1 Research and Demonstration Center for the Production of Large-Area Lithium-Ion Cells

G. Reinhart, T. Zeilinger, J. Kurfer, M. Westermeier, C. Thiemann, M. Glonegger, M. Wunderer, C. Tammer, M. Schweier, and M. Heinz

1.1 A Short Introduction to Electromobility

One of the major aspects leveraging the global efforts to reduce CO_2 emissions is the replacement of conventional vehicles using internal combustion engines (ICEs) by electrically powered vehicles (EVs). Main barriers for a wide consumer acceptance and a high market penetration of EVs are the limitations of current high energy storage solutions. Price and specific energy (energy per weight ratio) of state of the art lithium-ion batteries will never allow the full substitution of conventional fuels by pure electric energy. Firstly, this is owed to electrochemical limitations of the lithium-ion technology regarding materials and internal energy potential [14], secondly to the in-cell weight ratio of active materials to current collector materials (Bhardwaj et al.) and thirdly to the lack of cost-effective production processes for high energy battery cells [11]. The latter demands major research in the field of automation and production technology. E.g. cycle time, process availability, tool life and scrap rate of existing production systems need to be improved in order to reduce production costs of lithium-ion cells.

To provide an insight into the production of lithium-ion batteries this paper first presents an overview of manufacturing processes and technologies along with a closer look at the research domains in those fields. Subsequently it introduces the DeLIZ research and production center for lithium-ion cells and gives a deeper insight into the respective research activities of the Institute of Machine Tools and Industrial Management *(iwb)* of the Technische Universität München (TUM). In particular, research approaches in the fields of laser cutting, cell stacking and quality assurance are discussed. The paper concludes with an outlook on future research activities of the *iwb*.

1.2 Lithium-Ion Cells: Manufacturing and Research

1.2.1 Overall Value Chain

Lithium-ion cells consist of three different types of foils: the anodes, the cathodes and the separators. These semi-finished products are manufactured in the first step of the value chain. Electrodes are made by a coating process in which an active layer is applied on a copper (anode) or aluminum (cathode) foil. Separators usually consist of porous or punctured polymer film that is extruded out of polymer granulates.

The next step is called tailoring of electrodes and separators. For z-folding and single sheet stacking, precut electrode sheets are essential. For mere stacking processes the separator foil has to be cut in advance, too. Continuous processes such as flat winding do not require tailoring prior to the cell stacking, but the material has to be cut off at the end.

In the following process step the cell is stacked. Commonly used procedures are single sheet stacking, flat winding or z-folding. Thereafter the stacked cell is finished by joining the conductors of the copper and of the aluminum foils, packaging the stack, filling the cell with electrolyte and sealing the package under vacuum. Finally, the cell is formatted (= first time charging) and transferred to a testing and grading process station. Figure 1.1 shows the complete value chain for the production of the lithium-ion cells.

Research demand in the field of automated battery production can be divided in three thrust areas. The first area is the development of adequate coating processes to ensure a continuous, homogeneous and smooth electrode compound. The second thrust area addresses the design, evaluation and acceleration of new assembly processes. The third research

G. Reinhart • T. Zeilinger • J. Kurfer • M. Westermeier (✉) • C. Thiemann • M. Glonegger • M. Wunderer • C. Tammer • M. Schweier • M. Heinz
Institute for Machine Tools and Industrial Management (iwb), TU München, Garching, Germany
e-mail: Markus.Westermeier@iwb.tum.de

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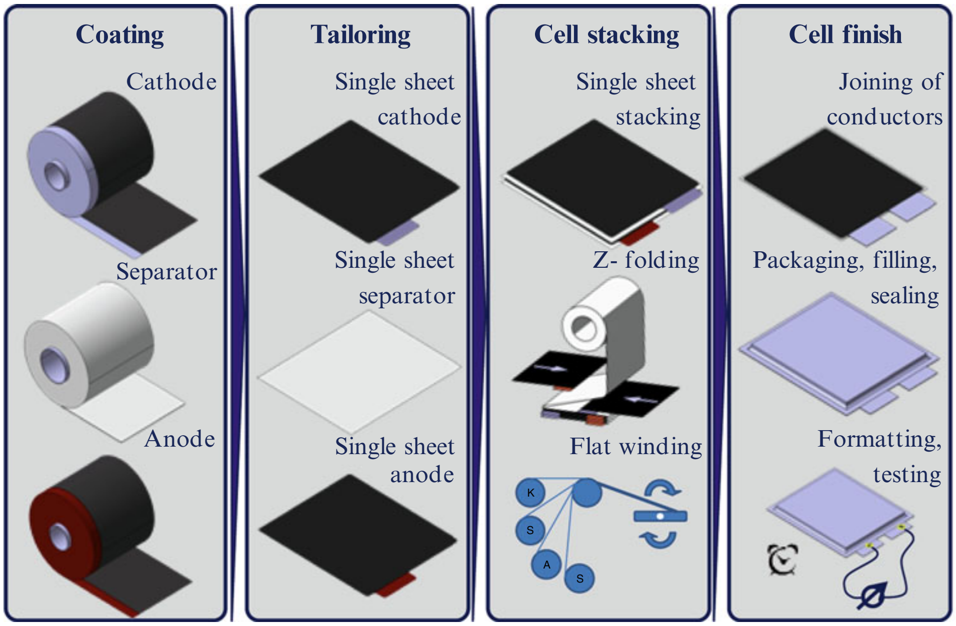

