Evaluating The Impact Of Natural Polysaccharides On The Production Process Of Silicon-Dominant Anodes

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Within the ever-moving panorama of the Li-ion batteries (LIBs), some important challenges are always the leading point: first of all, the necessity of increasing the energy density, secondly, and equally important, is the improvement in sustainability. The scenario where the generation 3b LIBs will be located is based on the use of high-content silicon anode (>10%). The advantage of silicon is that it has a capacity 10 times higher than graphite, however, this great characteristic is unfortunately bound to its great expansion (up to 300%) during the lithiation step.

This drawback is due to the chemistry of silicon lithiation, nevertheless, multiple solutions have been proposed in the literature, starting from the synthesis of nanomaterials with desired shapes and dimensions, up to the research for the most suitable binder. Multiple studies have already confirmed that the mixture of carboxymethyl cellulose (CMC) and styrene butadiene rubber (SBR), actually used for the commercial graphite anodes, is not suitable for silicon-based anodes, especially in the case of silicon-dominant anodes, when the amount of silicon is over 50 wt%. The most promising material is addressed to be the polyacrylic acid (PAA), which has a great interaction with the silicon surface thanks to its greater amount of hydroxyl and carboxyl groups [1]. However, it is sometimes characterized by poor elasticity, especially when the dried electrodes are subjected to mechanical stress during the industrial process, for example, in the case of welding for producing cylindrical cells. Hence, the idea of adding some natural polysaccharides with jelling properties to improve the lack of the PAA alone. The natural polysaccharides chosen for this project were sodium alginate, pectin, carrageenan and tragacanth gum because all of them are already widely used in the food industry.

The anode composition was 80 wt% of E-Magy nanoporous silicon, mixed with 5 wt% of graphite, 5 wt% of conductive additive and 10 wt% of PAA. For the samples with the natural polysaccharides used as additives, the amount of PAA is reduced in a certain amount and a small percentage of the natural polysaccharides is added. Even though the additive was added in a very small quantity, its presence could affect the properties of the electrodes, starting with the rheology of the wet slurries up to the mechanical properties of the dried electrodes. In fact, after performing a peel test, the additives led to slight changes in the adhesion of the active material to the current collector. These silicon-dominant anodes were also tested with a rate capability test: the silicon capacity was limited at 1000 mAh g^{-1}, demonstrating that the natural polysaccharide can affect the performance, especially at high rates. In fact, at 2C, the electrodes produced with the pectin led to a discharge capacity 100 mAh g^{-1} higher than the PAA alone.

These results highlight a promising strategy to enhance the electrochemical performance of next-generation silicon-dominant anodes. At the same time, their environmental impact was calculated through a Life Cycle Assessment (LCA), comparing their production process with that of currently commercialized graphite anodes.

Reference

[1] Magasinski et al., *ACS Appl Mater Interfaces*, **2010**, 2, 3004

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