Understanding of the Relationship between Electrode Structure and Electrochemical Performance in Li Ion Batteries

Chun Huang [a], Patrick S. Grant [a]

[a] *Department of Materials, University of Oxford, Parks Road, Oxford OX1 3PH, UK*

E-mail: ann.huang@materials.ox.ac.uk

Two novel electrode structures were fabricated by scalable manufacturing techniques to arrange active materials and porosity with greater precision inside the electrodes in order to improve Li ion transport.

For the negative electrode, a two layer electrode structure was fabricated by atomisation spray processing [1]. A layer of porous TiO_2 particles was first sprayed on a current collector to improve Li ion transport through the internal pores of the porous TiO_2 particles in the electrode region where Li ion diffusion is usually limited. A second layer of non-porous TiO_2 nanoparticles was then sprayed to increase volumetric capacity (Fig. 1a). The volumetric capacity of the two layer electrode was 76% higher at 2C compared with conventional electrodes with random structures of the same materials made by slurry casting. Local Li ion concentrations through the negative electrode thickness were measured directly by X-ray photoelectron spectroscopy (XPS) depth profiling and clearly showed the improvements of Li ion diffusion in the layered electrode structure over its alternatives.

For the positive electrode, a thick (900 μm) $LiCoO_2$ electrode with aligned pore arrays in the predominant ion transport direction through electrode thickness was fabricated (Fig. 1b). The aligned porosity electrode structure exhibited high areal and gravimetric capacities (14 mAh cm^{-2} and 142 mAh g^{-1} at 0.1 C) as well as a sustained rate capability (11 mAh cm^{-2} at 2 C) that outperformed the capacities (0.5 mAh cm^{-2} and 141 mAh g^{-1} at 0.1 C) and rate capability (0.3 mAh cm^{-2} at 2 C) of thinner (26 μm) electrodes containing the same materials made by standard slurry casting. X-ray computed tomography (XCT) and numerical modelling showed that the aligned porosity electrode reduced directional pore tortuosity through electrode thickness by 61% and consequently significantly improved ion transport despite the high electrode thickness.

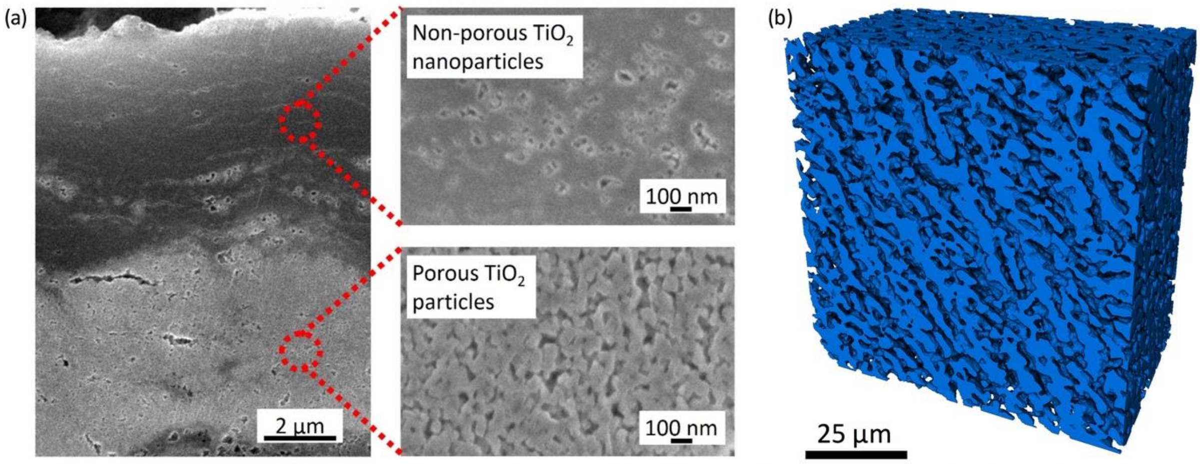

Fig. 1: (a) Cross sectional scanning electron microscopy (SEM) image of a two layer negative electrode; and (b) XCT 3D reconstruction of a positive electrode containing aligned pore arrays.

References:

[1] C. Huang, N. P. Young, J. Zhang, H. J. Snaith, P. S. Grant, Nano Energy, 31 (2017) 377-385.