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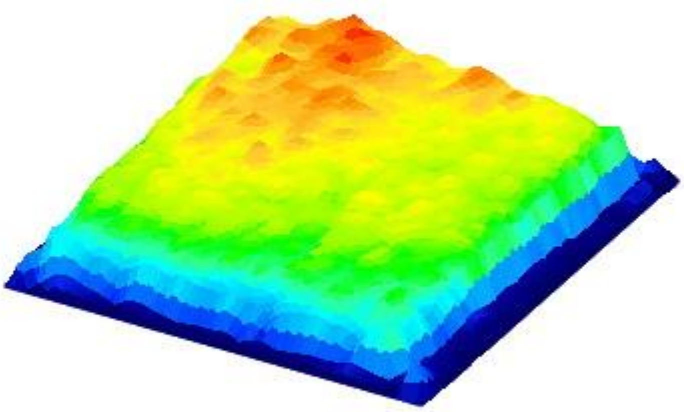
Application note

Mapping Pouch Cell Pressure Distribution *in Operando:* *CompreCell Pouch × TekScan sensor*



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Introduction

The pressure applied to pouch cell batteries is key to their performance and cycle life [1, 2, 3, 4]. One of two modes of pressure application is typically used: **Constant volume (CV)** or **constant pressure (CP)**. CV mode is achieved by fixing the pouch cell in a stiff jig to inhibit cell swelling. Nevertheless, in practice any cell fixture will expand under the high forces developed under cell cycling, in accordance with the spring constant of the jig. CP mode is usually accomplished by including springs in the cell fixture, but when the cell swells, the springs will be compressed, which increases the pressure, again in accordance with the spring constant. One way to realize true CP is to actively regulate the cell thickness in closed-loop control with a force sensor, as in the CompreDrive [5].

An inhomogeneous pressure distribution can lead to accelerated ageing and cell failure, due to locally high pressure [3, 6]. This can arise from unevenness in electrode coatings or other jelly roll components, but can also be an effect of imperfections in the cell fixture. Even minor tilting of the plates leads to zones with higher and lower pressures, and is exacerbated by thermal expansion and contraction. To circumvent this issue, the CompreCell Pouch cell fixture has very smooth and parallell plates. In this case, the non-uniformity of the pouch cells themselves are the main source of pressure inhomogeneities. Flexible foam compression pads (“compliance layers”) can help to smooth out the pressure, as well as providing an additional elastic layer that accommodates some cell breathing.

In this application note, the pressure distribution on a pouch cell was monitored *in operando* while it was cycled under CV and CP conditions in the CompreDrive. CP mode was achieved by active pressure regulation, while CV was achieved by disabling the pressure regulation, effectively fixing the cell thickness.

Experimental

A lithium ion battery pouch cell (ICP606168PRT, Renata AG) with a nominal capacity of 2.8 Ah was used for these tests [7]. It had a $LiCoO_2$ cathode and a graphite anode, with $LiPF_6$ in ethylene carbonate / ethyl methyl carbonate / diethyl carbonate (1 : 1 : 1) electrolyte and a polyethylene / polypropylene separator. The size of the pouch cell stack was 63.1 mm × 58.3 mm × 5.3 mm, and 1 MPa average pressure thus corresponded to 3.68 kN applied total force.

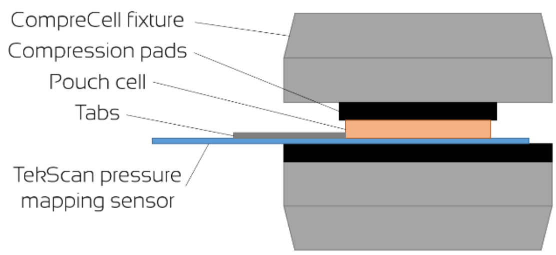

Figure 1. *Schematic experimental setup: The pouch cell (orange) and pressure mapping sensor (blue) are situated between the compression pads (black) and CompreCell Pouch cell fixture (grey).*

The setup is shown in **Figure 1**: The cell was mounted in a CompreCell Pouch 10S

HC cell fixture [8], either with or without Poron polyurethane compression pads (Rogers corporation) sandwiching the cell. Pressure and temperature control were achieved with a CompreDrive [5] equipped with a 10 kN force sensor and a Presto A40 circulator (Julabo GmbH), controlled with CompreDriveControl 1.15 (rhd instruments GmbH & Co. KG). A pressure mapping sensor (TekScan 5076, 84 mm × 84 mm, 500 psi) was placed directly underneath the pouch cell to monitor the pressure distribution online using I-Scan 7.70 (TekScan). For cross-validation against the CompreDrive force sensor, a TekScan 5101 sensor (112 mm × 112 mm, 500 psi, TekScan) was instead placed between the compression pads, without any pouch cell, and a two-point calibration at 1 and 10 kN was performed.

A Biologic SP-240 potentiostat/galvanostat controlled by EC-Lab 11.52 (Bio-Logic SAS) was used for cycling at 25 °C. The cell was charged by a C/2 (1.4 A) constant current to 4.2 V, followed by a constant voltage stage to C/5, and then C/2 discharge to 2.8 V.

