Visualization of ionic hot spots using an adapted ESM method in Silicon Anodes

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Electrochemical strain microscopy (ESM) and its derivative methods are an essential set of tools to study ionic solid materials and to help understand the difficulties in the design of new materials for next generation battery systems and their aging behavior.

Methods:

This poster presents a variation of the standard ESM proposed by Balke et al. [1]. We applied this technique to study the migration behavior of Li ions in laboratory-made nanostructured silicon anodes. In standard ESM, the Li-ions in the volume underneath the atomic force microscope (AFM) tip are excited by an alternating electrical field and cause a movement of the sample surface. Contrary to the standard ESM our approach applies a longer voltage step of several milliseconds with an AC voltage overlaid. This does not only lead to a vibration of the ions but also to a change in ion concentration in the vicinity of the AFM tip. The correlated volume expansion and the amplitude in sample height increase are extracted for every image point using Matlab Software. The silicon anodes were cycled against lithium metal and discharged before measuring.

Results and Conclusion:

Two electrodes, one after 3 cycles (fresh) and one after 60 cycles (aged) are compared. In the ESM images (Fig. 1,2), a clear difference of the ESM amplitude/Li concentration appears. The fresh electrode (Fig. 1) has areas with high amplitude and well separated areas with no signal, whereas the aged electrode shows a medium Li concentration across most of the measured surface, beside a few edges. In conclusion, in the fresh sample the Li-ions are located in specific regions/grains of the electrode, whereas in the aged sample, ions are almost homogeneously distributed. Capacity loss in Li ion batteries is partly caused by a loss of active material clearly visible in comparison of the two images.

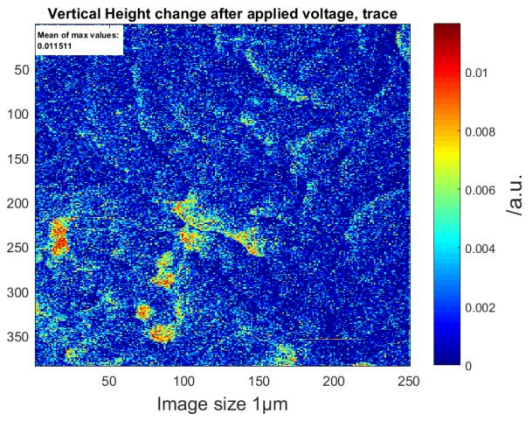

Fig. 1. ESM analysis of fresh Si anode

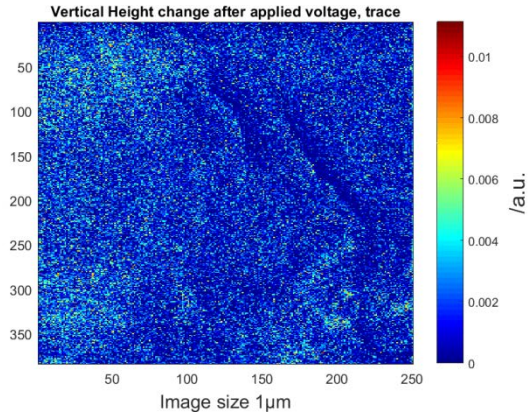

Fig. 2 ESM of Si anode after 60 cycles

References:

[1] N. Balke et al., Nano Letters, 10 (2010) 3420–3425.