Pressure Matters

Jensen Rocha, Heng Wang, Dr. Joe Stallard, Prof Michaël De Volder
CamVolt LTD, London, United Kingdom

Rechargeable batteries, including lithium-ion batteries (LIBs) and lithium-metal batteries (LMBs) have a critical role in the renewable energy transition as energy storage vectors for grid storage, transportation, and other difficult to decarbonize sectors[1]. This diverse set of applications makes it important that batteries have key properties such as high specific power, high capacity, and long cycle life[2].

However, LIBs and LMBs are complex, heterogeneous systems, where material, mechanical, and electrochemical properties are tightly interlinked. As a result, achieving key performance metrics like high power, capacity, and long cycle life often requires careful protocol optimization, making it critical to control external conditions in laboratory testing to ensure industrial scalability. One critical external property that has been historically difficult to control is the external stack pressure.

Applied stack pressure, which is integrated into industrial battery applications through battery module and pack design has been shown to impact the specific power, capacity, and cycle life of batteries, varying with material choice. The value of applied stack pressure during both the formation and lifetime cycling of batteries is important to optimizing LIB or LMB performance.

For companies and researchers in battery R&D and module manufacturing, leveraging CamVolt's cutting-edge stack pressure control system unlocks optimal cycling performance. This white paper provides a concise, science-backed argument for why mastering pressure control is critical to enhancing battery efficiency and application success.

Impacts of External Pressure During Cycling

Applied stack pressure can influence the cycle life, specific power, or specific capacity of a battery by changing the overall impedance of the battery, mitigating side reactions, and changing the mechanical properties of the battery. In terms of changing the impedance of a battery, optimal stack pressure can maintain electrical contact within the electrode by adjusting electrode porosity, improving the contact area between the electrode and electrolyte, and reducing the ion transport path in porous electrodes[2–4]. These factors all serve to decrease the battery's overall impedance and improve its power density. Optimal stack pressure also extends

cycling life in batteries by moving gaseous products generated from side reactions to the edge of the cell and away from the active material[5], limiting mechanical fracture and cracking[6], and preventing electrode delamination[7]. On the flip side, too great a value of external pressure can increase impedance by contributing to degradation[8]. This can occur when stack pressure is left unmonitored during continued cycling. Internal deformation that occurs during the cycling will continue to build up, causing increased cracking of active material and insufficient wetting of electrode when the increased pressure causes electrolyte to be squeezed out of the electrodes[6,9,10].

The value of the pressure that supports improved contact but doesn't lead to overly compressing electrodes is both material and electrode-construction process dependent, varying greatly with the initial porosity and contact of the electrodes and electrolyte system.

Stack Pressure During Formation

Varying among cell chemistries, stack pressure can also be of particular importance to the successful formation of cells. During the initial formation cycle, the formation of a uniform solid-electrolyte interphase (SEI), which plays an important role in battery cycle life, is highly dependent on an optimal stack pressure[2,6]. The absence of appropriate pressure can lead to a thickening solid-electrolyte interface between particles and electrolyte which can interrupt electrical transport in the battery leading to reduced power and capacity. Non-optimized pressure application equipment can also lead to particle-level deformations which will gradually contribute to a buildup of internal stress within the pouch cell after formation and over extended cycling, leading to reduced cycle life and increased capacity fade[10–13].

Traditional Pressure Rigs

The interactions between pressure and degradation, side reactions, SEI formation, and impedance highlights the importance of optimizing pressure to improve battery performance. Such optimization requires equipment that can accurately apply a known pressure to a battery and deliver consistent application across tests.

Traditional pressure rigs used by many material scientists in R&D often involved rigid plates clamped by bolts or foam-based stacking, which results in poor control of precise and accurate stack pressure especially during the formation stage. Additionally, pressure is often applied by tightening a bolt with a torque-wrench in

an uncontrolled way. These factors prevent successful optimization of stack pressure and limits both the reliability and accuracy of the data collected, by leaving too many unknowns in application of pressure.