Initially, a pressure of 1.0 MPa was applied to the cell, and the pressure regulation was switched off to enable the CV mode. Three charge/discharge cycles were performed in CV mode, followed by three cycles in CP mode (1.0 MPa constant pressure).

The graphs in this application note were created with Edelweiss 0.0.1 (rhd instruments GmbH & Co. KG).

Results and Discussion

The total force measured by the TekScan 5101 sensor corresponded well to the force measured by the CompreDrive force sensor (**Figure 2**) during a force ramp (1, 2, 3, ..., 10 kN) without any pouch cell. The TekScan force lagged behind slightly, likely due to the slow deformation of the elastic pads.

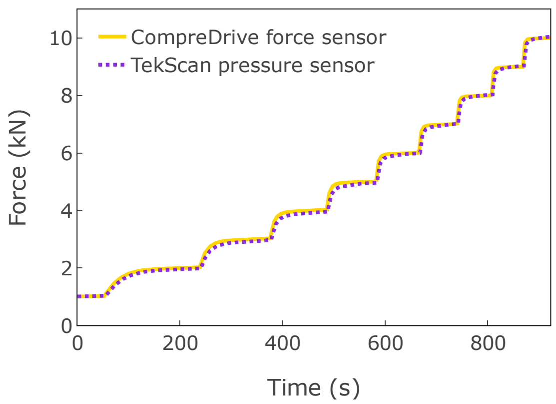

Figure 2. *Force measured by the CompreDrive force sensor (yellow solid line) and the total force measured by the TekScan pressure sensor (purple dotted line), during a force ramp without any pouch cell.*

When pressure was applied directly to a pouch cell, without any compression pads to smooth out the pressure, the pressure was concentrated to a few areas with a slightly larger cell thickness, *i.e.* where the tabs were welded to the current collectors, and where the jelly roll was taped and folded (**Figure 3a**). Employing compression pads yielded a smooth pressure distribution over the pouch cell surface (**Figure 3b**). Hence all further tests were done with compression pads in place.

The use of elastic compression pads gives the cell some room to swell even in CV mode. Removing the pads would lead to a more ideal CV mode, but as discussed above, even a stiff system has some spring constant in reality. It should also be noted that the temperature control of the pouch cell might be impeded by thermally insulating compression pads, which can lead to additional cell heating during high-power cycling. Therefore, both the hardness and thermal conductivity of any compression pads need to be considered for each specific application.

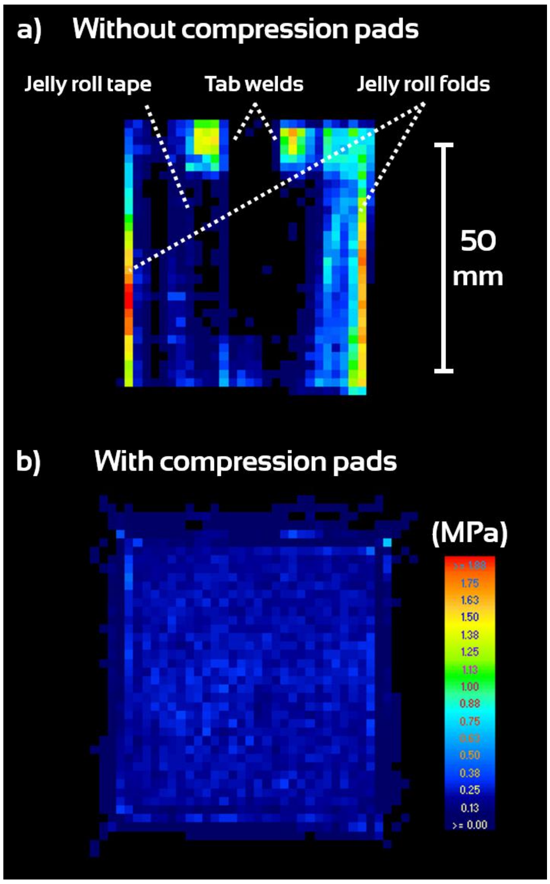

Figure 3. *Pressure distribution (0 – 2 MPa scale) of the pouch cell without (a) and with (b) compression pads under 1 kN (0.27 MPa).*

During the first three cycles, the pouch cell was kept in CV mode, *i.e.* the pressure was not regulated by the CompreDrive, and the pouch cell restricted to a fixed thickness. As can be seen in **Figure 4**, this led to pressure fluctuations of around 40% (0.9 – 1.3 MPa). Once the pressure regulation was turned back on (CP mode, cycles 4 – 6), the pressure stayed constant (within 0.1%).

Careful examination of the pressure in CV mode reveals two distinct stages of pressure change, arising from the different graphite lithium intercalation stages, as discussed previously [7, 9]. In CP mode, this process is instead manifested as a change in cell thickness [7].

