POSTDOC SUBJECT

Postdoctoral position in analog embedded electronics and electrochemistry, for Reference Electrode signal conditioning inside a Li-ion battery cell.

Scientific context and main objectives

In the field of Lithium-ion rechargeable battery cells, a **Reference Electrode** (RE) is a third electrode inserted into a cell, used for the individual electrochemical potential measurement of the other two electrodes, without interfering with the electrochemical reactions that are going on. It is useful to measure the potentials of the cathode and anode separately, by referring them to a stable and independent reference. The researchers take advantage of this technique to carry out better analysis of the state of the cell, optimizing the cycling protocols and improving its lifespan. For instance, the Lithium Plating phenomenon, which consists in the degradation of the anode of the cell, affecting the capacity of the cell itself, can be strongly reduced and even completely avoided by the monitoring of the anode potential against the RE; moreover, the overall stability and safety of the cell can be improved. In synthesis, the independent access to the potentials of the two electrodes, allowed by the presence of a RE, and the consequent cycling adaptations which can be put in place, improve the performances, the durability and the robustness of a Li-ion cell.

However, the measurement of the RE itself is not as easy as it seems. Its stored energy (expressed in terms of stored electrical charge in Ah – ampere.hour) is extremely small and must stay stable and constant for as long as possible. Nowadays, also because of this weakness, the RE is not used outside the research laboratories. Regarding this precise aspect of the RE measurement, only specific laboratory equipment, sometimes completed by custom electronic solutions, can perform harmless measurements, almost without modifying the charge of the RE in any way. Otherwise, general electronic systems, not designed for the RE, draw a certain amount of current for each performed measurement, show bias currents or, more in general, have an input impedance that is not adapted. As a consequence, researchers have to regularly reactivate the RE in case its stored charge is affected by a not adapted measurement procedure. The challenge we have to face is making the use of the RE easier to perform, safe and reliable, by any measurement system or BMS (Battery Management System), embedded or not.

The proposed project aims to solve this problem with a pragmatic approach. The goal is to develop and test an embedded electronic system, as simple and cheap as possible, to be joined to a general-purpose Li-ion cell, in order to make the RE potential available for the outside world (that means: it must be a simple voltage output of the cell to measure, possibly referred to the negative electrode's potential of the cell). First of all, the fact that this new electronic embedded system satisfies this demand has to be tested and proven, harmlessly for the stored energy on the RE itself. Then, the fact that the knowledge of this potential allows a better use of the battery cell, in terms of less problematic aging, better performances and stronger safety, must be explored and assessed.

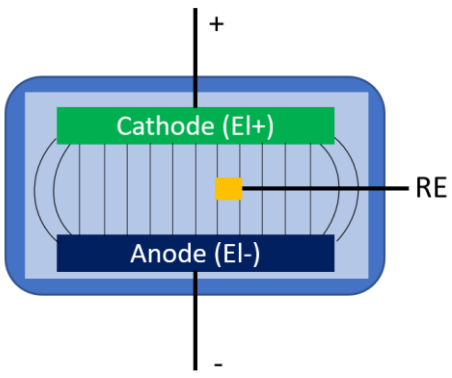

Figure 1: Qualitative representation of an inserted RE inside a Li-ion cell (cathode and anode material are just for example).

State of the art

The RE chemical composition, mechanical insertion and in-lab use is currently explored by public research institutes in Europe (CEA, FhG-IISB, TUE, …) and by some European consortia, which have carried out collaborative projects (SENSIGA). As a matter of fact, the problem of the effective measurement of the RE in everyday application, or general-purpose devices, has not been clearly addressed yet, limiting its use to the lab environment only, featured by specific equipment. The industry world is nowadays unable to design systems which can take advantage of the RE, as its long-term measurement is not possible.

Please refer to the bibliography here below to go into the depth of the subject:

1. Bichon, Alexia; Geniès, Sylvie; Azais, Philippe; Buzon, Didier; Raccurt, Olivier. (2025). *Operando Detection of Lithium Plating and Stripping in Fast-Charging Li-Ion Cells with a Reference Electrode*. Batteries; Supercaps. 10.1002/batt.202500071.
2. Genies, Sylvie; Bichon, Alexia; Buzon, Didier; Balfet, Pierre; Debruyne, Cédric; Villemin, Elise; Ranieri, Marco; Septet, Cédric; Franchi, Romain; Reynier, Yvan; Azais, Philippe; Raccurt, Olivier. (2023). *Using a Reference Electrode inside Li-Ion Cell As an Operando Sensor to Detect Aging Mechanisms.* ECS Meeting Abstracts. MA2023-02. 165-165. 10.1149/MA2023-022165mtgabs.
3. Genies, Sylvie; Balfet, Pierre; Villemin, Elise; Septet, Cédric; Ranieri, Marco; Franchi, Romain; Raccurt, Olivier. (2023). *Why Li (1-x) FePO 4 / LiFePO 4 Is a Good Candidate to be Used as Reference Electrode.* ECS Meeting Abstracts. MA2023-02. 330-330. 10.1149/MA2023-022330mtgabs.
4. Wang, Jinkun; Liu, Jianhong; Wang, Li; Xu, Hong; Yang, Yang; Sheng, Li; He, Xiangming. (2022). *The significance of imperceptible current flowing through the lithium reference electrode in lithium-ion batteries.* Journal of Power Sources. 546. 231953. 10.1016/j.jpowsour.2022.231953.
5. Raccichini, Rinaldo; Amores, Marco; Hinds, Gareth. (2019). *Critical Review of the Use of Reference Electrodes in Li-Ion Batteries: A Diagnostic Perspective.* Batteries. 5. 12. 10.3390/batteries5010012.

Detailed project objectives

The technological objective of the project is to design, build and test a completely new embedded electronic system, which transforms the Li-ion cell equipped with a RE into a reliable device, easy to implement into any energy storage system, by any user. The scientific objective is to demonstrate that such an approach allows an improved and optimized use of the Li-ion cell, higher than the current state of the art, in terms of performances, durability and robustness.

Three main steps of the project are planned as follows:

1. Design an electronic conditioning system that preserves the charge (therefore the potential) of the RE, ensuring its measurability by any system, including BMS;
2. Integrate the electronics as close as possible to the cell (flexible support), for easier use;
3. Carry out tests on Li-ion cells equipped with the RE and the new designed electronics, by controlling their cycling with the measurement of the RE potential – abuse cells test can be performed too.

More precisely, the technological solutions which will be developed must satisfy the following needs:

1. The electronics will be powered by the cell itself at any SOC (State Of Charge),
2. Its configuration must adapt to the different SOCs of the cell (patents pending),
3. The impact of electronics on the RE must be negligible in the very long term (>15 years!),
4. Provide a robust, easily measurable and stable buffered RE voltage,
5. A study on wireless measurement of the RE potential could be carried out (patents pending),
6. There will be no longer need to reactivate the RE, unless electrochemical degradation occurs, independently of the conditioning electronics and measurement.
7. Integration of the electronics as close as possible to the cell (flexible support and suitable connectors), for easier use.

Job offer, where to find it

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