Fig. 1.1 Value chain for the production of lithium-ion cells

area focuses on scrap reduction and quality assurance. All three areas address productivity and cost-effectiveness as major research goals. In addition, coating technology and process development have a strong impact on quality, performance and safety of the assembled battery cells.

1.2.2 Coating

The first step and a core element of the manufacturing process for lithium-ion secondary batteries is the coating process of the electrodes. During coating an electrochemically active layer is set on a copper (anode) or aluminum (cathode) foil, which acts as electron collector during the ion flow within the battery cell. Depending on the cell chemistry typical materials for cathode coatings are LCM (Lithium–Cobalt–Metal) or LFP (Lithium–Iron–Phosphate) compounds mixed up with coal and binder. Those materials provide the lithium for the ionization during charge and discharge of the battery cell. The anode material is usually graphite with binder, which intercalates the lithium ions from the cathode when the cell is in use.

Main goal of the coating process is the fabrication of a continuous, homogeneous and smooth electrode compound (overall deviation of thickness $< 1.5\%$) at reasonable labor and production costs. There are two main factors that influence the process: the coating method and the properties of the slurry. State of the art coating methods are slit coating, die coating, tape casting and blade scraping [10, 18]. Slurry properties are

- Rheological characteristics,
- Density,
- Porosity,
- Adhesion,
- Coating ability,
- Stability and
- Manufacturability [4].

According to Flynn et al. [4] those depend heavily on the mixing methods such as twin screw continuous mixing, ultrasonification, dry powder blending or ball milling.

After the coating process the electrode is dried and, in the final step, compressed. Thereby the drying temperatures and drying times are crucial for the resulting electrode properties. “*Depending on the mean drying time different pore size distributions, adhesion strengths and micromechanical properties result*” [12]. The electrode compression, called calendaring, increases the coating density and reduces the surface roughness. With that, cell safety and cycle stability of the battery increase [7].

Current research areas in the field of coating technologies are for example the reduction of passive inner cell mass (current collector materials, binder) in proportion to the mass of active materials (electrode compound) [2], the optimization of the electrode surface characteristics [17] or the acceleration of coating and drying processes [12].

1.2.3 Cell Assembly

The cell assembly consists of the steps tailoring, stacking and cell finish. During tailoring the rolled materials are spread out, prepared and cut for stacking. Currently, electrodes are cut out of continuously fed material by a cycled punching process or

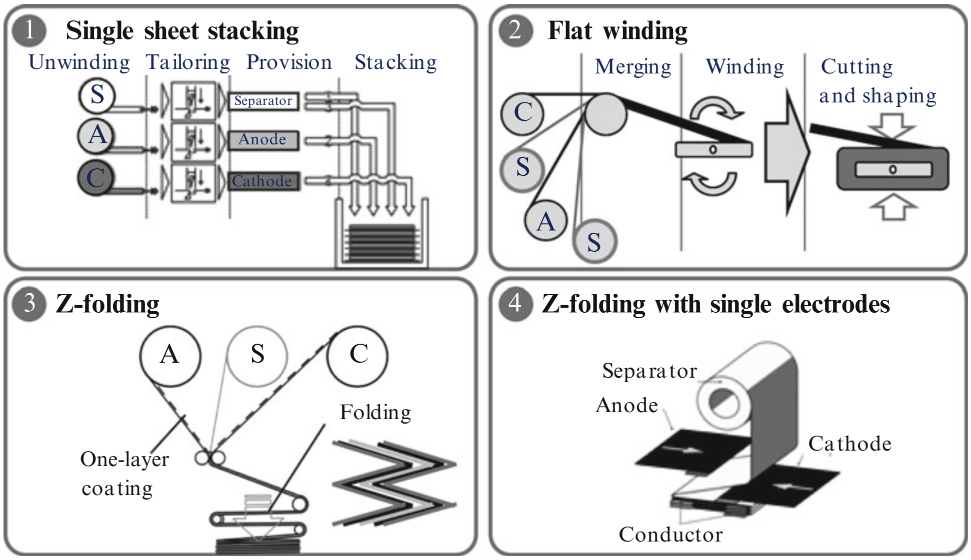

Fig. 1.2 Cell stacking processes for lithium-ion batteries

steplessly trimmed by a cutting blade. Due to the abrasive and brittle behavior of the electrode coatings, this results in poor durability of the cutting tools as well as burr formation and delamination at the cutting edges. Hence, new cutting processes need to be developed and implemented. One possible approach is the utilization of laser cutting technologies.