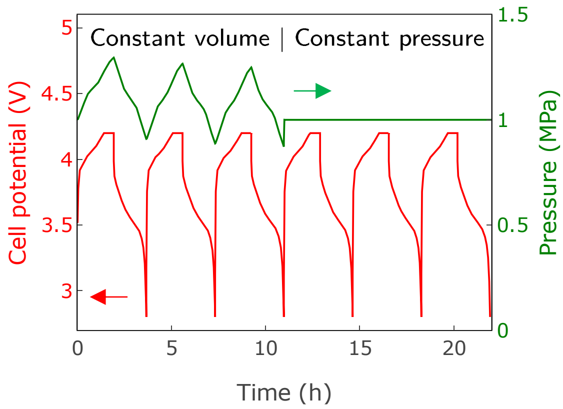

Figure 4. *Cell potential (red, left y-axis) and pressure (green, right y-axis, CompreDrive sensor) measured during cycling in CV (cycles 1–3) and CP (cycles 4–6) mode, respectively.*

Mapping the pressure distribution during the cycling reveals the higher pressure in the charged state during CV mode (**Figure 5a**), and the lower pressure in the discharged state (**Figure 5b**). In contrast, the pressure distribution remained unchanged during cycling in CP mode (**Figure 5c-d**).

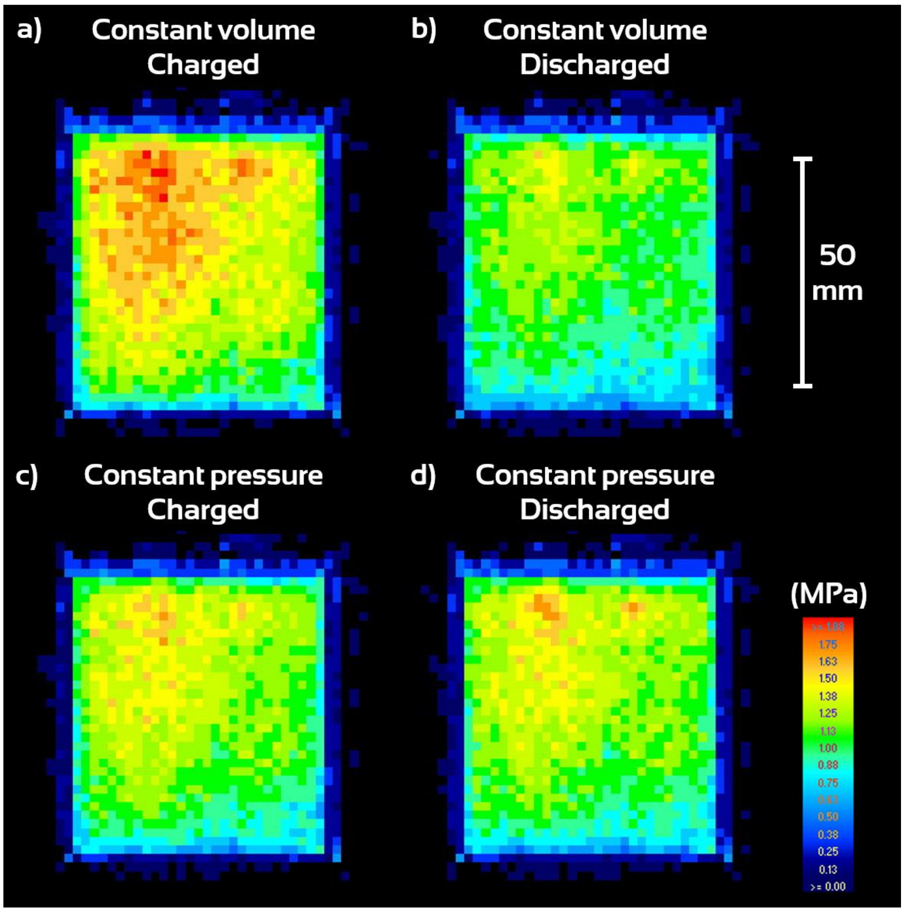

Figure 5. *Pressure distribution (0 – 2 MPa scale) during pouch cell cycling in CV (top row, cycle 3) and CP mode (bottom row, cycle 6), in the charged (left column) and discharged (right column) states, respectively (1 MPa applied pressure). Tabs are located at the top (as in Figure 3).*

Summary

Pressure mapping sensors from TekScan were used together with the CompreDrive/CompreCell Pouch setup for online monitoring of the distribution of the pressure applied to a pouch cell during cycling in constant volume as well as constant pressure mode. The values recorded by the TekScan pressure sensor and the CompreDrive force sensor agreed well after a two-point calibration. When a pouch cell was placed directly in the CompreCell Pouch cell fixture, pressure mapping revealed that almost all the pressure was concentrated to a few "hot spots" due to the uneven thickness of the pouch cell. The use of foam compression pads instead led to a very smooth and even pressure distribution. During cycling in constant volume mode, an increase in pressure in the charged state was apparent both in the total force recorded by the CompreDrive, as well as in the *in operando* TekScan pressure mapping sensor. On the other hand, this pressure increase was absent (in both sensors) while cycling the cell in the actively regulated constant pressure mode of the CompreDrive.

Acknowledgements

These tests were performed in collaboration with CMV Hoven GmbH, which is greatly acknowledged for providing the TekScan equipment setup.

Literature

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