ACOUSTIC EMISSION TO PREDICT THERMAL RUNAWAY IN LITHIUM-ION BATTERIES

Battery Failure Monitoring And Investigation

Marco Bruno Tomé Freire[1,2] James Robinson[2], Rhodri Owen[2], Arthur Fordham[2]

[1] Chemical Engineering, Imperial College London, London, SW7 2BX
[2] Electrochemical Innovation Lab, Department of Chemical Engineering, University College London, London, WC1E 7JE

Abstract

Batteries are widely used in consumer goods such as smartphones and will have a massive role in the automotive industry. These applications may subject batteries to extreme temperature ranges, charging rates, and physical damage. Failure events are a rarity, but the impact on users and public perception can be severe. For example, the total product recall of the Galaxy Note 7 due to manufacturing faults [1]. Battery State of Health and Charge must be analysed throughout lifetime to evaluate safety. Great candidates are acoustic techniques such as Ultrasound Testing and Acoustic Emission (AE). AE is a real-time, non-invasive technique of obtaining accurate data before a failure event, allowing this information to be integrated into a battery management system (BMS) and provide real-time warning signals to the user. Thermal runaway can be predicted by AE when batteries emit acoustic signals.

Motivation

In AE, a piezoelectric transducer is attached to the surface of a battery and measures the acoustic signals generated from mechanical, chemical, and physical processes occurring during cell cycling and failure.

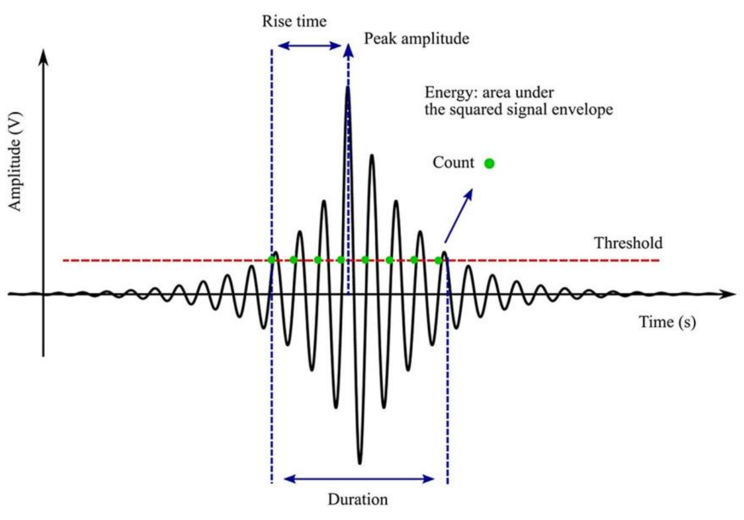

Figure 1: Typical AE signal [2]

Methods

AE cycling data was obtained by varying cell voltage. This was compared to data where cells were overcharged until failure. The aim was to find key differences in waveforms from the two situations. These are clearly shown in Figure 3(c).

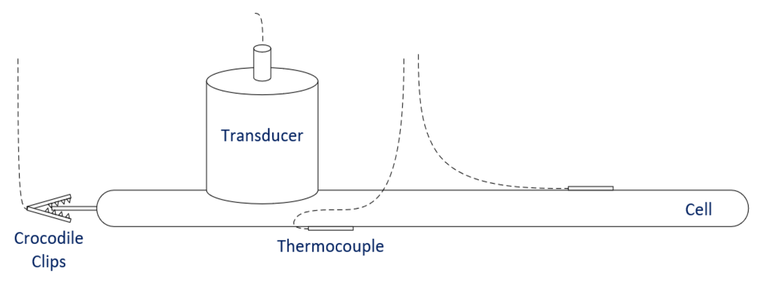

Figure 2: Cell Set-Up Diagram

Acoustic Hits Analysis

Figure 3(b) shows hit amplitude, described by the maximum AE signal excursion during an AE hit, expressed in decibels. All these measurements peaked at the point where the battery fails (4(b)). AE events seen in Figure 3(b) were recorded that indicated gas evolution and particle cracking [3]. Figure 3(a) shows the cycling current and voltage. Figure 3(c) shows the waveform difference produced at cycling and failure. A failure waveform has a very distinguishable shape, allowing programs to recognise system fault [4].

