Unlocking New Two-Dimensional Oxide Materials via MXene Transformation for Energy Storage

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Advancing energy storage technologies requires electrode materials with precisely controlled structure, composition, and morphology. Access to previously unattainable materials can be achieved through rationally designed synthesis pathways using complex nanoscale precursors. In this work, we demonstrate that two-dimensional (2D) MXenes serve as unique precursors for oxides that retain 2D morphology, an outcome not achievable with conventional precursors, and exhibit enhanced charge storage properties as battery electrodes. We illustrate this using V_2CT_x MXene-derived bilayered vanadium oxides (BVOs) preintercalated with Li^+ (LVO), Na^+ (NVO), K^+ (KVO), Mg^{2+} (MVO), Ca^{2+} (CVO), and Zn^{2+} (ZVO) cations. The choice of chemically preintercalated cation allows tuning of *d*-spacing and controlling the channels for ion transport during electrochemical cycling. Transformation of MXene nanoflakes through a two-step process, consisting in the reaction with H_2O_2 followed by hydrothermal treatment, results in crystallized oxides that maintain 2D morphology, with oxide nanoflakes assembling into flower-like agglomerates (Figure 1a). This unique morphology enhances cycling stability and rate capability in non-aqueous Li-ion cells [1]. Furthermore, by controlling MXene surface terminations via etching, we show that both 1D and 2D KVO nanoparticles can be obtained, with the 2D material exhibiting superior performance as a cathode in non-aqueous K-ion batteries [2]. Finally, MXene-derived chemically preintercalated BVOs demonstrate advanced cycling characteristics in aqueous Zn-ion batteries (AZIBs), with the ZVO phase outperforming other polymorphs (Figure 1b). The charge storage mechanism of ZVO electrodes in AZIBs, elucidated through a comprehensive suite of *in situ* and *ex situ* characterization techniques, will be discussed. This approach establishes a general platform for designing novel 2D oxide materials with tunable structures and compositions, opening new opportunities for high-performance energy storage devices.

References

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Figures

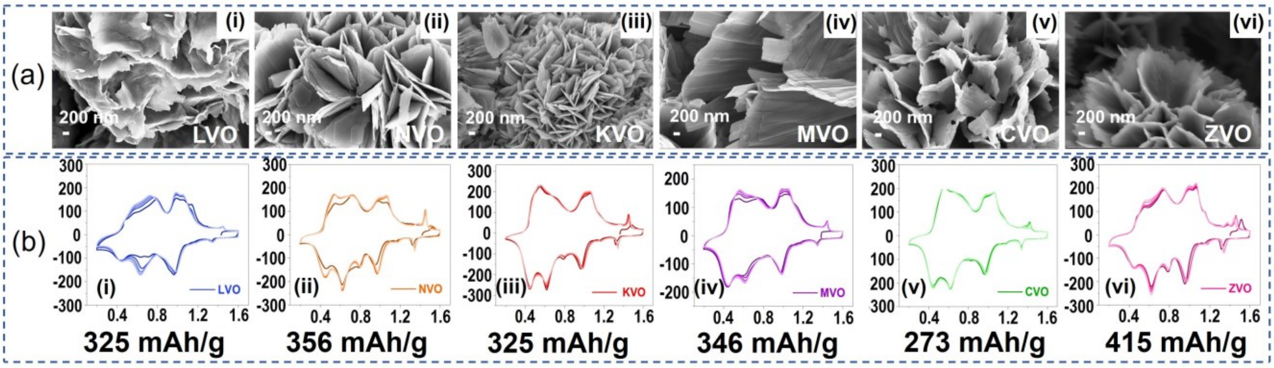

Figure 1: Chemically preintercalated V_2CT_x-derived bilayered vanadium oxides (BVOs): (a) SEM images and (b) 1st- through 5th-cycle cyclic voltammetry profiles in aqueous Zn-ion batteries with 2.6-M $Zn(CF_3SO_3)_2$ electrolyte in the potential window of 0.2–1.6 V versus Zn/Zn^{2+}: (i) LVO, (ii) NVO, (iii) KVO, (iv) MVO, (v) CVO and (vi) ZVO. In CV curves, X-axis shows potential vs. Zn/Zn^{2+} (V); Y-axis shows specific current (mA/g). The maximum capacities exhibited by each material are shown under the CV curves. LVO – Li-preintercalated BVO; NVO – Na-preintercalated BVO; KVO – K-preintercalated BVO; MVO – Mg-preintercalated BVO; CVO – Ca-preintercalated BVO; and ZVO – Zn-preintercalated BVO.