Scalable Sustainable Anodes for Li-ion Batteries by Structural Design

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Lithium-ion batteries (LIBs) have become the cornerstone of modern energy storage technologies, widely used in applications ranging from portable electronics to electric vehicles. However, as demand for higher energy densities grows, there is a need for new anode materials that can surpass the performance of conventional graphite. Nanostructured silicon oxides (SiO_x) have emerged as promising candidates for next-generation LIBs due to their high theoretical capacity and excellent cycling stability. Despite their potential, challenges remain in optimizing SiO_x anodes, particularly in controlling the oxygen content, achievieng a nanostructured morphology and meeting sustainability criteria.

SUSTBATT proposed for the first time the use of exoskeletons of industrially cultured single-species diatom microalgae as a sustainable feedstock material for the production of nanostructured SiO_x anodes. Our results show that reproducible nanoporous SiO_2 structures can be grown at large scale by culturing diatom microalgae [1,2], and that such structures can be used as templates for the production of SiO_x materials of tailored oxygen content through scalable magnesiothermic reduction reaction [3]. Advanced characterization via XPS, XAS, TEM/EELS and XRD demonstrated that partial reduction of diatom-SiO_2 to SiO_x occurs through the formation of silicon (Si) nanocrystals embedded in the SiO_2 matrix. The nanoparticle structure is highly sensitive to the heat generated during the MgTR process, and this structure can be preserved only by incorporating controlled amounts of NaCl as a heat scavenger. The electrochemical performance of the SiO_x anodes was found to be highly dependent on the ratio of the reactants, with the optimal SiO2-to-Mg-to-NaCl molar ratio of 1:1:2.5 delivering superior capacity stability. These anodes exhibited excellent performance, maintaining high capacity after 200 charge-discharge cycles.

Nanostructures of SiO_x are now been used to fabricate full cell prototypes of high mass loading SiO_x-graphite blended anodes for LIBs. These findings provide a pathway for the development of sustainable, high-performance diatom-derived SiO_x anodes, offering key insights into the synthesis of optimized materials for future LIB applications, contributing to the advancement of energy storage technologies

References

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