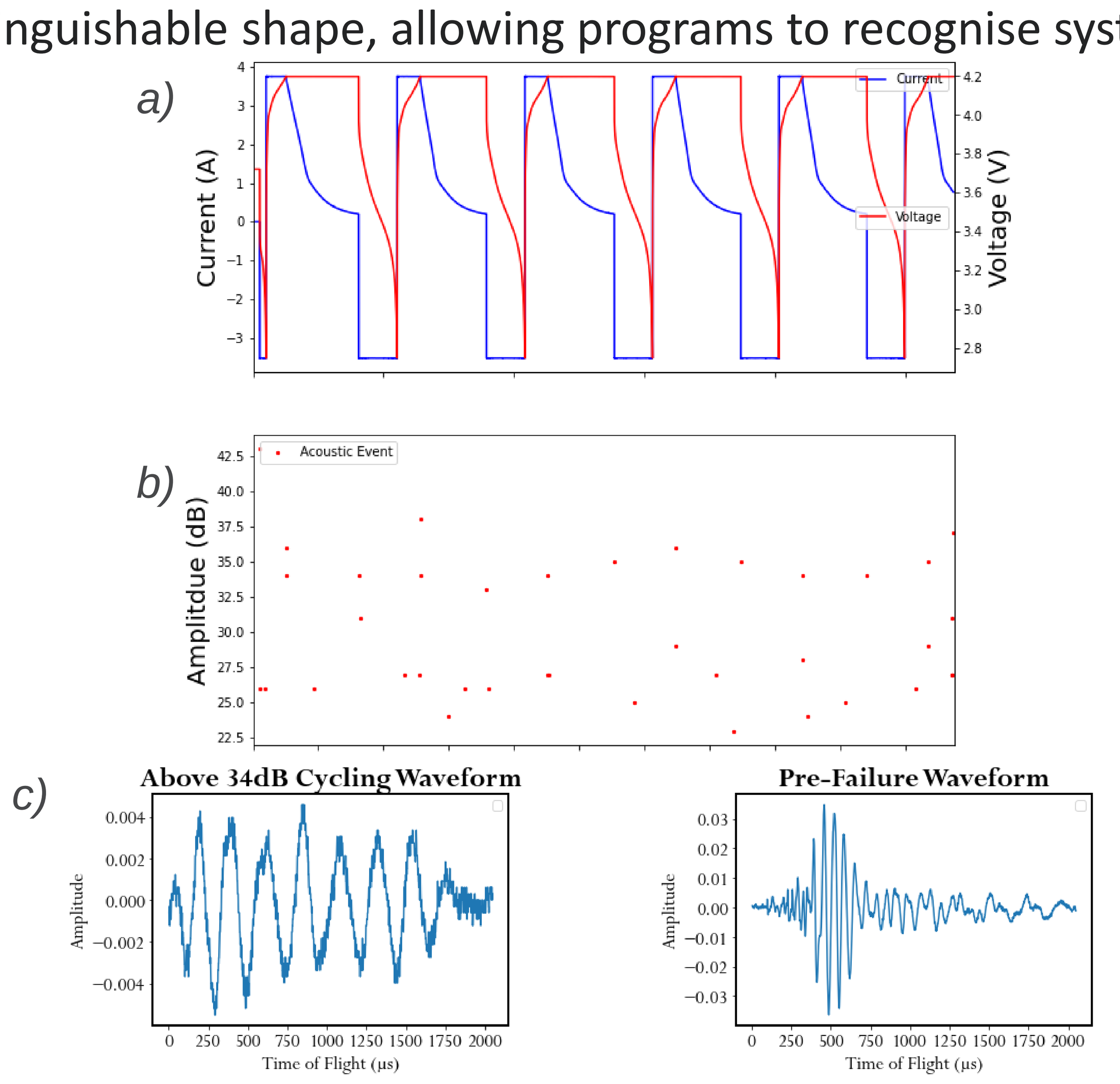

Figure 3: a) Voltage/Current plot. b) AE Hits plot. c) Cycling and Pre-Failure Waveforms

Conclusions

The data in Figure 4(b) clearly shows AE's thermal runaway predictive capability and proves signals from AE techniques could play a key part in a battery management system. AE provides real-time data in a non-invasive and rapid manner, and key indicators of cell damage and degradation can be determined. These warning signals would provide accurate mitigations to avoid thermal runaway. This was supported through temperature, voltage, and current measurements as well as CT, SEM and Ultrasound scans.

