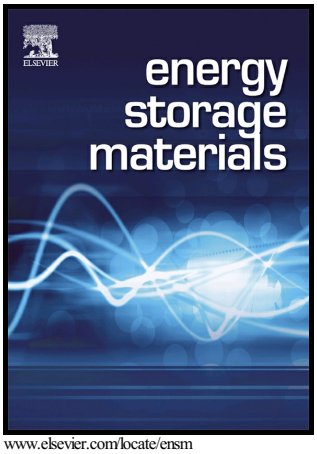

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Mallory Clites, Ekaterina Pomerantseva

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Mallory Clites, Ekaterina Pomerantseva*

Department of Materials Science and Engineering, Drexel University, Philadelphia, PA 19104, USA
* Corresponding Author: Phone: 215-571-4612; E-mail: epomeran@coe.drexel.edu

Permanent Address: 3141 Chestnut Street 27-344, Philadelphia, PA 19104

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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 δ-$M_xV_2O_5$ (M = Li, Na, K, Mg, 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 δ-$M_xV_2O_5$ 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, δ-$Li_xV_2O_5$, serving as a reference material. Our analyses indicate that cyclability and rate performance of the δ-$M_xV_2O_5$ 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 δ-V_2O_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.