Operando transmission electron microscopy observation: Dynamic structural changes of Si anode in Li-ion battery

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In the last two decades, Li-ion battery (LIB) is successfully commercialized, and used in various applications such as mobile electronics, electric vehicles etc. However, better performance such as higher power, energy density and capacity is required for next-generation LIB, which, especially, is a crucial factor for the success of electric vehicle industry. Thus, extensive studies have been conducted to seek new electrode materials to replace current electrode materials, however, some critical problems still remain unsolved, hindering the use of high capacity electrode materials and/or high energy density materials in LIB industry.

Si has attracted a great deal of attention for anode material in LIB due to its high theoretical capacity and relatively low discharge potential. In addition, Si is cheap and abundant and environmentally friendly. Despite numerous research, practical use of Si in LIB is still limited by some critical issues: severe volume changes of Si during charge/discharge, which results in poor cycle performance. Remarkable results are reported, which shows significant improvement of cycle performance through nano-engineering of Si or fabrication of Si-based composites with various buffer phases. However, the detailed structural changes of Si associated with Li+ insertion and extraction and defects structures are still unclear. Here, we developed the operando transmission electron microscopy (TEM) based on the electrochemical liquid cell to observe dynamic structural changes and electrochemical information of Si anode material simultaneously. The dynamic structural changes and detailed defects structures are investigated directly in the liquid cell by high-angle annular dark-field scanning transmission electron microscopy (HAADF-STEM) and nano-area electron diffraction techniques.