Crystalline Silicon as Structured Anode Material for Lithium-Ion Batteries

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Silicon containing anodes for lithium-ion batteries have attracted much attention due their high gravimetric charge density (4211 mAh/g, $Li_{22}Si_5$) [1, 2] as compared to conventionally used graphite-based materials (372 mAh/g, LiC_6). However, as is well known, during Li uptake Si suffers from significant volume expansion. The formation of phases with quite different volumetric densities leads to mechanical tensions causing irreversible changes of the anode material. This issue can be handled somewhat by the use of nanostructured or even amorphous silicon, for example [3, 4]

Certainly, besides the attractive assets of Si in general, the use of *crystalline* silicon entails some challenging characteristics greatly affecting the cycling performance of a battery. However, it has the superior advantage that it can be processed by means of well-engineered and sophisticated lithographic manufacturing techniques which are used in semiconductor industry since many decades. Large-scale production with the possibility of easy miniaturization allows automatization on a high level and brings along low unit costs.

The present study addresses the capability of structured, crystalline semiconductor-grade silicon used as an anode material in lithium-ion batteries. We used a complementary set of techniques such as cycling in half-cell and full-cell configuration, SEM-EDX investigations using Focused Ion Beam (FIB) preparation as well as HATR/FTIR spectrometry to elaborate the usage of microstructured Si anodes as high-capacity anode material.

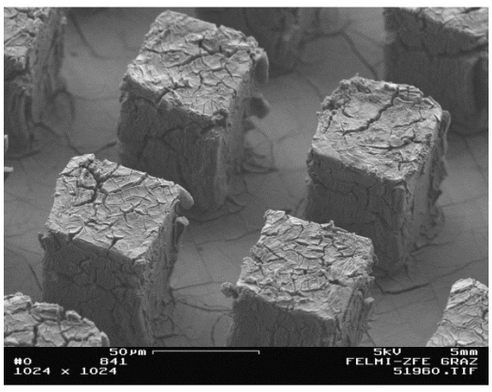

Figure 1: SEM image of a silicon anode after three cycles vs. Li in EC:EMC 3:7, 1M $LiPF_6$ at a charge density of 6,3 mAh/cm².

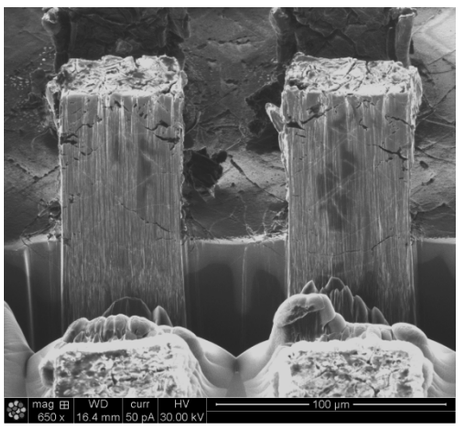

Figure 2: SEM image of a lateral Focused Ion Beam (FIB)-cut through a silicon anode after three cycles vs. Li. in EC:EMC 3:7, 1M $LiPF_6$ at a charge density of 6,3 mAh/cm².

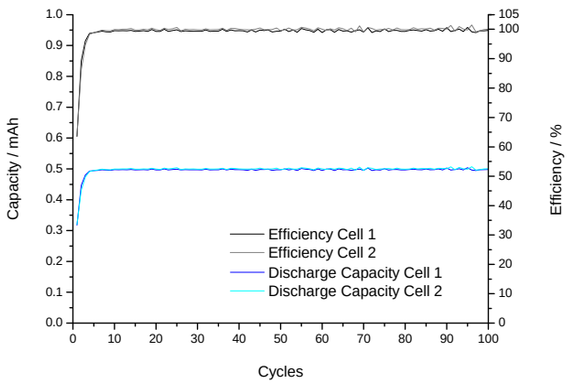

Figure 3: Cycling experiment of a quadratic 4x4 mm² silicon anode vs. NCA cathode in EC:EMC 3:7, 1M $LiPF_6$, 100 cycles at a charge density of 3,1mAh/cm².

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