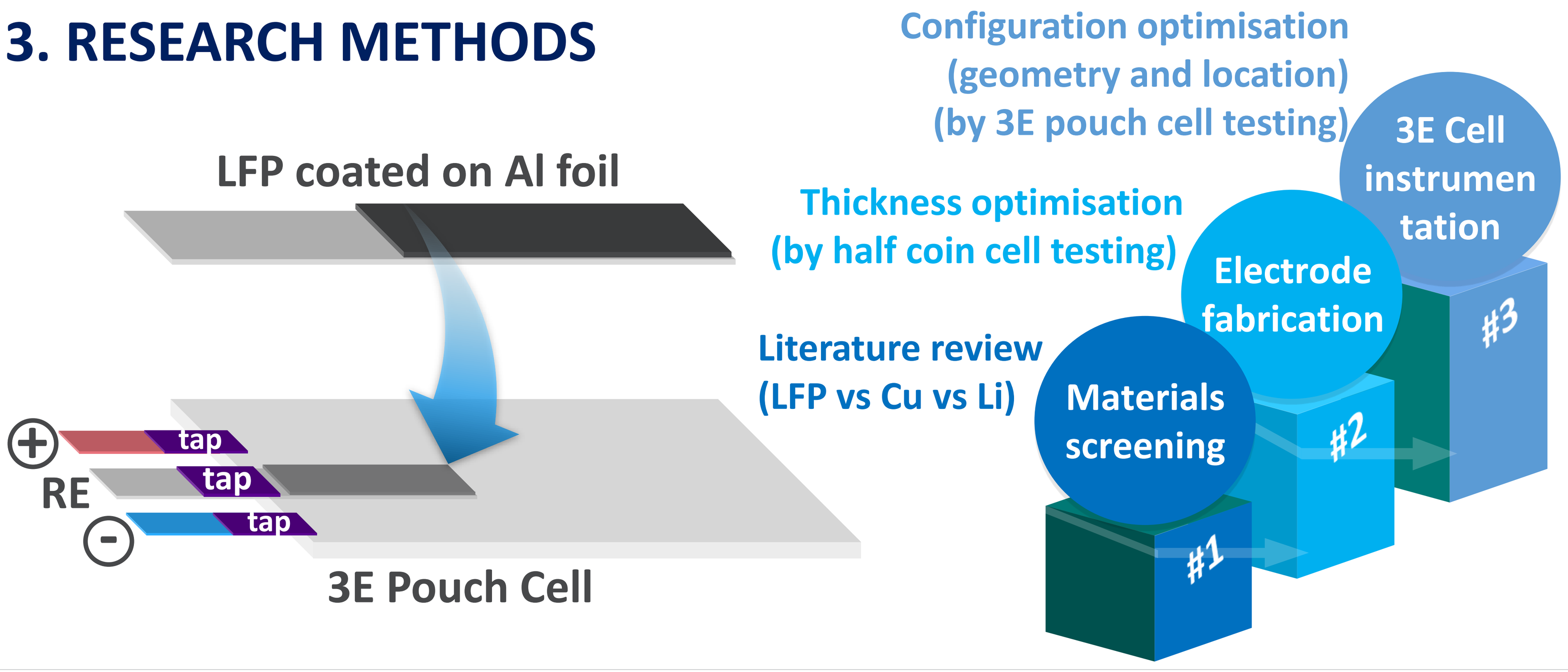
Detecting early signature failures of batteries

Need of Differentiating electrochemistry of cathode and anode

Need of Reference Electrode (RE)



