Clean and dry - Safe air technology solutions for lithium-ion battery production

Laser technology has been used to process materials for over 50 years. Both a better understanding of beam generation and beam shaping technology, as well as more complex material structures of current products, regularly open new and challenging applications for lasers.

A recent example is the production of lithium-ion battery cells. These are used in large numbers in electric vehicles. This is a market that is currently growing exponentially, and a product that places the highest demands on reliability and service life.

Such a cell is built up in the basic production process in about 20 basic manufacturing steps. Starting with mixing the active materials, coating the electrodes, stacking the cells, sealing, and forming. In particular, the last step, "forming," shows how successful and precise the manufacturing process was. The smallest particles in the cell or even minimal amounts of water can already be responsible for rejects at this point.
But that is not all. Since alternating loads occur during operation due to continuous charging and discharging processes, a particle in the cell would be able to promote dentrite growth. Water in the cell leads to the decomposition of the electrolyte, which in turn negatively affects the service life of a cell.

Both effects reduce the operating time of a battery and must therefore be strictly controlled. The famous triad of extraction and filtration technology "for man, machine and product" is brought to life in a special way in lithium-ion cell technology.

Fig. 1: Location of the measuring equipment on the laser cutting system

Figure 1 shows a measurement setup at the Fraunhofer Institute for Material and Beam Technology (IWS). Here, anodes made of lithium were contoured by the laser. From measurement data from the fabrication of lithium anodes it could be proven that the exhaust gas volume flow contains the elements as shown in table 1/figure 2.

	M1	M2
Filter designation	24/06/SI-IWS#01	24/06/SI-IWS#02
Extraction volume	16.615 m^3	22.792 m^3
Cobalt (µg absolute)	6.34	6.23
Manganese (µg absolute)	6.96	6.52
Nickel (µg absolute)	24.44	23.88
Cobalt (µg/m^3)	0.4	0.3
Manganese (µg/m^3)	0.4	0.3
Nickel (µg/m^3)	1.5	1.0

Fig. 2: Workplace measurement, measurement results gravimetric examination

Among other things, this resulted in so-called "CMR substances", which are subject to separate consideration in TRGS 910. These "carcinogenic, mutagenic and reproduction-toxic substances" can have a massive negative impact on human health. According to the current state of the art, they must be extracted, passed with the air flow through HEPA filters (High-Efficiency Particulate Air) and separated. In addition, the air must be exhausted to the outside if employees could be exposed to it.

Since the detection of pollutants at the point of origin always plays a special and important role, it demands outstanding attention in the design process. At this point, flow simulations and visualization tests are recommended.

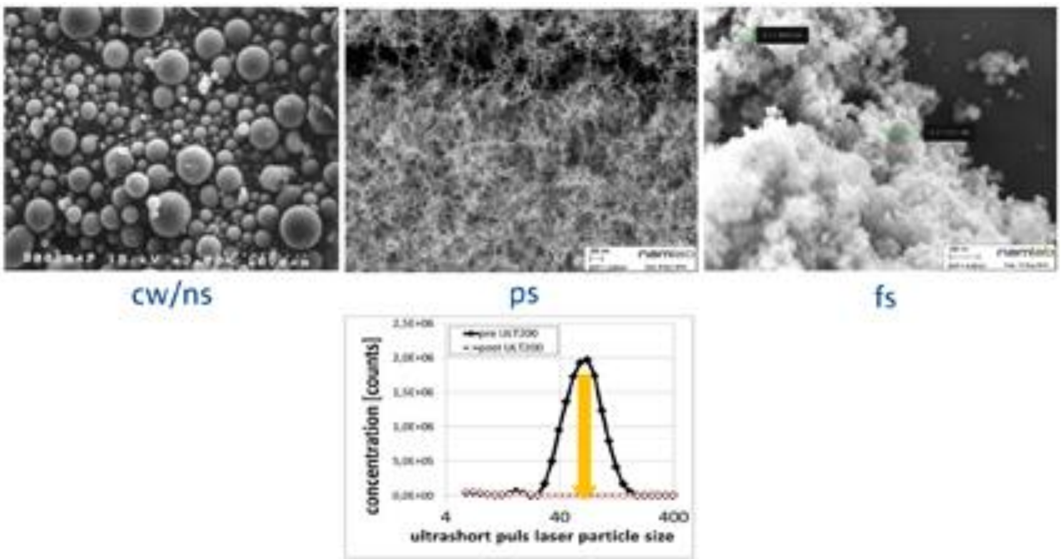

Fig. 3: Particle shapes after processing with different laser techniques.

