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Structural Analysis and Electrochemical Studies of Carbon-$Li_4Ti_5O_{12}$ Nanocomposites used as Anode for Lithium Ion Battery

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Abstract:

Carbon-$Li_4Ti_5O_{12}$ (C-$Li_4Ti_5O_{12}$) nanocomposite particles have been successfully synthesized by high-temperature calcinations and carbonization using a mixture of precursors of micro-sized $Li_4Ti_5O_{12}$ and conducting black. The coating layer nature has been characterized by high resolution transmission electron microscopy (HR-TEM). The C-$Li_4Ti_5O_{12}$ exhibited a spinel cubic spherical nanocrystal with average sizes around 50-70 nm. HR-TEM images confirmed the graphitic carbon layer on the surface of the nanocrystal. Electrochemical studies of galvanostatic discharge/charge testing and cycling performance indicated that the C-$Li_4Ti_5O_{12}$particles show much improved rate capability and specific capacity. There is clear evidence of nanoscale graphitic layers uniformly coated the particles give rise to improve the kinetics of $Li_4Ti_5O_{12}$ toward fast lithium insertion/extraction, which is highly effective in improving the electrochemical properties of those $Li_4Ti_5O_{12}$ nanocomposites applied as the anode candidate in advanced Li-ion cell.

Introduction:

Spinel lithium titanate $Li_4Ti_5O_{12}$ has been considered a promising anode material in lithium secondary batteries for many years [1]. Such a spinel-type $Li_4Ti_5O_{12}$ structure does not change during the discharge-charge cycling, provides a steady voltage of 1.55 V against a lithium metal electrode [2], accommodates Li ions with a theoretical capacity of 175 mAh/g, and the actual discharge capacity is greater than 160 mAh/g [3].
In this work, we reported the synthesis and characterization of C-$Li_4Ti_5O_{12}$ particles, demonstrated that the nanocomposite particles showed the improved capacitive performance, making it an efficient and high rate electrode for the development of rechargeable Li-ion cells. The current facile reaction technique also demonstrates to be an effective method for synthesizing a promising $Li_4Ti_5O_{12}$ anode material for lithium ion batteries.

Experimental:

Firstly, micro-size $Li_4Ti_5O_{12}$ particles were hydrothermally synthesized using commercial anatase TiO_2 powders as raw materials. In a typical synthesis, a stoichiometric amount of anatase TiO_2 powder (0.4 g) was dispersed in $LiOH\cdot H_2O$ aqueous solution (60 ml). After stirring for 15 min, the suspension was transferred into a 50 mL Teflon-lined autoclave and heated at 180°C for 15hrs. Subsequently, the white precipitate was separated by filtration, and washed several times with deionized water to remove the excess hydroxides before drying at 80°C for 6 hr. Finally, the micro-size particle based white powder was mixed with carbon sources and then the mixture calcinated at 800°C for 5-10 hrs under Ar gas to obtain the spinel C-$Li_4Ti_5O_{12}$ nanoparticles. Crystal structures were characterized by X-ray diffraction (XRD).The CNT-$Li_4Ti_5O_{12}$ materials was examined using a CR2016 coin-type cell for which the lithium metal was used as a counter electrode. The coin cells were galvanostatically charged–discharged at different current densities between 1.0 and 2.5 V (vs. Li/Li^+) using a CT2001A cell test instrument (LAND Electronic Co).

Results:

Fig. 1 shows the high-resolution TEM image and the XRD pattern of C-$Li_4Ti_5O_{12}$ samples. It is clear that a nano-carbon layer with a thickness of approximately 5 nm coats the surface of the $Li_4Ti_5O_{12}$ particles, and was formed during the calcination process. The interplanar distance is measured to be 0.48 nm, corresponding to the (111) lattice planes of spinel cubic $Li_4Ti_5O_{12}$. The XRD pattern is also confirmed the formation of spinel cubic crystal phase of $Li_4Ti_5O_{12}$. All the peaks in the XRD pattern are in a good agreement with the spinel cubic $Li_4Ti_5O_{12}$ phase in the *Fd*-3*m* space group. This indicates that the carbon coating did not influence the formation of spinel cubic $Li_4Ti_5O_{12}$ during the high temperature calcinations.

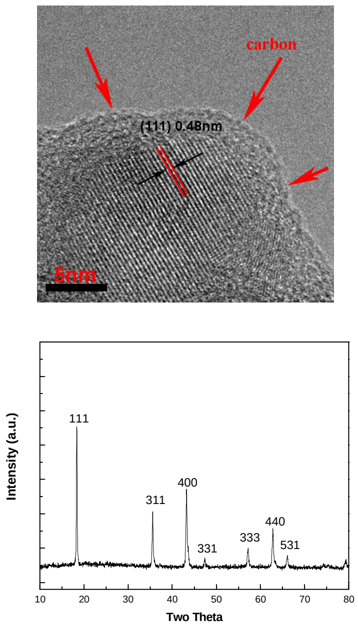

Fig.1 Typical HRTEM image and XRD pattern of C-$Li_4Ti_5O_{12}$ particles

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