3. RESEARCH METHODS

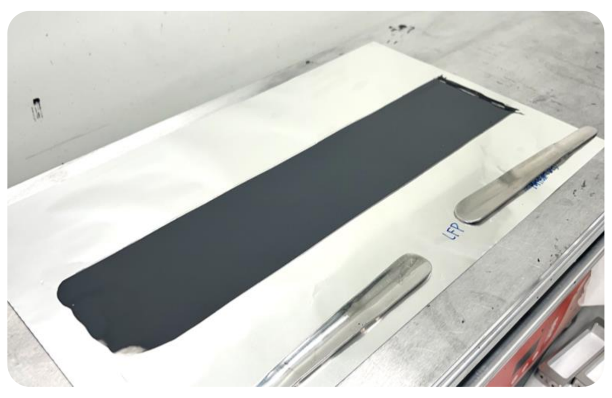


4. LFP ELECTRODE FABRICATION

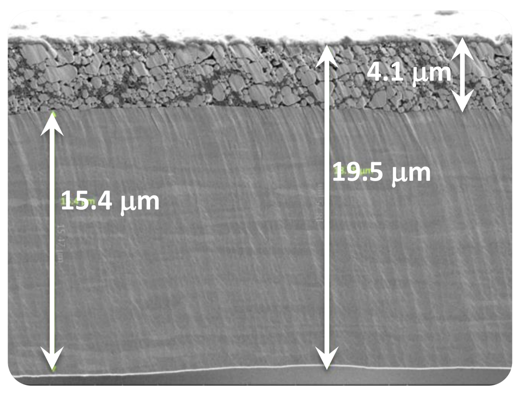
Electrode Coating

- Slurry mixture = LFP: PVDF: Carbon black = **95: 2.5: 2.5** (43% solid content)
- Blade gap in applicator = **20, 50, 100, 220** μm

LFP slurry



LFP slurry coating on Al foil



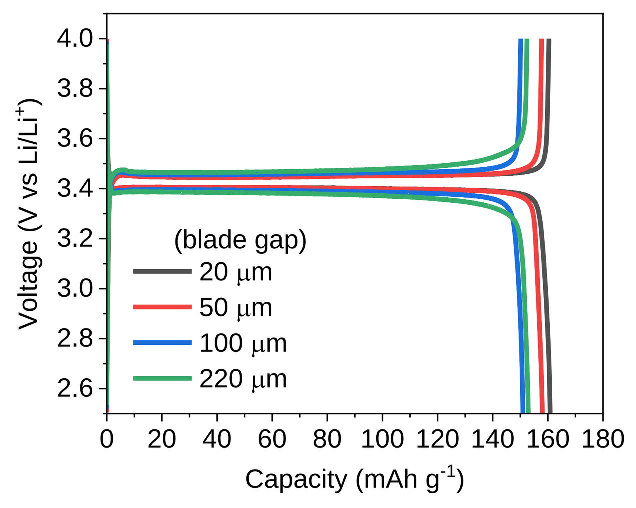
SEM image of calendared LFP electrode with 20 μm blade gap

(For more detailed activities/results please visit here)

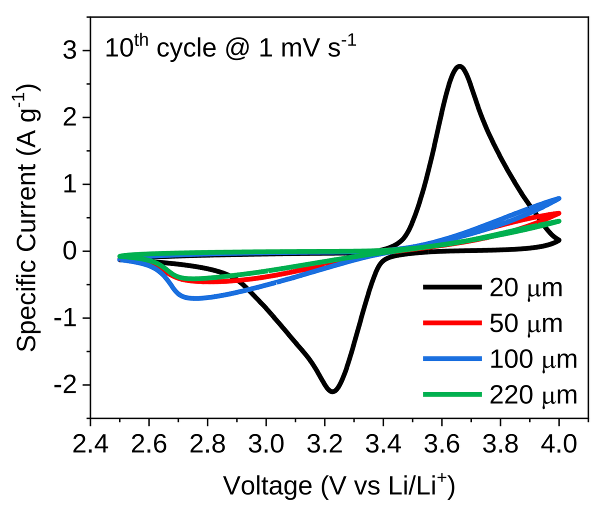
Half Coin Cell Fabrication (to Determine the Best Coating Thickness)

- Electrolyte = LP57 (60 μL, 1M $LiPF_6$ in EC/EMC 3:7 wt%)
- Separator = 2325 (PP/PE/PP) (Celgard) and Spacer = 1 mm

Half Coin Cell Results



Voltage profiles of different thickness LFP REs



Cyclic voltammogram (CV) of different thickness LFP REs

- The curves for LFP REs coated with 220 and 100 μm blade gaps indicate slightly larger overpotentials
- The applicator used for RE coating should have a **blade gap <50 μm,** giving an **RE thickness <10 μm** after drying and calendaring.

- The CV results suggest that the electrode coated with **20 μm blade gap (actual electrode thickness after drying and calendering 4 μm) is the most suitable for use as a reference electrode** because it shows the most suitable redox potentials.