For the stacking of prismatic or pouch cells for automotive cells three fundamentally different processes are established (Fig. 1.2). These are flat winding [19], stacking of single sheets [16] and z-folding [5, 9]. Any of these processes are adequate to produce energy storage devices based on lithium ions for electric vehicles. However, it is assumed that the cell quality and the electrical properties of the battery depend significantly on the cell stacking process. In Asia the most applied process is flat winding, a procedure well known for consumer cells. Cell manufacturers in Europe favor production systems based on a single sheet stacking process. Until now, neither both stacking and winding have been methodically compared, nor have these processes been benchmarked against the newer z-folding technique.

The cell finish, as the last part of the cell assembly, follows the stacking process. It covers

- Joining of the copper and aluminum conductors,
- Packaging the stack into a thermoformed aluminum barrier film or a rigid metal case,
- Filling in the electrolyte,
- Sealing the package under vacuum and
- Formatting and testing the cells.

A critical step of the cell finish is the joining of the conductor lugs. Currently, this is realized by means of ultrasonic welding processes. The investigation of alternative processes, such as laser welding, promises joints with improved properties in terms of electric resistance and mechanical durability. The leak tightness of the filled and sealed cells, particularly in the area of the conductor lugs, is also an important issue. For instance the pretreatment of the sealing surfaces by plasma processes is a starting point for further investigations. In addition, the automated testing of the leak tightness of the finished cell requires a close process control. Last but not least, formation and testing of the lithium-ion cells take a considerable amount of time and thus need to be accelerated without reducing the cell life.

1.2.4 Quality Assurance

1.2.4.1 Quality Methods in the Battery Cell Manufacturing

Innovative technologies require a sufficient monitoring of its process parameters and the product quality right from the design or planning stage [13]. This allows both, an optimization of the production process at an early stage and the detection of possible defects. That way a high standard of quality and safety can already be guaranteed to the customer with the first delivered products. Concerning these matters, the main challenge in the production of lithium-ion cells is the wide influence of every single production step on the final product quality. Until now, for most of the process steps of lithium-ion cell manufacturing, there are no appropriate procedures for continuous in-line quality assurance available. Therefore, research activities in this field follow two major objectives: On the one hand, a comprehensive process quality management concept needs to be developed to ensure the overall process and product quality. On the other hand, non-destructive testing methods for critical production parameters and quality-relevant cell properties need to be evaluated and selected in order to allow in-line process control.

1.2.4.2 Quality-Relevant Properties of Lithium-Ion Cells

One of the most important properties that have a serious influence on the quality of lithium-ion cells are particle-free electrode and separator foils. The critical particle size is expected to be about 30 μm, because larger particles might penetrate the thin separator, whose thickness is usually less than 30 μm. Although these particles do not inevitably cause an immediate damage of the separator, considering regular shocks and vibrations in EVs, a defect might appear at a later time when the cell is in use within a running battery system.

Any penetration of the separator might cause an internal short-circuit. This not only leads to a high self-discharge rate of the battery cell and therefore reduces the battery capacity and its general performance, but also involves the peril of an explosion due to a thermal runaway of the cell. Other types of defects in separator and electrode foils such as cracks, holes, inclusions, delaminations or coating irregularities reduce the effective electrode surface and therefore lead to a decrease in the general cell performance. Furthermore, due to multiple charging and discharging cycles these defects might act as seeds for more serious defects in the long-term usage of batteries.

There also exist high quality requirements for the edges of the ready-for-use electrodes. The edges, which are mostly affected by the cutting process, must not show a burr as it can damage the separator analogous to particles. Furthermore, any flaking of the electrode coating at the edges needs to be avoided, because this will reduce the effective electrode area.

The positioning accuracy of the electrodes in the cell stack is another influencing factor on the cell quality. An anode or cathode that is positioned incorrectly, i.e. exceeds a tolerance of about 0.1 mm, negatively influences the electrical and chemical behavior of the cell. This results in a reduced capacity and lifetime of the battery or, if the electrode is placed beyond the separator's edge, can cause a short-circuit within the cell [10].

