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Procedia CIRP 44 (2016) 251 – 256

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6th CIRP Conference on Assembly Technologies and Systems (CATS)

Design of an Automated System for the Evaluation of Materials for Battery Research

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Abstract

During the development of new materials for battery production the produced materials have to be evaluated. Usually several single-layer battery cells of the developed material are assembled manually and characterized electrochemically. The results depend very largely on the manual assembly where an amount of random deviations tolerances affect the performance of the product (e.g. alignment of the electrodes or electrolyte filling).

In this contribution possible sources of errors of the manual assembly are analyzed and a conceptual design of a new assembly system for a variant flexible and size-adapted automated system for the use in compact environments is created.

Peer-review under responsibility of the organizing committee of the 6th CIRP Conference on Assembly Technologies and Systems (CATS)

Keywords: New assembly system concepts; Variety management; Battery manufacturing; Battery production; Desktop Factory; Automation; Assembly; Conceptual design

1. Introduction and motivation

1.1. Motivation

In order to increase the capacity, performance and cost of new battery systems, the capabilities of active materials have to be increased. This objective includes a number of research activities, especially in the material research and electrode processing. To develop new materials, a number of pre-development in the development phases steps can be performed. In order to check the interaction of all process steps from material research and processing test cells of the processed material are usually made (“full-cells”). The processed anode and cathode is assembled and an electrochemical characterization and performance tests are conducted.

Figure 1 shows the process steps that are necessary to create a lithium-ion based battery cell. The important steps of electrode processing are the material, particle treatment, mixing, coating, drying and calendaring. These steps have a major influence on the final battery cell and its electrochemical performance. For the evaluation of a process candidate of electrode production the materials are created with different process parameters. From these material a test cell is assembled manually. The manual assembly process for material evaluation is subjected to restrictions. The major problem is the uncontrollable reproducibility of manual work, which results in deviations of the electrochemical performance of the test cell due to a non-capable manual assembly process. For a quick and focused research evaluation of new materials, such as silicon anodes, has to be fast and efficient.

1.2. Target of this work

The manual assembly of battery cells for research purposes includes many random effects caused by the influence of human caused imperfectness and a varying efficiency. This paper gives a brief introduction to electrode processing and established methods of testing. The focus of the paper is set to the assembly of prototypic electrodes to a full cell. Here are possible errors to the evaluation of the material due to errors of the assembly identified. Based on this information automated solutions are proposed and weighted. Finally, a proposal for the design of an automated system for the evaluation of materials for battery research is made and discussed.

Peer-review under responsibility of the organizing committee of the 6th CIRP Conference on Assembly Technologies and Systems (CATS)
doi:10.1016/j.procir.2016.02.083

2. Introduction to electrode processing and common approaches of testing

2.1. Process chain lithium-ion battery development

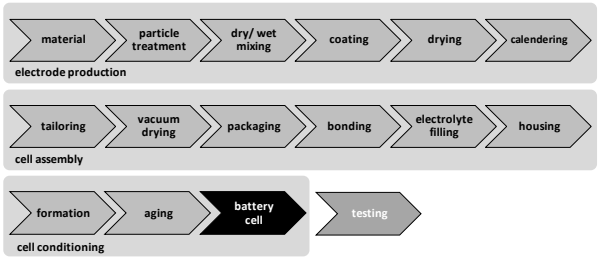

Fig. 1: Process chain lithium-ion battery production (TU Braunschweig – Battery LabFactory)

Figure 1 shows the process chain of lithium-ion production for test cells. The process can be divided in three section electrode production, cell assembly and electrochemical characterization.

The electrode production begins with the materials that form the electrochemical active and conducting part of the electrode. The particle treatment includes shearing and conditioning the material. The material is added with solvents and additives which is mixed afterwards. This created slurry is coated to a thin copper or aluminum foil (current collector). The coated foil is calendared in order to compact the material and modify the porous structure.

After the electrode production is finished the test cell assembly can be performed. From the processed electrode single sheets of electrodes are tailored and then vacuum dried in an oven to remove possible remaining of solvent or humidity. The anode is usually tailored bigger than the cathode in order to prevent lithium plating later on and reduce errors of the positioning. After this the electrodes are assembled to a package. The package consists of the anode, cathode and a separator. The electrodes of the package are bonded to an external conductor. The package then is put into a housing, gets filled with electrolyte and is sealed. The order of the steps housing and electrolyte filling vary depending on the kind of housing that is used. The electrolyte for lithium-ion batteries contains fluorine compounds, so the process of electrolyte filling is carried out under inert and dry atmosphere in order to prevent chemical reactions that alter the electrolyte and form corrosive components (e.g. hydrofluoric acid). Because of this and amongst others the sealing of the cell is usually performed under vacuum. [1]

After sealing the cell is assembled and can be electrochemical characterized. The characterization consists of the formation where the initial electrochemical active parts of the battery are formed. After the formation various test of aging or performance can be performed. Detailed methods for testing shall not be topic in this paper and can be found in common literature.

For the development of new materials or new processing strategies the process steps of electrode production are varied. The steps can be processed with a huge variety of machines and machine parameters. In order to find good processing strategies for the material a lot of research can be done on basis of knowledge, but many parameters have to be varied repeatedly and evaluated experimentally with test cells. In order to evaluate the influence of the electrochemical performance of these variations, a test cell has to be assembled and tested.

The cell assembly and conditioning have to be performed accurate and reproducible. All non-reproducible errors that are performed during the cell production and conditioning affect the results of the electrochemical performance test of the cell. With this dependence, small improvements of the electrode production can remain undiscovered because of errors in the assembly. There are different ways and established methods to assemble full-cells for material evaluation.

2.2. Manual pouch cell assembly

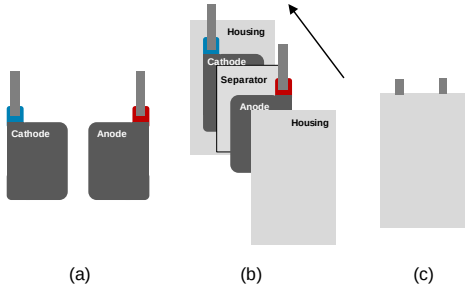

Fig. 2 Electrodes with tabs (a) cell compartment with housing (b) and assembled cell (c)

A common and established way to evaluate the material performance of full-cells is using pouch cells. Figure 2 shows the components and assembly of such a cell. The anode and cathode are confectioned into the shown shape with a current collector on one side during tailoring.

The two electrodes are placed over another with a sheet of separator and form the package. The current collectors of the electrodes are bonded to terminal tabs, that reach out of the housing later. After this step a housing of pouch-foil is created by sealing the foil together on three sides. The housing is brought to an inert atmosphere where electrolyte is filled in. Afterwards the cell is exposed to a vacuum where the housing is finally sealed on the fourth side and then prepared for the conditioning and electrochemical characterization.

2.3. Specialized test cells

Besides the described pouch cells there are a few commercial systems available, that are specialized to the evaluation of battery materials by design of a fixture and the housing. All systems aim to simplify the assembly process and increase the confidence level of the experiments. This is reached by a number of design features, which differ the assembly of this cells from the described pouch cells.

The systems usually consist of a housing, where the electrodes can be placed. In some systems the separator has to be placed as well, others have the separator fixed to the housing in a defined position. Some housings support the alignment of the elements with a spigot, otherwise the operator has to place and center the elements with a pair of tweezers or a vacuum pipette. After the positioning the elements are being wetted with electrolyte. The housing is sealed and fixes the separator and the electrodes in their current position. Afterwards the test cells can be conditioned and electrochemical characterized.