Abstract:
Carbon-Li$_4$Ti$_5$O$_12$ (C-Li$_4$Ti$_5$O$_12$) nanocomposite particles have been successfully synthesized by high-temperature calcinations and carbonization using a mixture of precursors of micro-sized Li$_4$Ti$_5$O$_12$ and conducting black. The coating layer nature has been characterized by high resolution transmission electron microscopy (HR-TEM). The C-Li$_4$Ti$_5$O$_12$ 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$_4$Ti$_5$O$_12$ 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$_4$Ti$_5$O$_12$ toward fast lithium insertion/extraction, which is highly effective in improving the electrochemical properties of those Li$_4$Ti$_5$O$_12$ nanocomposites applied as the anode candidate in advanced Li-ion cell.

Introduction:
Spinel lithium titanate Li$_4$Ti$_5$O$_12$ has been considered a promising anode material in lithium secondary batteries for many years [1]. Such a spinel-type Li$_4$Ti$_5$O$_12$ 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$_4$Ti$_5$O$_12$ 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$_4$Ti$_5$O$_12$ anode material for lithium ion batteries.

Experimental:
Firstly, micro-size Li$_4$Ti$_5$O$_12$ 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 H$_2$O 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 particles 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$_4$Ti$_5$O$_12$ nanoparticles. Crystal structures were characterized by X-ray diffraction (XRD). The CNT-Li$_4$Ti$_5$O$_12$ 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$_4$Ti$_5$O$_12$ samples. It is clear that a nano-carbon layer with a thickness of approximately 5 nm coatings the surface of the Li$_4$Ti$_5$O$_12$ 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$_4$Ti$_5$O$_12$. The XRD pattern is also confirmed the formation of spinel cubic crystal phase of Li$_4$Ti$_5$O$_12$. All the peaks in the XRD pattern are in a good agreement with the spinel cubic Li$_4$Ti$_5$O$_12$ phase in the Fd-3m space group. This indicates that the carbon coating did not influence the formation of spinel cubic Li$_4$Ti$_5$O$_12$ during the high temperature calcinations.

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