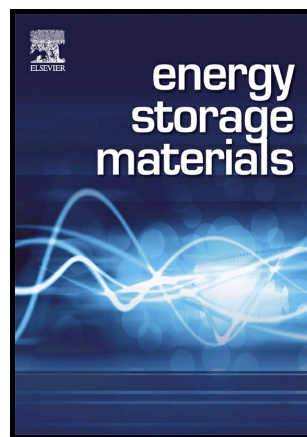


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Bilayered Vanadium Oxides by Chemical Pre-Intercalation of Alkali and Alkali-Earth Ions as Battery Electrodes

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ABSTRACT

We report the use of the chemical pre-intercalation synthesis technique to insert alkali (Li^+ , Na^+ , K^+) and, for the first time, alkali-earth (Mg^{2+} and Ca^{2+}) ions into the structure of vanadium oxide leading to the formation of the bilayered $\delta\text{-M}_x\text{V}_2\text{O}_5$ ($M = \text{Li}, \text{Na}, \text{K}, \text{Mg}, \text{Ca}$) phase with expanded interlayer spacing, enabling a large number of insertion sites for and faster diffusion of charge-carrying ions. By altering the nature of the chemically preintercalated ion, interlayer spacing of the synthesized $\delta\text{-M}_x\text{V}_2\text{O}_5$ materials was varied between 9.62 and 13.40 Å. We for the first time show that the interlayer spacing increases with the increase of the hydrated ion radius. The ion (Na^+ , K^+ , Mg^{2+} , Ca^{2+}) stabilization effect was investigated in Li-ion cells, with Li-preintercalated phase, $\delta\text{-Li}_x\text{V}_2\text{O}_5$, serving as a reference material. Our analyses indicate that cyclability and rate performance of the $\delta\text{-M}_x\text{V}_2\text{O}_5$ improves with increasing interlayer spacing. The highest initial capacity (198 mAh g^{-1}), greatest capacity retention (81.8% after 50 cycles at 20 mA g^{-1}), and highest capacity retention at higher current rates (74.5% when current rate was changed from C/15 to 1C) were exhibited by Mg-stabilized $\delta\text{-V}_2\text{O}_5$ with the largest interlayer spacing (13.40 Å). This research demonstrates the efficacy of a facile chemical pre-intercalation strategy to synthesize ion-stabilized layered electrode materials with improved electrochemical stability. Ion-stabilized layered materials with large interlayer spacing are attractive for applications that involve electrochemically driven movement of ions through two-dimensional diffusion channels, ranging from beyond Li-ion energy storage and electrochromics to actuation and water treatment.

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