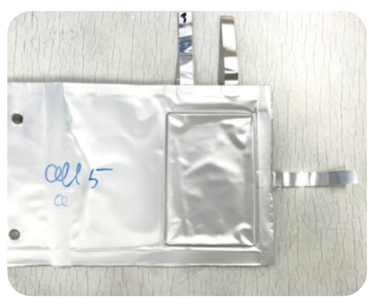
5. 3E CELL FABRICATION

3E Pouch Cell Fabrication

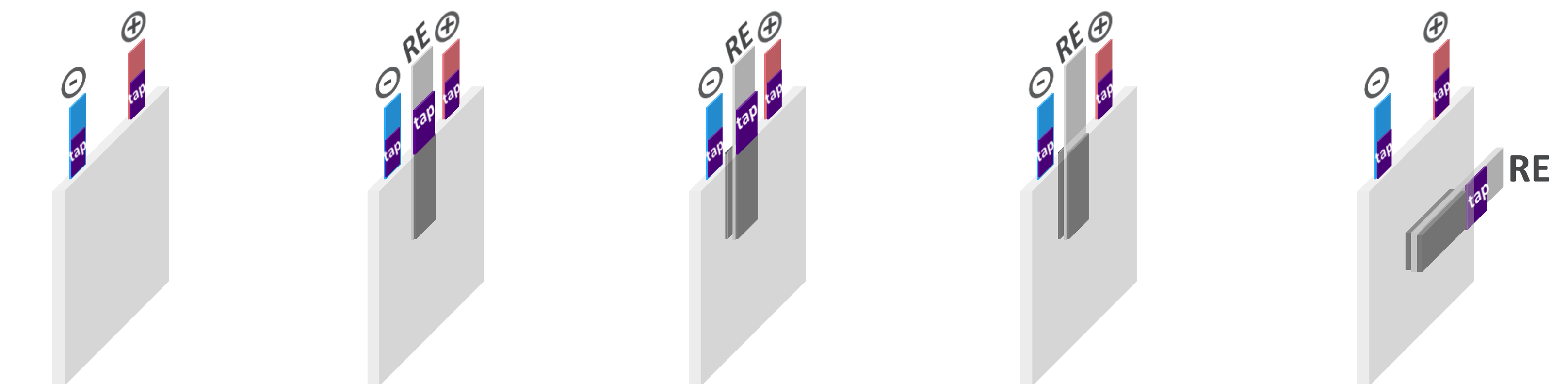
Cut electrodes into A7 size

Cell 1-3 (cell 1 is without RE)

Cell 4

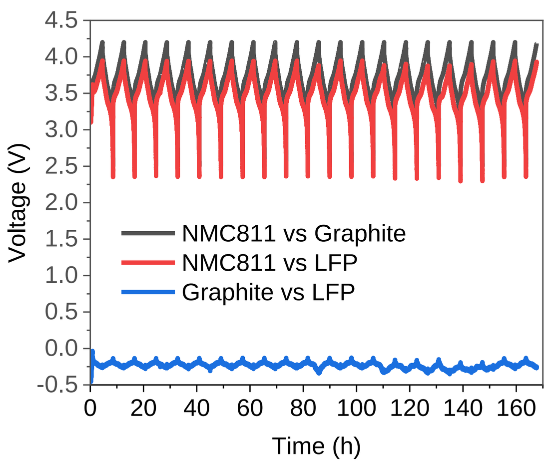


Cell 5

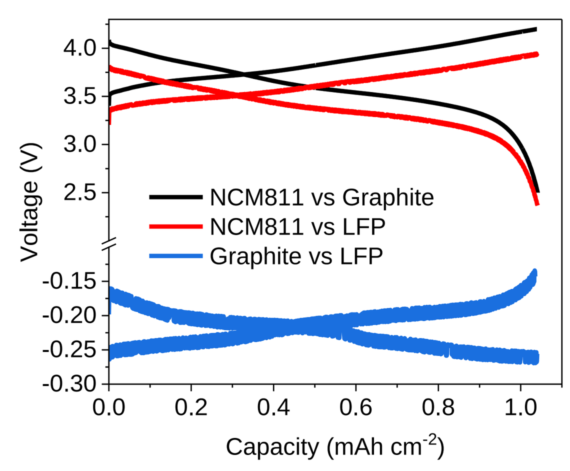


Cell 1 (2E)	Cell 2 (3E)	Cell 3 (3E)	Cell 4 (3E)	Cell 5 (3E)
Without RE Baseline	One-side coated RE Welded tap Electrolyte leakage ✗	Double-side coated RE Welded tap Electrolyte leakage ✗	Double-side coated RE Without welded tap Electrolyte leakage ✗	**Double-side coated RE** **Welded tap** **Inserted at the side** **No Leakage** ✓

