Elucidating the Electrochemical Impact of the Calendering Process on Three-Dimensional Designed Electrodes for Lithium-Ion Batteries

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Significant advancements in battery technology are imperative to meet the ambitious demands for electromobility and stand-alone energy storage devices. This stems from the need to achieve operations with high energy and power density, coupled with stringent safety standards and extended lifespans, while reducing production and material costs. The preferred energy storage technology for the coming decade is anticipated to remain lithium-ion battery (LIB) technology. The focus on researching high-energy active materials to optimize this technology is paramount. In addition to optimizing materials, significant performance enhancements can be achieved by using electrodes with high mass loading and a multiscale tailored electrode design that can be scaled up to production level.

The technological challenges of achieving a breakthrough in gaining simultaneously high energy and power density characteristics while maintaining high process and operational reliability with significant cost savings are the subject of current research and development in the field of LIB technology. To tackle this, the study explores the laser-assisted generation of three-dimensional (3D) electrode architectures and assesses its impact on battery performance and future integration into battery production. The advanced electrode design involves micro and sub-micron structures that can be tailored in various ways, leading to notable improvements in battery lifespan, battery safety, and fast charging and high-power operation capabilities compared to batteries with conventional two-dimensional (2D) electrodes. High-power ultrafast laser ablation emerges as a precise method for introducing such structures.

Coordinating the production of 3D electrodes with laser assistance necessitates synchronization with established manufacturing steps in the battery production process. Notably, the calendering of electrodes holds significance due to its substantial influence on the microstructural properties of the electrode material, encompassing porosity, material density, and layer adhesion. The study investigates the impact of laser-induced structuring, encompassing micro-/nano-porosities and microtopography, on electrodes with varying mass loadings ranging from 2mAh/cm² to 6mAh/cm². Electrochemical characteristics such as high-rate capability, fast charging, and cycle lifetime are evaluated accordingly, employing cells with graphite anodes and lithium-nickel-manganese-cobalt oxide cathodes.

Keywords: 3D battery, ultrafast laser structuring, calendering, fast charging, lithium nickel manganese cobalt oxide, graphite