After stacking and fixing the cell stack, all anodes and all cathodes plus a conductor are joined by a welding process. The resistance of the electrical contact between all components needs to be as low as possible to avoid local heating, loss of energy and reduced cell performance. Furthermore, the mechanical strength needs to be high and durable, because all joints have to cope permanently with shocks during the operation of the vehicle.

A further challenge associated with the manufacturing of lithium-ion cells is the contamination by water, e.g. air moisture. At normal atmospheric conditions water is drawn out of the air and incorporated into the hydrophilic electrode coating. The water molecules in the electrodes can lead to a chemical reaction with the conducting salt contained in the electrolyte [15], so that the resulting abrasive hydrofluoric acid influences the condition of the battery negatively.

Consequently, due to their strong influence on the overall battery quality all of the aforementioned cell properties as well as the underlying critical process parameters need to be supervised reliably.

1.3 The Research Project DeLIZ

1.3.1 Overview

The research and demonstration center for the production of large-area lithium-ion cells (DeLIZ) is a research project funded by the Federal Ministry of Education and Research (BMBF) and supervised by the Project Management Agency Karlsruhe with subsidies provided by the Konjunkturpaket II. The main objectives of DeLIZ can be summarized as follows:

- Finding solutions and technologies for the industrial bulk production of lithium-ion cells;
- Establishing research infrastructure and production facilities on demonstrator levels at the involved research institutes;
- Transferring the results into industrial applications.

The partners, the Fraunhofer IWS Dresden, the Technische Universität Dresden (TUD) and the Institute for Machine Tools and Industrial Management (*iwb*) of the Technische Universität München, cooperate on different levels along the value chain of the lithium-ion cells. Thereby, the Fraunhofer IWS focuses on the coating of the anode and of the cathode material as well as the fundamental research in the field of laser cutting. The automated, laser based tailoring of the electrodes, the cell stack assembly and the fixation of the stacks are researched and enhanced by the *iwb*. The fixed *iwb* stacks are then shipped to the TUD and the IWS in order to join the conductors. Finally, the cells are completed at Li-Tec Battery GmbH where they are filled with electrolyte, sealed, formatted and tested.

According to the project goals the research topics at the *iwb* address the reduction of production costs and the increase of the cell quality. Improved process steps, such as separation of the electrodes by laser cutting, cell assembly by means of an innovative z-folding process and an advanced quality inspection system are part of this strategy. The demonstration center at the *iwb* consists of three major parts: a laser cutting module, a z-folding machine for single electrode z-folding and an integrated quality assurance system.

Fig. 1.3 Climatic chamber at the *iwb*

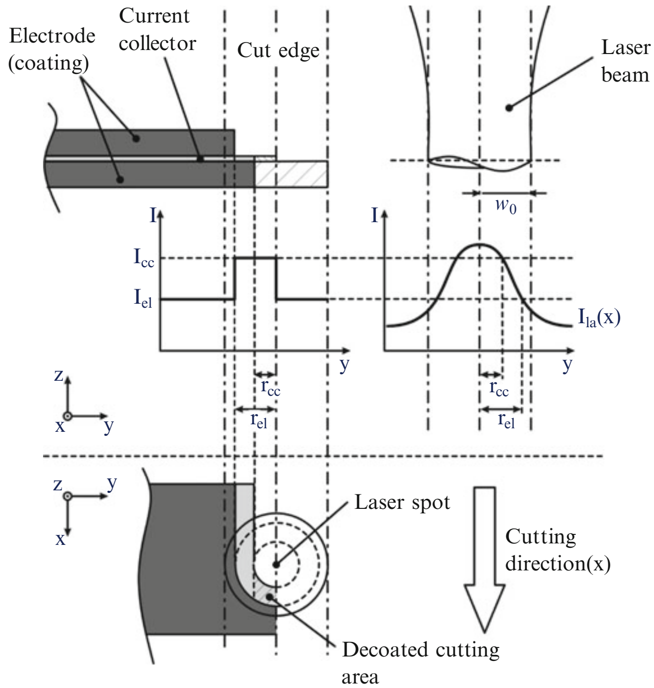

Fig. 1.4 Intensity threshold and cutting edge geometry during electrode laser cutting

In order to provide real production conditions, the demonstration center is built up in a climatic chamber. This facility guarantees the steady and dry production atmosphere required for processing electrolytes and lithium based coatings, which are both sensitive to water and moisture. The former react with water releasing fluoric acid, which is extremely toxic to humans and harmful for the inner cell materials. Nevertheless, new research results have shown that a certain and very little amount of water that is intercalated in the electrode coatings increases the cell performance [7], so that the regulation of the water concentration in the production area is very important. The climatic chamber was built up in cooperation with KlimaSYStems GmbH & Co. KG. The room enables a cell production with humidity of less than 0.07 g water per kg air, equivalent to a dew point of −42°C. This water concentration can be reached through a drying system containing an air cooler and an adsorption dryer. In the climatic chamber two additional air connectors can be used to directly flood the production machines with dry and clean air. Furthermore, an exhaust system enables the climatic chamber to house the process of electrolyte filling, which is planned to be realized in a later expansion of the production system. Since the machines for cell production use compressed air in different applications, a special air drying and cleaning system (KAESER Kompressoren GmbH) was installed. Consequently, even a potential cleaning process of material surfaces with compressed air is possible. Figure 1.3 shows the climatic chamber at the *iwb* testing area.

