MXene and hybrid electrodes for high performance energy storage

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The field of battery research continually seeks to improve energy storage capabilities while addressing sustainability concerns. This applies in particular to the exploration and development of novel materials, such as the promising material group of MXenes. MXenes, known for their two-dimensional morphology, vast chemical composition range, and excellent electrical conductivity, require the synergistic integration of conversion or alloying materials to achieve high charge storage capacities.

The presentation highlights the development of high-performance sodium-ion batteries using MXene / antimony hybrid electrodes.[1] By carefully optimizing synthesis parameters and material design strategies, researchers achieved an optimized electrode composition. This hybrid material exhibited a high reversible capacity of 450 mAh/g at 0.1 A/g, along with excellent cycling stability and rate capability. We also explore the combination of MXenes and SnO_2,[2] a conversion material, for enhanced lithium-ion battery performance of over 500 mAh/g for 700 cycles at 0.1 A/g. The researchers synthesized a nanocomposite consisting of a 50/50 mixture of SnO_2 and MXene. The resulting nanocomposite demonstrated high-capacity retention over numerous cycles and excellent rate capability.

Additionally, we demonstrate MXene electrode recycling and upcycling.[3] With binder- and additive-free MXene paper electrodes, we show the significance of finding sustainable and efficient approaches to recycle spent batteries. Researchers investigated the use of annealed delaminated MXene electrodes, obtained through vacuum-assisted filtration and annealing processes, in lithium-ion and sodium-ion batteries. The electrodes exhibited good electrochemical performance and were easily recovered through direct recycling processes, achieving high capacity recovery rates. Moreover, the cycled MXene electrodes could be transformed into TiO_2/C hybrids with adjustable carbon content, providing opportunities for their utilization in various battery and electrocatalysis applications.

Collectively, we emphasize the potential of MXenes and MXene hybrid materials for enhancing charge storage capabilities in batteries. They also underline the significance of developing sustainable recycling and upcycling approaches for MXene electrodes, contributing to the overall advancement of battery technology.

References

[1] S. Arnold, A. Gentile, Y. Li, Q. Wang, S. Marchionna, R. Ruffo, V. Presser, Design of high-performance antimony/MXene hybrid electrodes for sodium-ion batteries, Journal of Materials Chemistry A 10(19) (2022) 10569-10585.

[2] A. Gentile, S. Arnold, C. Ferrara, S. Marchionna, Y. Tang, J. Maibach, C. Kübel, V. Presser, R. Ruffo, Unraveling the electrochemical mechanism in tin oxide/MXene nanocomposites as highly reversible negative electrodes for lithium-ion batteries, Advanced Materials Interfaces 10(12) (2023) 2202484.

[3] Y. Li, S. Arnold, S. Husmann, V. Presser, Recycling and second life of MXene electrodes for Lithium-ion batteries and Sodium-ion batteries, Journal of Energy Storage 60 (2023) 106625.