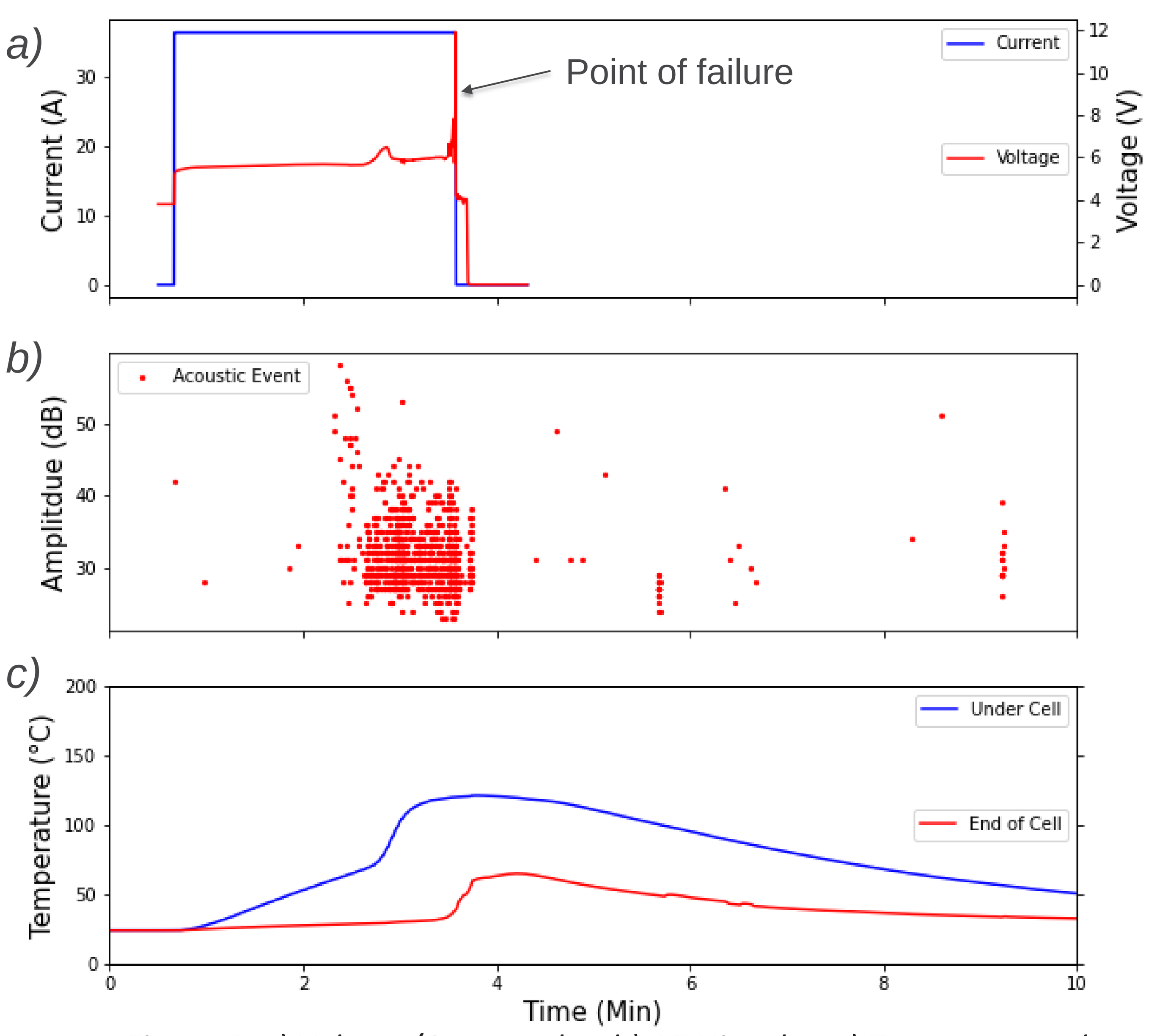

Figure 4: a) Voltage/Current plot. b) AE Hits plot. c) Temperature plot

Impact / Next steps

Thermal runaway situations for EV batteries can be predicted by AE measurements. Current *in-situ* methods of monitoring battery state of health and charge can be complemented by AE's speed and accuracy, as well as its failure prediction ability [5]. Despite positive results, the batteries tested in this project have only been put in abusive situations. The next step is to see the ability of AE in long-term cell degradation where failure does not occur in dramatic fashion but through a slow decline in performance.

References

[1] Loveridge, M. J. *et al.* Looking deeper into the galaxy (Note 7). *Batteries* **4**, 1–11 (2018).

[2] Majasan, J. O. *et al.* Recent advances in acoustic diagnostics for electrochemical power systems. *JPhys Energy* **3**, (2021).

[3] Huang, J., Boles, S. T. & Tarascon, J. M. Sensing as the key to battery lifetime and sustainability. *Nat Sustain* **5**, 194–204 (2022).

[4] Zhang, K., Yin, J. & He, Y. Acoustic emission detection and analysis method for health status of lithium ion batteries. *Sensors (Switzerland)* **21**, 1–17 (2021).

[5] Wang, S., Jin, S., Deng, D. & Fernandez, C. A Critical Review of Online Battery Remaining Useful Lifetime Prediction Methods. *Front Mech Eng* **7**, 1–19 (2021).

Intern bio

Marco Bruno Tomé Freire is studying MEng Chemical Engineering at Imperial College London. He is interested in the research and development of new techniques to limit the impact of anthropogenic pollution. Bruno aspires to pursue a career in academia or industry relating to the renewable energy field and energy storage, to further the global green energy transition toward Net-Zero. He has built up a skillset in the upscaling of these green processes through his undergraduate course.

THE FARADAY INSTITUTION
SCIENCE OF BATTERY SAFETY
SafeBatt
UCL
UK Research and Innovation