1.3.2 Laser Cutting

Mechanical cutting processes, such as die cutting, are state of the art for tailoring of electrode foils. Drawbacks of these processes are high investment costs and tool wear. Additionally, a change of the electrode format inherently goes along with a redesign of the cutting tools and results in significant setup costs and time. Hence, a laser cutting process is a promising alternative for the substitution of conventional die cutting. Since laser cutting is a contactless process, it is free from wear, offers a fast and flexible adaption of cutting geometries and provides increased process speeds compared to conventional cutting technologies within the same investment range. In the research project DeLIZ the decollation of the electrodes is realized by means of a recently developed and completely automated production line. The implemented separation process is laser sublimation cutting.

The coated electrodes are multi material systems, in which every material has its own intensity thresholds for sublimation. Figure 1.4 shows the cutting edge and the cutting geometry in correlation with the laser intensity (I_{la}).

For the removal of the coating relatively low laser intensity (I_{el}), as occurring on the rim of the beam waist (w_0), is sufficient. The sublimation of the current collector materials, in particular the copper foil, requires higher laser intensity (I_{cc}). Hence, when cutting electrodes continuously, the focus area of the laser beam with high intensity (radius r_{cc}) is always cutting metal foil which is already free from coating (stripped area radius r_{el}). Thus, assuming a gaussian shaped intensity distribution of the laser beam, as shown in Fig. 1.5, the laser beam will necessarily sublimate a wider band of electrode material than of current collector material, due to

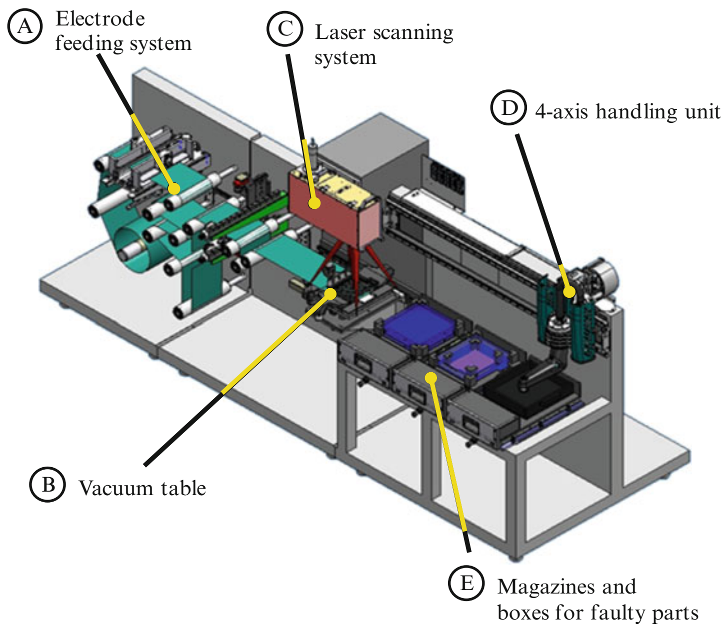

Fig. 1.5 CAD model of the automated laser cutting system for electrodes

their different sublimation thresholds. As a consequence laser radiation with small focus diameter is to be preferred, since the cutting process results in a sharper cutting edge with a smaller decoated zone.

For the cutting of copper foils laser radiation with short wavelengths is advantageous, since the absorptance of copper at the visible wavelength range is higher when compared to that of the infrared spectral range [3, 6]. In order to minimize the heat affected zone, a laser with short pulse width should be used. While the material is exposed to laser radiation, energy is absorbed and transferred into heat, which is then conducted to the surrounding material. This effect leads to an increased temperature in the area of the cutting kerf that can result in thermal damage of the coating. Therefore, continuous wave lasers are inappropriate for this application. Lasers with a pulse width in the range of nanoseconds are a reasonable tradeoff between reduction of thermal damage, achievable cutting speed and investment costs. However, more expensive laser sources emitting in the visible, green spectrum (frequency doubled disk lasers, $\lambda \approx 515$ nm) would perform even better in cutting the copper foils for the anodes. Lasers with ultra short pulse widths have not been investigated, since they are not expected to be industrially used for the manufacturing of lithium-ion cells due to their high investment costs.

