Multi-Stage Magnesiothermic Reduction for Uniform Silicon Oxide Anodes Enhancing Lithium-Ion Battery Performance

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BACKGROUND

Silicon is one of the most promising anode materials to replace or complement the commercial graphite in lithium-ion batteries, due to its ten times the theoretical capacity of the graphite. The main challenges for silicon anodes are pulverization and instability of the solid-electrolyte interphase caused by the large volume change (~300%) during cycling and undesirable side reactions between the active material and the electrolyte. Improving cycling stability is a key factor in silicon-based anode materials moving into the energy storage commercial market. It has been demonstrated that reducing the particle size to the nanoscale allows for silicon to withstand the (de)lithiation strains of the large volume change without fracture. However, nanosized silicon suffers from poor cycle life and low volumetric capacity density due to the unstable solid-electrolyte interphase and its low tap density.

DESCRIPTION

Researchers at the University of California, Santa Barbara introduce a novel multi-stage magnesiothermic reduction process that produces silicon oxide composites with smaller, more uniform silicon grains to improve lithium-ion battery anode performance. By limiting magnesium usage and distributing heat at each stage of the exothermic reaction, this method reduces the positive-feedback effect that typically causes uneven silicon grain sizes and formation of large silicon domains. The resulting nanosized, uniform silicon grains within the SiOx matrix demonstrate enhanced electrochemical properties including higher initial Coulombic efficiency, improved cycling stability, and better rate capability as lithium-ion battery anode materials. This approach also leverages low-cost borosilicate precursors to produce a novel electrode structure that avoids the need for carbon coatings, making it appealing for commercialization in the energy storage sector.

ADVANTAGES

- Fine control over silicon grain size resulting in smaller, more uniform particles
- Improved initial Coulombic efficiency (71.7%) and cycling stability (85.1% capacity retention over 100 cycles)
- Enhanced rate capability and consistent Coulombic efficiency during cycling
- Reduction of undesirable side reactions through silicon oxide matrix encapsulation
- Utilization of low-cost, abundant borosilicate precursors
- Elimination of the need for carbon-coating modifications
- Scalable and controllable production process suitable for commercial manufacturing

APPLICATIONS

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OTHER INFORMATION

KEYWORDS

battery, batteries, silicon, lithium, lithium-ion, energy, energy storage, electric

CATEGORIZED AS

- Energy
  - Storage/Battery

RELATED CASES

2021-972-0

- Anode materials for next-generation lithium-ion batteries with higher capacity than graphite
- Electric vehicles and portable electronics requiring longer battery life and improved cycling stability
- Energy storage systems benefiting from high-performance silicon-based anodes
- Commercial battery manufacturing seeking cost-effective, scalable silicon oxide composites
- Research and development in advanced battery chemistries and materials optimization

PATENT STATUS

Country	Type	Number	Dated	Case
United States Of America	Published Application	20230108286	04/06/2023	2021-972

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