Characterization of the Electrode Microstructure in Lithium Ion Batteries by Using Computed Tomography

Cheolwoong Lim[1], Yan Bo[2], Leilei Yin[3], and Likun Zhu[1]

[1]Department of Mechanical Engineering, Indiana University–Purdue University Indianapolis, Indianapolis, Indiana 46202
[2]National Engineering Research Center of Die & Mold CAD, Shanghai JiaoTong University, Shanghai, 200030, P. R. China
[3]Beckman Institute, University of Illinois, Urbana, Illinois, 61801, USA

Lithium ion batteries (LIBs) have already been employed in electric or plug-in hybrid electric vehicles such as Nissan Leaf and Chevy Volt. However, the energy density of LIBs is not high enough to support long distance commute. The LIBs used for Nissan Leaf and Chevy Volt only can support 50 – 100 miles per charge. To successfully implement the LIB technology in electric vehicles, further improvements in energy density are required. Present-day batteries have only ~50% of their volume occupied by the active materials. To increase the energy density of LIBs, new materials and processing technologies that can increase the fraction are of great interest. However, higher fraction of active materials in LIB electrodes could change electrodes' structural properties significantly, which could affect the electrochemical and thermal processes in LIBs. Therefore, it is necessary to investigate the structural properties in LIB electrodes.

In the past several years, some virtualization technologies have been developed to obtain the real configuration of LIB electrode microstructure. For instance, micro-scale morphologies of porous materials in LIBs have been reconstructed by advanced tomography techniques such as FIB-SEM (1, 2) and x-ray Computed Tomography (CT) (3-5). Compared to the homogeneous geometry model (6), the real microstructure of LIB electrodes is complicated and inhomogeneous. In this work, we analyzed the realistic microstructures of LIB electrodes in order to investigate the morphological characteristics and structural change of an aged electrode. A graphite electrode cycled at 1C rate for 2400 times and a new graphite electrode were scanned to obtain the microstructure using x-ray micro-CT technology. To represent the whole electrodes, five randomly chosen sub-divisions (50 x 50 x 50 μm^3) and five continuative sub-divisions were reconstructed for the each electrode. The structural properties such as porosity, tortuosity, specific surface area, pore size distribution and particle size distribution of the inhomogeneous geometry were calculated for the sub-division microstructures. In Fig. 1, the porosity and tortuosity results of the sub-divisions demonstrate the inhomogeneity of the graphite microstructure. Fig. 1 also shows the structure change between the new and aged electrodes. It could be caused by material loss during cycling.

Acknowledgments: This work was supported by the American Chemical Society Petroleum Research Fund and the Faculty Startup Fund from IUPUI.

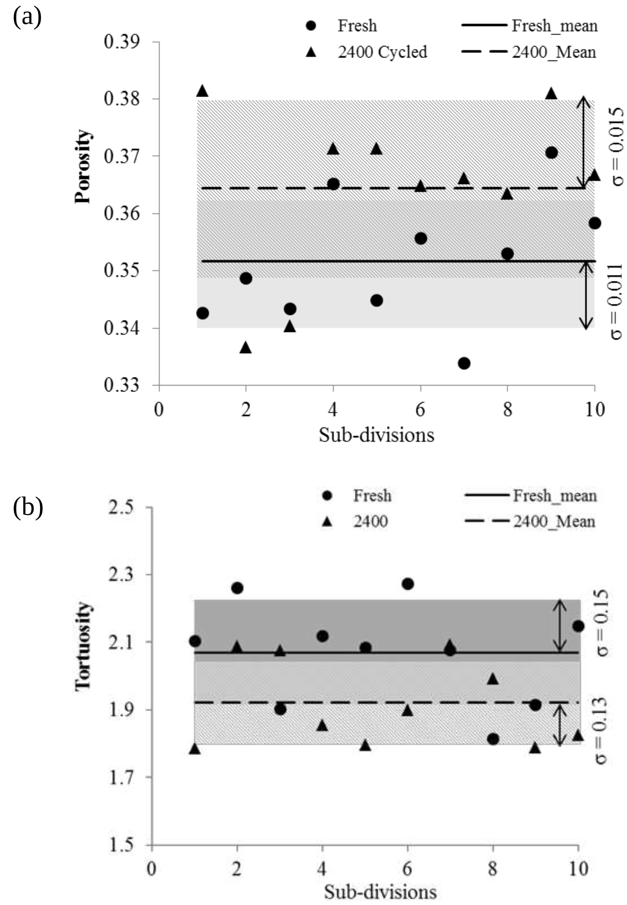

Fig. 1 Structural characterization of the reconstructed electrodes (a) porosity and (b) tortuosity.

References:
1. T. Hutzenlaub, S. Thiele, R. Zengerle and C. Ziegler, Electrochem. Solid State Lett., **15**, A33 (2012).
2. J. R. Wilson, J. S. Cronin, S. A. Barnett and S. J. Harris, J. Power Sources, **196**, 3443 (2011).
3. P. R. Shearing, L. E. Howard, P. S. Jørgensen, N. P. Brandon and S. J. Harris, Electrochem. Commun., **12**, 374 (2010).
4. B. Yan, C. Lim, L. Yin and L. Zhu, J. Electrochem. Soc., **159**, A1604 (2012).
5. C. Lim, B. Yan, L. L. Yin and L. K. Zhu, Electrochim. Acta, **75**, 279 (2012).
6. M. Doyle, T. F. Fuller and J. Newman, J. Electrochem. Soc., **140**, 1526 (1993).