

Investigation of Manufacturing Strategies for Advanced Silicon/Graphite Composite Anodes for Lithium-Ion Cells

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Abstract

Due to the advancing electrification in mobility, the production capacity of cells with high power and energy density needs to be increased, while a reduction in production costs is to be aspired. For the gravimetric energy density, 350 to 400 Wh/kg are defined as a goal from the European Union for the so-called cell generation 3b, which is to be achieved by approximately 2025. For this type of next generation lithium-ion batteries volumetric energy densities of about 750 Wh/L are targeted. For this purpose, novel anode materials with increased specific capacities have to be applied. Silicon is a promising candidate for this application, since it has a theoretical specific capacity of 3579 mAh/g at room temperature, which is one order of magnitude higher compared to the state-of-the-art graphite anode material (372 mAh/g). While silicon is lithiated, a volume change of about 280 % can be observed, which reduces the mechanical integrity of the electrodes and leads to a strong decrease in capacity and therefore a short cell lifetime. To overcome this issue, several approaches are pursued, whereof the most promising candidate to fulfil the requirements of scalability for industrial applications is the utilization of silicon nanoparticles. The establishment of a water-based slurry preparation process for silicon/graphite composite anodes with a fine dispersion of the silicon nanoparticles is crucial. Several manufacturing routes are investigated with special focus on the scalability, processability, spatial distribution of the binder, silicon and graphite active material as well as on the performance during galvanostatic cycling.

For this purpose, different binder configurations are applied, where the amount as well as the degree of polymerization and substitution of sodium carboxymethylcellulose (Na-CMC) and the content of styrene butadiene rubber (SBR) are of interest. Additionally, the destruction of the silicon nanoparticle agglomerates, which can only be achieved with high intensity impact realized by a ball mill, is separated from the whole mixing process. Therefore, the destruction of the graphite active material by the ball milling process is reduced. A dry mixing process of the graphite and the conductive carbon black is investigated as well.

The implementation of additional porosity with a laser patterning process was also proven to be effective to increase the cell lifetime of silicon/graphite composite electrodes. Therefore, an ultra-short pulsed laser source is applied to generate line patterns in the composite material. This significantly improves the wetting of the electrode with liquid electrolyte, but also reduces the mechanical stress inside the electrode due to the increased artificial porosity available for volume expansion which finally leads to an immense impact on cell lifetime.