Nanostructured H\textsubscript{2}Ti\textsubscript{8}O\textsubscript{17} Nanoarrays as Three-Dimensional Anodes for Lithium-ion Batteries

Zhongwei Chen\textsuperscript{1,}\textsuperscript{*}, Jin-Yun Liao,\textsuperscript{1} Xingcheng Xiao,\textsuperscript{2} 

\textsuperscript{1}Department of Chemical Engineering, University of Waterloo, 200 University Avenue West, Waterloo, ON, N2L 3G1, Canada 
\textsuperscript{2}General Motors Global Research & Development Center, 30500 Mound Road, Warren, Michigan 48090, USA

Lithium-ion batteries (LIBs) with prominent advantages of high energy and power density as well as long cycling life have now shown that they have a promising future in the coming era of hybrid electric vehicles (HEVs) and electric vehicles (EVs).\textsuperscript{1-4} However, the commercialization of LIB based electric vehicles has proceeded slower than projected, partially due to two pertinent technical challenges facing the commercial carbon based anode materials (typically graphite), particularly: (i) unstable SEI formed on graphite below high charge-discharge rates, the slow Li\textsuperscript{+} diffusion in the graphite anode materials will be a source of large polarization, resulting in decrease power density and effectiveness limiting the practical application in commercial HEVs/EVs. Being inherently safe and chemically compatible with the electrolyte, titanium (Ti) based materials (anatase TiO\textsubscript{2}, TiO\textsubscript{2}-B, Li\textsubscript{4}Ti\textsubscript{5}O\textsubscript{12}) with high operating voltages (> 1 V vs Li/Li\textsuperscript{+}) that ensure improved safety are considered the most promising alternatives to the conventional anode materials used in LIBs. Among the Ti-based compounds investigated, TiO\textsubscript{2}-B has emerged as a promising candidate boasting a high theoretical capacity of 335 mA h g\textsuperscript{-1}.\textsuperscript{5} On other hand, Idemoto et al. recently reported the use of H\textsubscript{2}Ti\textsubscript{5}O\textsubscript{12} as novel anode materials for LIBs, and depicted a higher cycling performance of 175 mA h g\textsuperscript{-1} with excellent cycling performance.\textsuperscript{6} This successfully illustrated the promise of using hydrogen titanium oxides (HTO) as a new class of anode materials for LIB applications.

In the present work, we have successfully synthesized single crystalline H\textsubscript{2}Ti\textsubscript{5}O\textsubscript{12}, H\textsubscript{2}Ti\textsubscript{5}O\textsubscript{17}, TiO\textsubscript{2}-B and anatase TiO\textsubscript{2}/TiO\textsubscript{2}-B nanowire arrays directly on a flexible Ti foil. Prepared by subjecting H\textsubscript{2}Ti\textsubscript{5}O\textsubscript{12} to heating at different temperatures, these nanowires have average diameters of 74 nm and lengths of around 15 μm. For the first time, the electrochemical Li ion insertion/extraction properties of these 3D single crystalline HTO and titanium oxide nanowire array anodes have been characterized, providing a gauge of their practical applicability towards LIBs. The prepared H\textsubscript{2}Ti\textsubscript{5}O\textsubscript{12} nanowire based electrode demonstrated optimal cycling stability, delivering a high specific discharge capacity of 157.8 mA h g\textsuperscript{-1} with a coulombic efficiency of 100% even after the 500th cycle at a current rate of 1 C. Furthermore, the H\textsubscript{2}Ti\textsubscript{5}O\textsubscript{12} nanowire electrode displayed superior rate performance with rechargeable discharge capacities of 127.2, 111.4, 87.2 and 73.5 mA h g\textsuperscript{-1} at 5 C, 10 C, 20 C and 30 C, respectively. These results present the potential opportunity for the development of high-performance LIBs based on nanostructured Ti-based anode materials in terms of high stability and high rate capability.

**References**


**Figure 1.** SEM image (a), HRTEM image (b) of H\textsubscript{2}Ti\textsubscript{5}O\textsubscript{12} nanowire, and electrochemical performance of TiO\textsubscript{2}-B and H\textsubscript{2}Ti\textsubscript{5}O\textsubscript{12} nanowire electrodes.