CamVolt Pressure Rigs

In contrast to traditional pressure equipment, pressure equipment by CamVolt applies known and even pressure to pouch cell batteries. The equipment is designed by battery engineers and scientists based in Cambridge, UK. The pneumatic press developed by CamVolt can load pressure onto cells with an accuracy of ±1.6% and a repeated accuracy of ±1%. Additionally, the bespoke solutions offered by CamVolt are designed such that the pressure rig fits perfectly with our clients' pouch cell batteries, ensuring that homogeneous stack pressure is maintained across cells. Every component is calibrated three times for high precision and accuracy before being handed to our clients, guaranteeing that the pressure being applied to a tested battery is not only known, but consistent across tests.

CamVolt's mission is to accelerate battery development by enabling researchers and engineers to collect better cycling data and better model the optimal conditions for their industrial battery application. Our high quality and carefully designed pressure products embody this mission.

Contact Us

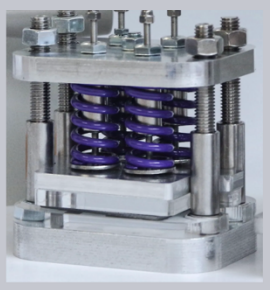
Interested in collecting the data you need to optimize your battery for pressure? Want to learn more about the pressure solutions we offer? Contact CamVolt Ltd. We would love to help you accelerate your battery research.

CamVolt Ltd - info@camvolt.co.uk

252 Shakespeare Tower, Barbican, London, EC2Y 8DR, UK

Company No. 15735364, England & Wales

Featured Products



Sprung Float Plate

Pneumatic Press

Formation Tower

References

1. IEA. *Batteries and Secure Energy Transitions*. https://www.iea.org/reports/batteries-and-secure-energy-transitions (2024).
2. Li, R. *et al.* Effect of external pressure and internal stress on battery performance and lifespan. *Energy Storage Mater.* **52**, 395–429 (2022).
3. Wang, M. J., Choudhury, R. & Sakamoto, J. Characterizing the Li-Solid-Electrolyte Interface Dynamics as a Function of Stack Pressure and Current Density. *Joule* **3**, 2165–2178 (2019).
4. Müller, V., Scurtu, R.-G., Memm, M., Danzer, M. A. & Wohlfahrt-Mehrens, M. Study of the influence of mechanical pressure on the performance and aging of Lithium-ion battery cells. *J. Power Sources* **440**, 227148 (2019).
5. Berckmans, G. *et al.* Electrical Characterization and Micro X-ray Computed Tomography Analysis of Next-Generation Silicon Alloy Lithium-Ion Cells. *World Electr. Veh. J.* **9**, 43 (2018).
6. Mussa, A. S., Klett, M., Lindbergh, G. & Lindström, R. W. Effects of external pressure on the performance and ageing of single-layer lithium-ion pouch cells. *J. Power Sources* **385**, 18–26 (2018).
7. Cannarella, J. & Arnold, C. B. Stress evolution and capacity fade in constrained lithium-ion pouch cells. *J. Power Sources* **245**, 745–751 (2014).
8. Li, X. *et al.* Investigation of inhomogeneous degradation in large-format lithium-ion batteries. *J. Energy Storage* **42**, 103113 (2021).
9. Li, Y., Wei, C., Sheng, Y., Jiao, F. & Wu, K. Swelling Force in Lithium-Ion Power Batteries. *Ind. Eng. Chem. Res.* **59**, 12313–12318 (2020).
10. Michelini, E., Höschele, P., Heindl, S. F., Erker, S. & Ellersdorfer, C. Experimental Investigation on Reversible Swelling Mechanisms of Lithium-Ion Batteries under a Varying Preload Force. *Batteries* **9**, 218 (2023).
11. Niu, S. *et al.* Analysis on the effect of external press force on the performance of LiNi0.8Co0.1Mn0.1O2/Graphite large pouch cells. *J. Energy Storage* **44**, 103425 (2021).
12. Cannarella, J. & Arnold, C. B. State of health and charge measurements in lithium-ion batteries using mechanical stress. *J. Power Sources* **269**, 7–14 (2014).
13. Louli, A. J., Ellis, L. D. & Dahn, J. R. Operando Pressure Measurements Reveal Solid Electrolyte Interphase Growth to Rank Li-Ion Cell Performance. *Joule* **3**, 745–761 (2019).