Electrodeposition of V_2O_5 on nanostructured 3-D aluminium current collectors for Li-ion microbatteries

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Current rechargeable lithium-ion (Li-ion) batteries show excellent performances when it comes to energy and power density, making them ideal for consumer electronics. However, the rapid development of microelectronics and the continuous miniaturization of microelectromechanical systems (MEMS) has outpaced the development of suitable energy storage technologies. A great demand for small-scale rechargeable storage devices has therefore arisen, where higher energy and power densities on an ever decreasing electrode footprint area are needed [1]. Three-dimensional (3-D) microbatteries are currently the most promising approach addressing these requirements. Expansion in the third dimension offers an increased surface area for the electrodes while preserving the same areal footprint, as energy density is not substituted for power density [2]. Furthermore, incorporating all battery components in a 3-D arrangement results in shorter diffusion lengths for charge carriers, e.g. Li^+ ions and electrons, while contributing to the decrease of the overall volume of the device [3]. The fabrication of 3-D microbatteries requires techniques that allow the manufacturing of 3-D current collectors coated with thin layers of active materials and suitable electrolytes, e.g. polymer or solid state electrolytes [2, 4]. Electrodeposition has emerged as a particularly promising tool for this type of fabrications, enabling easy and cost-effective preparation of 3-D microbattery components [2]. Although, extensive work has been performed regarding the synthesis of nanostructured anode materials [5], there is a need for a corresponding development of 3-D cathodes. Cathode materials mainly include intercalation compounds such as: oxides, phosphates and sulphides, which require well defined lattice planes to enable reversible lithium ion transport within the structures [2, 6]. Electrodeposition of cathode materials is therefore generally more challenging than its anode counterpart, particularly as the low temperature synthesis technique limits the possibility to deposit highly crystalline materials. Vanadium oxide is an interesting microbattery cathode candidate based on its theoretical capacity of 147 mAh/g, the possibility to electrodeposit the material as well as its relative high abundance in nature [7].

This study is focused on the use of electrodeposition to coat aluminium nanorods with V_2O_5 thereby fabricating an inexpensive and versatile 3D-cathode. The intrinsic hurdles to attain stable V_2O_5 coatings without compromising the underlying Al structures are described and the crucial points addressed during the synthesis process are discussed, as well as the novel strategy implemented to facilitate V_2O_5 electrodeposition on nanostructured Al current collectors.

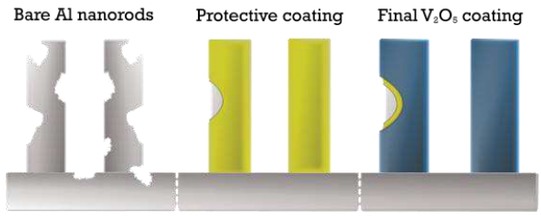

Figure 1: Schematic representation of V_2O_5 electrodeposition on Al nanorods with and without protective coating.

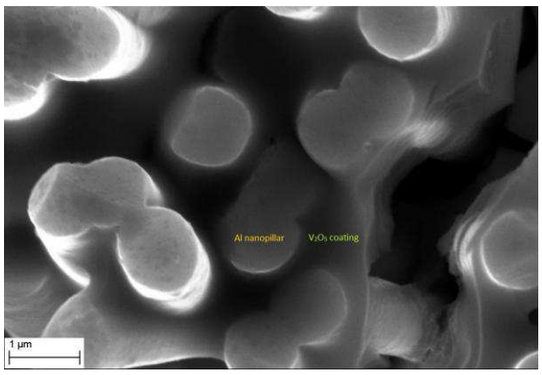

Figure 2: Electrodeposited V_2O_5 coating on nanostructured aluminium current collector.

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