Decisive for the downstream filtration can also be which laser process was applied. Figure 3 shows particle shapes after their processing with different laser techniques. Even though today, due to the working speed, continuous wave (cw) and nanosecond (ns) pulsed lasers are used for the most part, the quality of the cut edges often also speaks in favor of picosecond (ps) pulsed laser processes. The latter in particular produce extremely fine "ablation particles." These agglomerate to form aerosols with sizes around 100 nm. The filter technology in the extraction system must be specially designed for such particle sizes and shapes.

A system designed to meet these requirements is shown in Figure 4. The LAS 800 laser fume extraction system for air volume flows of around 800 m³/h can be quickly adapted to complex dust mixtures thanks to its integrated metering of special filter aids. These include laser fumes from ps applications, but also plastic fumes from laser processes.

Fig. 4: LAS 800 extraction and filter system for laser emissions

With the help of the procedure outlined here of an exact design of the extraction system combined with a high-quality filter technology, it is possible to design the manufacturing process for lithium-ion battery cells in such a way that reliable cells with a long service life can be created from a particle point of view.

Thus, at least one of the critical scenarios described at the beginning - the particles responsible for dentrite formation - has been eliminated.

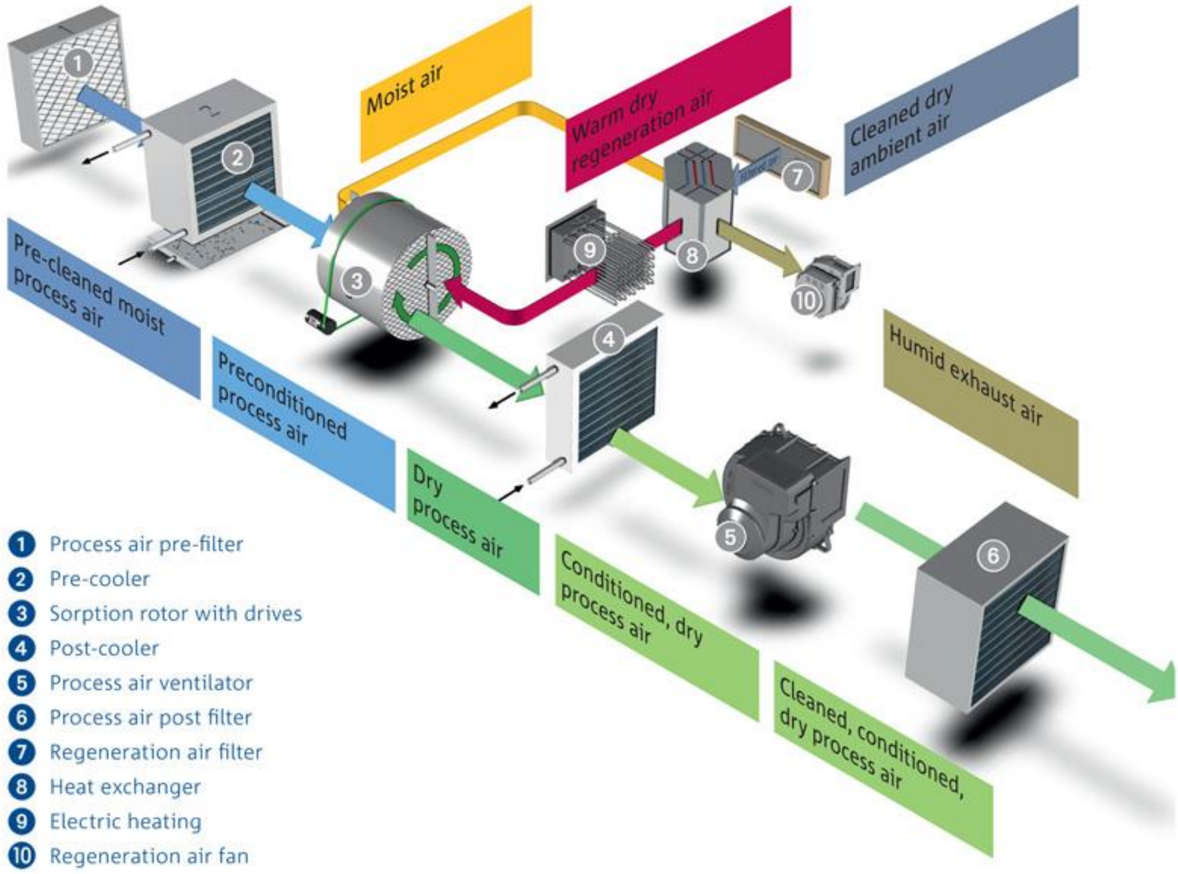

Fig. 5: Functional diagram of the sorption air drying process.