Besides the aforementioned aspects, the type of laser also affects the contamination of the cutting edge. Laser sources with pulse energies in the range of 1 mJ or more lead to small particles which remain in the area surrounding the cutting kerf. This can be avoided by reducing the pulse energy to 0.1–0.2 mJ. The possible cutting speed is increasing with the available laser power and pulse frequency respectively. For instance a cutting speed of 0.5–1 m/s requires a laser that provides a power in the range of 100 W. The fully automated laser cutting module set up in DeLIZ (Fig. 1.5) is based on a pulsed fiber laser by IGP Photonics. This generator features the following properties:

- Wavelength: 1,064 nm
- Beam quality: M = 2
- Pulse width: 30 ns
- Pulse energy: 0.2 mJ
- Repetition rate: 500 kHz
- Average output power: 100 W

Amongst all applicable laser sources, the selected laser system offers the best tradeoff between investment costs and performance. The automated cutting module is developed in cooperation with Manz Automation AG. The process sequence can be described as follows. In the first step the material is loaded into the machine by chucking an electrode roll on the clamping mandrel. The material is then unwound via a guide roll enhanced dancer system (A) which enables a constant, adequate web tension and guidance. In the next step the material is pulled by a vacuum table (B) towards the laser scanning system (C) and positioned in the laser scanner's operating range. The table is equipped with an exhaust system, which is fitted to the electrode geometry and the cutting kerf, to ensure that that the area of laser beam propagation is free from particles and gases In order to position and focus the laser beam, a 3D scanning system is used. Besides the deflection of the laser beam the scanning system adjusts the focal position of the laser beam along the z-axis, so that it can be positioned on the electrode foil surface. The working distance is about 360 mm to assure that the 350 mm by 350 mm working area of the laser is fully covered. A focus diameter of 50 µm and a Rayleigh length of 0.9 mm are achieved by a focal length of 500 mm and an optical aperture of 50 mm. During the cutting process the material is fixed on the vacuum table. Afterwards, the cut to shape electrode is taken by a vacuum gripper, moved by a four-axis handling unit (D) and is stored in a magazine (E). Electrodes with defects (faulty parts) are stored in a different box to assure that they do not infiltrate the cell assembly.

1.3.3 Z-Folding

Before developing the automated stacking machine for lithium-ion cells, a methodical comparison for the spectrum of different stacking methods has taken place in order to identify the process promising the best compromise of low costs, high yield and high quality. Conventional z-folding (Fig. 1.2, nr. 3) and flat winding processes (nr. 2), well-established in the consumer electronics sector, have serious disadvantages in processing high energy electrodes. Their coating thickness from 50 to 60 µm per layer leads to a high critical bending radius of the electrode material. By folding, winding or pressing the electrodes as usually applied during z-folding or winding processes, the coating is seriously damaged in the bending area. The consequences are a loss of active surface of the electrode and the risk of particles that can penetrate the separator. The latter can cause an internal shortcut. In contrast to conventional z-folding and flat winding, stacking of cut single sheets (electrodes and separator) is very gentle for the processed materials but, due to its sequential cycle, it is relatively slow (z-folding and winding proceed material continuously). Additionally, the handling of cut separator sheets is difficult due to of their material behavior. High electrostatic charge and porosity inhibit a controlled handling with conventional grippers. Therefore, the z-folding process with continuous feeding of the separator and single sheet handling of the electrodes, which combines the advantages of conventional z-folding and stacking (Fig. 1.6), is set up at the *iwb*. This method assures quick material processing as well as gentle, bending-free handling of the electrodes.

The technical implementation of the z-folding process as described above is also realized in cooperation with Manz Automation AG. Some of the major challenges are the handling of the separator material for the z-folding process, the positioning of the electrodes in the stack and the detection of defects on the surface of the continuously fed separator foil. These defects must be segregated out of the stack. Figure 1.7 shows a CAD model of the designed machine. The separator feeding system (A) consists of an unwinding module, a system of balancers to guide the foil

