Whitepaper

Performance Comparison of Magnetic Cell Clusters (mcc©) to Conventional Welded Battery Cell Contacts

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Introduction

Today's Lithium-Ion rechargeable batteries consist of multiple cells connected in series and in parallel in order to reach the desired voltage and current ratings of the battery pack. For applications ranging from small hand tool batteries up to large automotive batteries, these contacts are usually established by welding thin sheet metals to the cell poles or connecting them by the use of bonding machines with wire. While these methods have proven to show good performance in terms of low contact resistance [1] and manufacturing cost, it is in general not feasible to repair packs in the case of defective cells or disassemble packs without destroying cells in order to use them for second life applications.

Neomium has developed an innovative concept, called Magnetic Cell Cluster (mcc©), that establishes the cell to cell contact by magnetic force and allows for economic disassembly of a battery pack down to the cell level. Compared to conventional battery pack welding technologies, this enables easy repair of battery packs in case of single defective cells and, at the end of live, for economic disassembly and efficient recycling.

This work shows that cylindrical cells, connected by the mcc© technology, result in contact resistances in the same order of magnitude as conventional methods while adding the benefits or repairability and longer battery lifetime.

Methods

First of all, the contact force of a sheet metal attached to a commercial cylindrical INR21700 (21 mm diameter, 70 mm length) Lithium-Ion cell by an 18 mm diameter Neodymium disk magnet of 3.0 mm height in grade N52 was determined by the pull force test setup depicted in Figure 1.

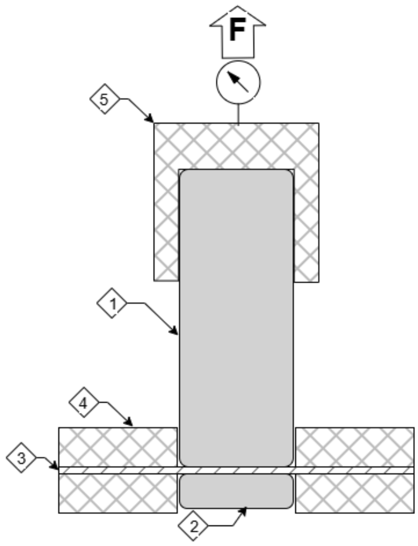

Figure 1: Setup for contact force measurement: 1 - cylindrical cell (steel), 2 - disk magnet, 3 - diamagnetic sheet metal spacer, 4 fixture plate with cell and magnet alignment holes, 5 - cell clamp

Cell (1) and magnet (2) are separated by a diamagnetic sheet metal, e.g. a 0.2 to 0.4 mm copper sheet (3) which is clamped in between two alignment plates that have holes for coaxial alignment of magnet and cell. The cell is clamped in a fixture (5) which is attached to a vertically pulling force tester. The force is measured by a strain gauge and the peak force at detachment of cell from magnet is recorded. The contact force of sheet metal to cell results from the measured peak force minus the weight of the cell body.

In order to measure the contact resistance, a cell without external insulator was mounted in a setup as indicated in Figure 2.

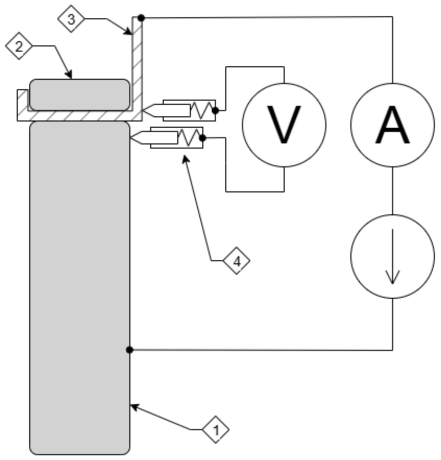

Figure 2: Setup for contact resistance measurement: 1 - cylindrical cell (steel), 2 - disk magnet, 3 - sheet metal contactor, 4 - spring loaded pins

On the flat side of the cell can (1) a bent conductive sheet metal (3) was clamped by the previously described disk magnet (2) to the cells minus pole. Two spring loaded contact pins placed less than 1.5 mm from the contact interface were connected to a precision voltmeter. Cell and sheet metal were connected in series with an amperemeter and a DC-power supply forcing a constant current through the contact interface. The Voltage determined by this 4-wire Kelvin-probe setup was divided by the applied current in order to calculate the ohmic resistance of the contact interface.

