2023 U.S. DRIVE Highlight

Disruptive Silicon Anode Technology for Next-Generation Lithium-Ion Batteries.

Novel processing method for silicon nanoparticles could revolutionize lithium-ion battery anodes.

National Renewable Energy Laboratory

The National Renewable Energy Laboratory (NREL) has pioneered a novel processing technology for silicon that could disrupt current lithium-ion battery (LIB) technology. Conventional LIBs use graphite anodes – a non-domestic, critical material – that limit cell performance. Silicon can be a drop-in replacement for graphite. NREL's silicon is first made into silicon nanoparticles (Si NPs) via a process similar to semiconductor chip and solar cell manufacturing. The Si NPs are then coated with molecules that transform them into a form compatible with conventional battery electrode manufacturing. These Si NP-based anodes are free from critical materials and could be manufactured entirely with a U.S. domestic supply chain.

This revolutionary advance was made possible by years of work to understand failure processes in silicon-based LIBs. These studies resulted in strategies to engineer silicon that led directly to development of NREL's patented Si NP molecular coating technology, which can be seen clearly in images of the Si NPs with and without the molecular coating (Figure 1). Detailed studies[1] have shown this processing methodology:

1. Stabilizes the Si NP active material against degradation during handling in air, potentially simplifying manufacturing.
2. Enables full access to all the Si NP active material in the electrode during the first lithiation cycle, enhancing the available specific capacity.
3. Encapsulates the Si NP active material in an organic matrix material, mitigating cycle and calendar life performance declines.

This technology is on track to meet U.S. DRIVE's Cell Active Material Goals for Advanced High-Performance Batteries for Electric Vehicle Applications for 2025 commercialization. For instance, research-scale cells achieve the goals for cycle life, available specific capacity and nominal voltage as shown in the Figure 2. Calendar life – the major performance metric limiting commercial adoption of silicon-based LIBs – is under active investigation with promising initial results.

[1] https://doi.org/10.1039/D2TA08935A and https://doi.org/10.1002/aenm.202203921

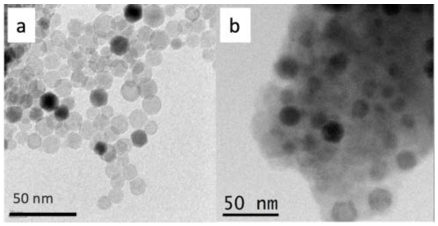

Figure 1. Images of Si NPs (a) before and (b) after applying a molecular coating and processing into an electrode.

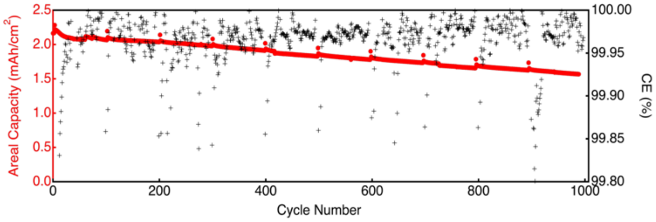

Figure 2. The cycle life of batteries containing a Si NP-based anode and an NMC811 cathode achieves U.S. DRIVE goals of cycle life >1000 with an anode available specific capacity >2000 mAh/g at a nominal voltage of 0.01 V vs Li/Li^+.

NREL/FS-5900-88587
May 2024