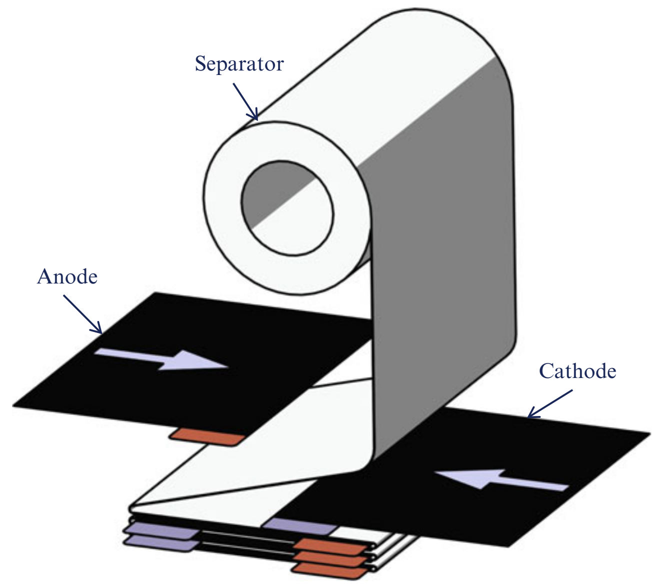

Fig. 1.6 Z-folding with single sheet electrodes

and to connect the continuous unwinding process with the cycled z-folding. The separator is fixed on a vacuum table (B), which is mounted on a horizontal linear axis. The alternating movement of the table combined with a guiding roll above the table generates a folded separator. The electrodes are provided out of magazines in sector C. They are placed in the fold by means of two 4-axis handling systems. Step by step, a lithium-ion cell is formed through the alternating arrangement of separator, anode and cathode (Fig. 1.6). Process control is provided by two vision systems for position control, a tension control system and a control mechanism for the number of layers. After the stack is finished, it is transferred to the fixing station (D) by a mechanical gripper, where the stack is fixed with tape. The system control and the control box (E) are located behind the supply sector.

1.3.4 Quality Assurance

1.3.4.1 Comprehensive Quality Assurance Concept

For a comprehensive quality assurance of lithium-ion batteries not only the current process parameters and cell properties have to be documented. In order to be able to take corrective measures at an early stage, trends within a given tolerance window must be identified, for example the cutting geometry or the homogeneity of the coating of the foil material. As there hardly exist any data of long-term experiences for the continuous operation of large area lithium-ion cells in application, it is significantly important to document

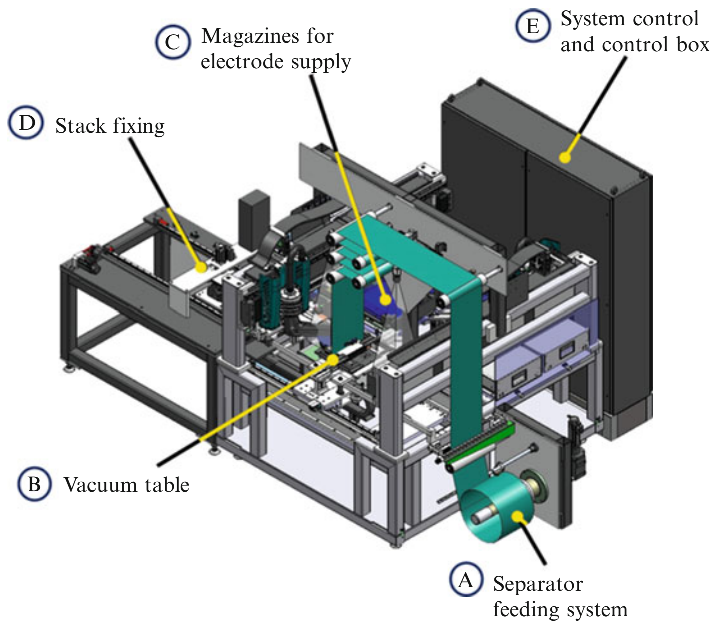

Fig. 1.7 CAD model of the z-folding module

and archive the decisive parameters of every single cell. If, despite careful monitored production conditions, a failure occurs later on, an accurately managed quality database would allow the traceability of all battery parts down to the level of manufacturing parameters [20]. On the one hand, this supports a reasonable proceeding in case of product liability issues; on the other hand, valuable knowledge concerning failure of cells can be gained.

1.3.4.2 Quality Assurance Within the Value Chain

To comprehensively control the product quality, the specific influence of all manufacturing steps on the quality as well as their relevant process parameters must be determined and analyzed. Furthermore, it is necessary to monitor and actively influence those parameters in a closed quality control loop.

Web tension and web edge control units are used to guarantee a steady feeding of foil material to the cutting and folding processes when unwinding the electrode and the separator coils. In the z-folding system additional position and attitude controls must be integrated to enable a safe process sequence. Furthermore, a detection of the electrode coating edges on both sides is necessary to adjust the laser cut in an optimal position. This is accomplished by a camera system that also allows the detection of unusable regions of the continuous web material that have been previously marked by the electrode material supplier.

During the laser cutting particles that are highly relevant for cell and process safety can emerge. Hence it is necessary to integrate a particle detection system in addition to the detection system for the cutting edge and the burr.