Results

The force exerted onto the contact interface between sheet metal conductor and cell can depends on the thickness of the diamagnetic copper sheet and the side of the cell where it is attached to (positive or negative pole). The results are shown in Figure 3 for INR21700 cells. It can be seen that the force is larger for the negative pole of the cell (flat side of can) compared to the positive pole where less ferromagnetic material is in the external field of the disk magnet due to the isolation gaps to the can and the safety vent present on this side of the cell.
As expected, the force drops for thicker sheet metals. This means, that for the system design the sheet metal has to be as thin as possible to increase the contact force but at the same time must not get too thin in order to obtain sufficient conductivity from cell to cell. In general, for high power applications an 0.2 mm sheet has proven to be sufficient. With this thickness the forces are always above 10N.

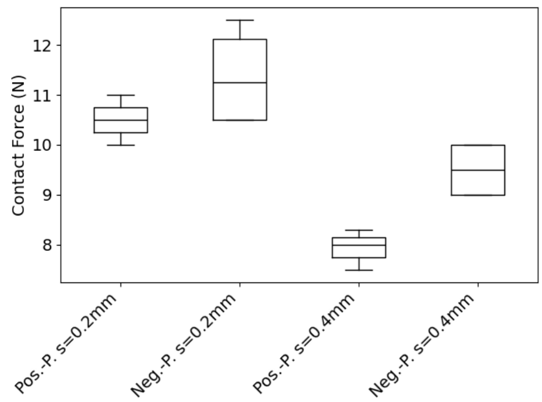

Figure 3: Contact force of D18x3.0 mm N52 disk magnet to different poles of 21700 cell with varying spacer thickness s in-between cell and magnet.

Contact resistance measurements on cylindrical cells by pressing conductors onto cells with mechanical force are well documented in literature [2], [3]. The resistance depends on multiple parameters like material, surface oxide layer thickness, roughness, and contact area[4]. Experimental results for contact resistances obtained in this work with bare copper on a D=18mm interface and purely magnetic force clamping of conductor to cylindrical cell are shown in Figure 4.

The best low resistance contact is established with bare 0.2mm bare copper sheet metal. The obtained contact resistance around 200µΩ is well in the range of values documented for laser welds in literature [2] and therefore competitive. Also, for Nickel and Nickel-plated copper the contact resistances are well below 450µΩ. Even though bare copper would return the best results here, it is known to degrade over time due to growing oxide layers, whereas Nickel surfaces are known to be more stable against corrosion [2]. Therefore Ni-plated copper sheets were found to give the best compromise with respect to durability, conductivity and contact resistance.

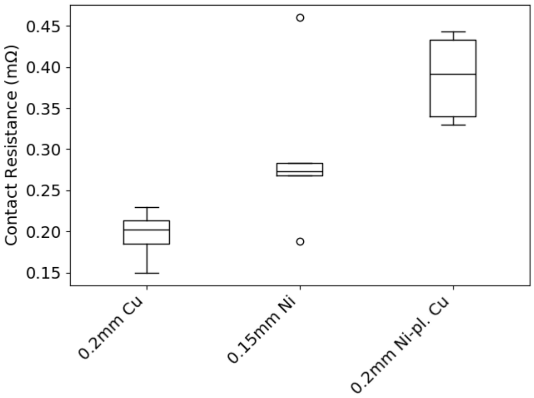

Figure 4: Contact resistance of different sheet metals clamped by a D18x3.0 mm N52 disk magnet to the negative pole of 21700 cells.

Summary

It has been demonstrated that magnetic cell contacting shows comparable performance to welded contacts with contact resistances well below 450µΩ for cylindrical 21700 cells. Even though the magnets add additional cost to the overall system, it was shown in independent studies [5], [6] that the total cost of ownership of a battery pack will be lower and battery life can be extended significantly by the ability of replacing defective cells. This is the case for the mcc© technology. Additional economic opportunities will arise in terms of circular economy and second life for used cells from mcc© battery packs.

Bibliography

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