Hierarchically structured porous TiO$_2$ for high performance lithium batteries

Jun Jin, a Xiaoning Ren, a Liang Wu, a Junmeng Xu, a Yu Li, b* Bao-Lian Su a, b, c

a State Key Laboratory of Advanced Technology for Materials Synthesis and Processing, Wuhan University of Technology, 122 Luoshi Road, 430070, Wuhan, China

b Laboratory of Inorganic Materials Chemistry (CMI), University of Namur, 61 rue de Bruxelles, B-5000 Namur, Belgium

c Department of Chemistry and Clare Hall, University of Cambridge, Cambridge, CB3 0FA, United Kingdom

*Corresponding author: yu.li@whut.edu.cn

Rechargeable Lithium-ion batteries (LIBs) with high storage capacity and cycling stability are considered to be the versatile, clean and promising source for the rapid development on portable electronic devices, hybrid electric vehicles and electric vehicles. Titania based materials are a class of promising alternative materials to graphite as exhibiting relatively high lithium insertion/extraction voltage 1.7 V. This feature leads to better overcharge protection and safety by efficiently avoiding the solid-electrolyte interphase (SEI) layers formation and lithium electroplating during cycling process. Moreover, TiO$_2$ is an abundant, low cost and environmental benign material with a low volume change (3-4%), being suitable for energy storage.

Theoretically, lithium intercalating into anatase TiO$_2$ can reach a composition of approaching Li$_{0.96}$TiO$_2$, leading to a maximum capacity of 335 mAh g$^{-1}$. Phase transition however from the original tetragonal phase to orthorhombic symmetry caused by the elastic interaction force between the intercalated lithium ions and the formation of weak Ti-Ti interactions leads to a practically only 0.5 Li inserting into the unit of TiO$_2$. It has been reported that the porosity introduced into TiO$_2$ can improve cycling stability and capacity at high charge-discharge rates. Thus, porous TiO$_2$ structures have attracted special interests in LIBs due to their unique properties, such as high surface area, narrow pore-size distribution and good permeation.

Herein, we report various hierarchically structured porous TiO$_2$ for high performance lithium ion batteries, including mesoporous TiO$_2$ nanowire bundles superstructure with amorphous surface and straight nanochannels (HM-TiO$_2$-NB), nanosheet-constructed yolk-shell TiO$_2$ porous microspheres (NYTiO$_2$), hierarchical nanokebab of nanorods constructed TiO$_2$ hollow microspheres (HNC-TiO$_2$-HMSs), 3D interconnected cobweb macroporous structured TiO$_2$ with inner-particle mesoporosity (RPC-P TiO$_2$). All the hierarchically structured porous TiO$_2$ demonstrate very good performance with high capacity, long cycle life and rate capability. The most interesting thing is that there are Li$_2$Ti$_2$O$_4$ nanocrystallites formed for all the TiO$_2$ structures during the charge-discharge process. These results show that the hierarchically structured porous TiO$_2$ could be very promising anodic materials for lithium ion batteries.

References