Vanadium Oxide Nanotubes as Electrode Material

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Vanadium oxide nanotubes were first reported by Spahr *et al*. in 1998 [1]. Recently, we showed that this new form of vanadium oxide can be used as electrode material for rechargeable Li-ion batteries [2]. The capacity is comparable with other commonly used electrode materials.

Vanadium oxide nanotubes are synthesised as multiple layers of vanadium oxide, separated by structure directing molecules (templates), for example primary alkylamines. The embedded templates can easily be exchanged for other alkylamines or for various metal cations without destroying the tubular structure [3,4].

In general, the tubes consist of 2-30 layers of vanadium oxide and have open ends. The tube-openings range from 5 nm to 50 nm and the outer diameters are 15-100 nm (figure 1). Lengths between 1 μm and 10 μm can be obtained. Transmission electron microscope (TEM) images reveal scroll-like nano-rolls together with well developed tubes (figure 1). The formers are more abundant.

X-ray diffractograms show 00ℓ type reflections at $2\theta < 15°$ (figure 2). The d-value associated with the 001 peak corresponds to the distance between the vanadium oxide layers. Substituting larger structure-directing molecules (*e.g.* dodecylamine, $C_{12}H_{25}NH_2$) for smaller (*e.g.* Na^+ ions) results in a pronounced decrease of the interlayer distance, and accordingly a shift in the 001 peak position. The low intensity peaks at $2\theta > 15°$ (figure 2) are generated by the intralayer structure. The positions of these peaks do not change, indicating that the intralayer structure is independent of the embedded cation or molecule.

The electrochemical properties of vanadium oxide nanotubes have been discussed in recent reports [2,5,6]. We found that the capacity was dependent on the type of salt used in the electrolyte [2]. In this report, we discuss the influence of the embedded metal ion on the cycling performance. Vanadium oxide nanotubes with Na^+, K^+ and Ca^{2+} as layer separating ions have been investigated and compared to the original (*as synthesised*) material containing dodecylamine. The average capacity for these materials is around 150 mAh/g. More details concerning the cycling performance will be discussed.

References

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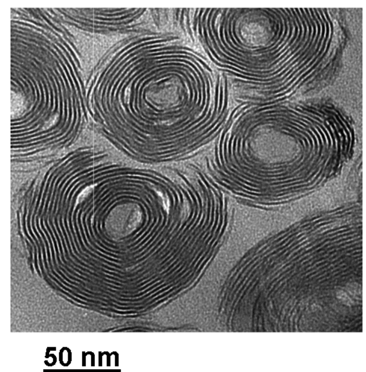

Figure 1. TEM micrograph taken perpendicular to the axis of the nanotubes. The scroll-like structure of the vanadium oxide nanotubes can be clearly seen. The displayed material was synthesised with hexadecylamine ($C_{16}H_{33}NH_2$) as template.

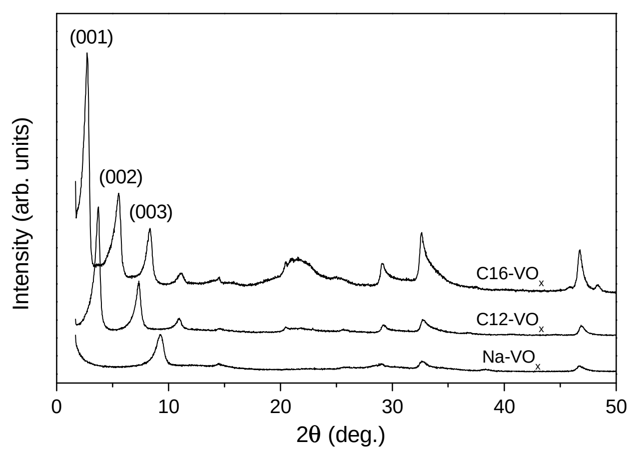

Figure 2. X-ray powder diffractograms for vanadium oxide nanotubes with embedded hexadecylamine (C16-VO_x), dodecylamine (C12-VO_x) and Na^+ ion exchanged nanotubes (Na-VO_x). The interlayer distances (as derived from XRD results) are 32 Å, 23 Å and 9.6 Å respectively.