

RuO₂-V₂O₅ (Aerogel) Nanocomposites as Intercalation Hosts for Li⁺ Ions

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In this paper we report on the synthesis of a high surface area V₂O₅ composite with electrically conductive RuO₂ nanoparticles as cathode materials for lithium rechargeable batteries. Highly porous vanadium oxide was synthesized by sol-gel processing routes.

Sol-gel processes have become a common method for preparing self-assembled inorganic network materials via hydrolysis and condensation reactions that start from inorganic salts or organometallic compounds. Aerogels are derived from sol-gel precursors by a supercritical drying step. In the gel stage, the solid network is bicontinuous with interconnected pores filled with liquid solvent. Removal of pore liquid by normal drying causes collapse of the solid network by surface tension forces. The smallest pores are destroyed by the collapse, and the internal surface area is reduced, sometimes by a factor of 10² or more.

Connecting the interior of porous materials with conductive nanoparticles would allow the direct electronic control of chemical reactions and the creation of nanostructures for high-density electronic materials. The goal of this study was to create such a network without greatly occluding its free (pore) volume and the surface area of the electrochemically active structure. The active material network is coated and interconnected by in situ formed ruthenium oxide nanoparticles (~10%) that ensure mechanical stability and electronic conductivity. (RuO₂)_{0.1}V₂O₅ was synthesized successfully and was found to have higher specific capacity and electronic conductivity than pure aerogel V₂O₅. Those results will be presented in this paper.

It should be noted that other workers are active in this area of research as well. Jeong and Mathiram (1) have reported that amorphous ruthenium-chromium oxides support high rate intercalation of Li⁺ ions with capacitance values that approach 800 F/g. Ryan, et al. (2) and Long, et al. (3) investigated composites of RuO_x with porous SiO₂ or porous TiO₂, respectively, and found that additions of ruthenium oxide enhanced the electronic conductivity about two orders of magnitude. In both the latter papers, RuO_x was deposited via a low temperature route that has been used to prepare polymeric composites (4,5). A recent paper by one of the present authors (6) reports on intercalation into composites of RuO_x with crystalline LiMn₂O₄. There is also previous work on aerogel films (7,8), and composites of aerogel V₂O₅ (9,10,11) was also studied recently at very low mass loadings (12) and were shown to support capacitances of 1000-2000 F/g. Porous films of electrodeposited V₂O₅ were shown to support high rates of intercalation (13). The highest rates of intercalation yet reported for V₂O₅ (aerogel) were measured on self-assembled nanofibers and revealed capacitances of 20,000 F/g (14).

We successfully obtained amorphous V₂O₅ which contained 10% (mole) RuO₂ nanoparticles. The electrochemical properties of the (RuO₂)_{0.1}V₂O₅ materials are excellent even at high mass loadings. The materials showed high lithium insertion capacity up to 400mAh/g (C/10) and with enhanced electronic conductivity of the active material. The materials showed good cycling behavior, over more than 1200 cycles. Monolithic (RuO₂)_{0.1}V₂O₅ could be an excellent cathode material for lithium batteries and for electrochemical supercapacitors.

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