It remained open how the moisture in the process can be minimized. The sorption dehumidification technique shown in Figure 5 is suitable for this purpose. The great advantage of this approach is that the sorption wheel used allows continuous dehumidification at a constant humidity level. With the help of good control technology and heat recovery, this process can be designed to minimize energy consumption.

Particularly critical are the manufacturing steps shown in Figure 6 "Cell structure", for which it is crucial that moisture can no longer enter the cell. These steps are therefore preferably carried out at room air humidities with a dew point of less than -60°C (Tp). In this way, it is also possible to eliminate the second point of humidity which has a negative effect on the reliability of a battery cell.

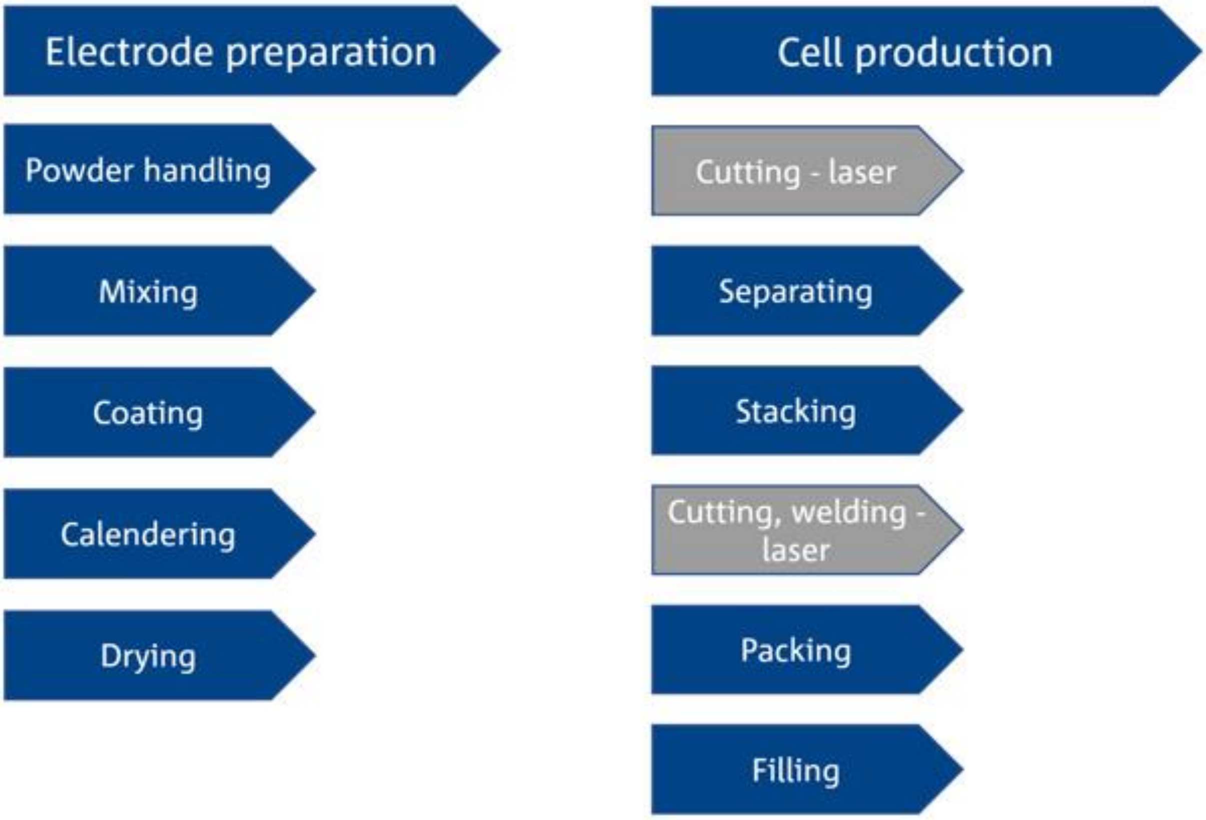

Fig. 6: Process steps in battery cell production

Great potential for process optimization and cost reduction lies in a joint coordination of the two steps - particle extraction and air dehumidification. Process control and reliability are improved, while TCO (total cost of ownership/operating total cost) is significantly reduced.

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