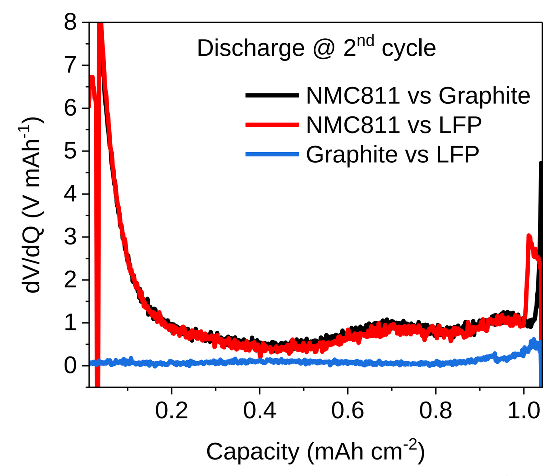
3E Pouch Cell Results (Cell 5)



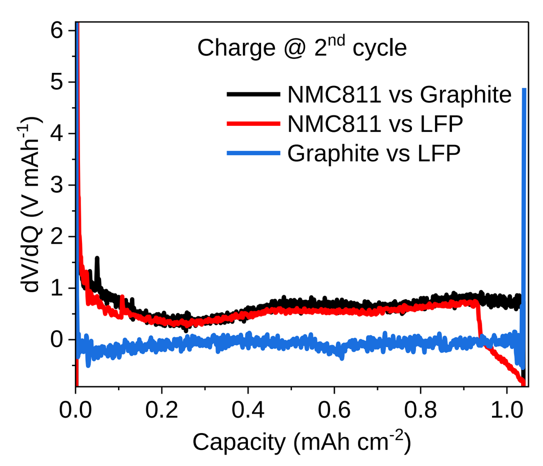
Voltage profile of Cell 5 after 20 cycles



Charge/Discharge profile of Cell 5 during formation cycles



Discharge DVA Curve of Cell 5 at 2nd cycle



Charge DVA Curve of Cell 5 at 2nd cycle

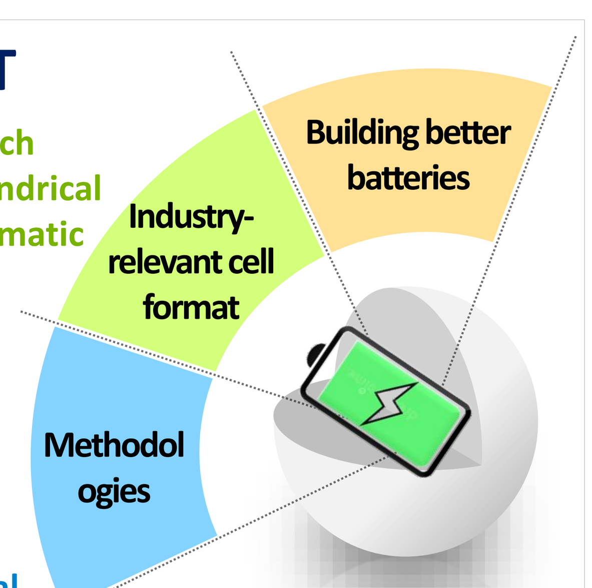
- Cell 5 (with RE inserted at the side) shows the voltage profiles consistent with Cell 1, confirming **NO negative effect of RE insertion into pouch cell.**
- The differential voltage analysis (DVA) curves exhibit **the individual electrochemical profile of cathode and anode,** where measuring cells with 2E configuration could not provide, **indicating the importance of RE.**

(For more detailed activities/results please visit here)

6. IMPACT

- Pouch
- Cylindrical
- Prismatic

Applicable to instrument cells for other purposes, e.g., **internal cell heating to simulate thermal runaway event.**



7. REFERENCES

- *J. Electrochem. Soc.*, **2016**, 163, A1232-A1238 (doi: 10.1149/2.0591607jes)
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- *Electrochim. Acta*, **2023**, 441 (doi: 10.1016/j.electacta.2022.141768)

8. BIOGRAPHY

Yazmin is a 3rd year Chemical Engineering student at the University of Bath, interested in renewable energy technology and the electrification of the automotive industry. She conducted the FUSE internship with the Warwick Manufacturing Group (WMG) at the University of Warwick.

Find me on LinkedIn
ymm29@bath.ac.uk

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