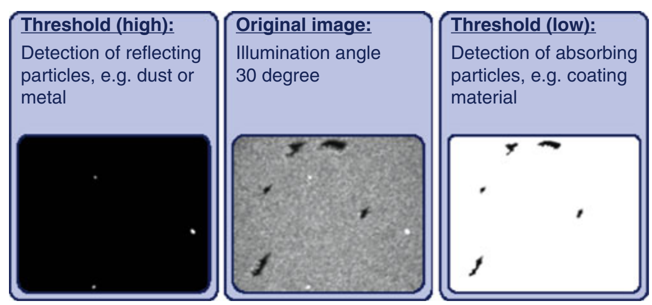

Fig. 1.8 Particle detection on lithium-ion electrodes using vision systems (particle size is approximately 50–100 μm)

In this context, the main difficulty is the detection of small particles (diam. $> = 30$ μm) on a large surface within the cycle time of the system. In the demonstrator, an optical, high resolution line-scan camera is used for electrode scanning. For this purpose, the handling unit of the laser cutting module places the electrode sheet on an inspection table, which allows a precise linear movement below a vision system of Dr. Schenk GmbH. The associated lighting is cyclically switched between bright and dark field to guarantee the best possible identification of different defects. An integrated flip unit also allows the inspection of the back side of the electrode sheets. Depending on the inspection result, the electrode sheets are then placed into a magazine or, if a critical amount of particles has been detected, discharged into a scrap box or transferred to a cleaning system. Figure 1.8 shows the results of preliminary investigations to detect particles on the electrode surface.

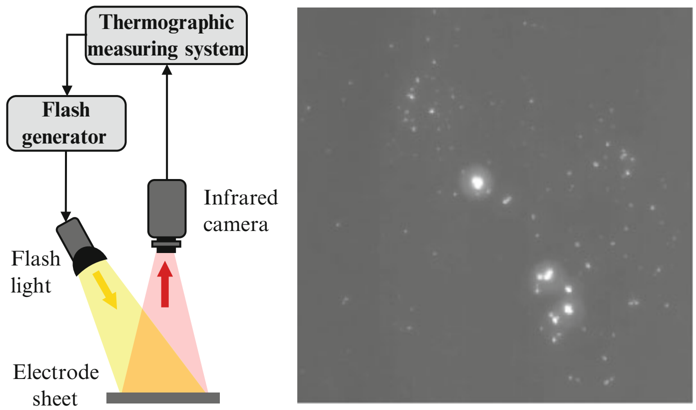

Fig. 1.9 Particle detection on lithium-ion electrodes using flashlight thermographic inspection (*left*); thermographic results for contaminated electrode sheet (*right*; particle size is approximately 50–100 µm)

The detection of very small particles in the dimension of 20–50 µm is difficult with common vision systems due to the signal noise of the electrode surface. Hence, further research will be carried out to determine and improve the particular detection limits of up to date vision systems.

A second approach for the detection of particles and contamination is the use of thermographic inspection systems (Fig. 1.9). For this purpose the electrode surface is thermally stimulated with a flashlight and the resulting heating and cooling behavior of the surface is simultaneously observed with an infrared camera. Any particles that might be present on the surface heat up much quicker and more intense than the surrounding sound surface, so that they can be identified with a high contrast in the infrared picture (Fig. 1.9 right).

Besides the monitoring of the humidity in the climatic chamber, an online humidity testing of completed stacked cell structures is advisable. Considering potential damages of the sealed electrode coils during transportation as well as new water-based coating processes, which are currently in development, the moisture content in the assembled cell structure has to be checked before its filling with electrolyte. In this context, methods of infrared-reflection, which take advantage of the special absorption characteristics of water in the cell components, are promising [8].

In order to check the conductor joints after remote laser welding, a test system needs to be developed, which can measure the mechanical strength and the electrical contact nondestructively. A possible approach is the combination of heat flow thermography with electrical testing systems.

1.3.5 Future Work

Based on the facilities of the current research center at the *iwb*, future work will focus on completion of the whole value chain of lithium-ion cells, i.e. the integration of coating technologies, cell electrolyte filling modules, cell packaging and formation. In addition to the initial experimental and conceptual results that have been gained so far, the research and demonstration center will then allow further intensive research and development in various fields of high-performance energy storage in the future. The short term research activities imply the improvement of laser cutting parameters for electrode materials and the evaluation of the z-fold process and new quality inspection systems according to their industrial transferability. Once the value chain has been completed, various process parameters can be placed in the context of the electrical properties of manufactured cells, so that dependencies on energy density, cycle stability and age behavior, inter alia, can be derived from the manufacturing parameters. In the medium term research activities at the *iwb* in cooperation with its partners will not only focus on one specific cell chemistry, but will also evaluate alternative cell materials to cope with new technologies.

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