Development of 5 Ah lithium-ion batteries with laser-structured electrodes for improved electrolyte wetting and high C-rate capability

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Abstract

High-capacity lithium-ion batteries are composed of several layers of thick film cathodes and anodes which are separated by a porous membrane. Generally, thick film electrodes show-up with thicknesses in the range of 50 - 100 µm while the separator layer thickness is in the range of 10 - 30 µm. The texture of both the electrode and separator layers is of porous nature for allowing liquid electrolyte penetration and therefore, providing proper lithium-ion diffusion kinetics within the electrodes and separators. Nevertheless, drawbacks of thick electrodes are insufficient electrolyte wetting properties accompanied with high ohmic resistances within the layers which can counter the high C-rate capability. Furthermore, many polyolefin separator membranes suffer from insufficient electrolyte wetting as well due to pore sizes in the nanometer range. These drawbacks become even more substantial for large electrode footprints.

In order to enhance the electrochemical cycling properties of thick film electrodes at high charging and discharging rates, laser-structuring processes have been recently developed. Therefore, nanosecond, picosecond and femtosecond laser radiation has been applied for direct-writing of three-dimensional (3D) micro-structures into the thick film electrodes. It has been shown that laser-generated 3D structures exhibited both higher C-rate capability and improved electrolyte wetting.

Currently, these laser-based modification processes are under intense investigation for process up-scale from laboratory-scale to industrial roll-to-roll processes with respect to processing speed, electrode area, process compatibility and reliability. The outstanding advantages of high-capacity lithium-ion batteries with laser-structured electrodes have to be transferred to the industrial process. Advantages which result from superwicking of laser-modified electrodes are significantly lowered production costs due to reduced cell storage time-spans, enhanced cycling life-time and improved high C-rate behavior. We present the current status of investigation of a 5 Ah lithium-ion battery with laser-structured electrodes with $80 \cdot 80\ mm^2$ footprint.