Use self-ordered mesoporous carbon (CMK-3) for anode materials of rechargeable lithium battery

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There is a big and increasing demand for portable electronic devices with high energy capacity such as the rechargeable battery and fuel cell. The lithium rechargeable battery, appearing as most promising system, attracts remarkable attention for its high energy density. However, it is still need to improve the electrode materials to obtain highest energy capacity.

Now, carbonaceous material is a main material for negative electrode in rechargeable lithium battery because it exhibits both higher specific capacity and more negative redox potential than most metal oxides, chalcogenides and polymers. The quality of lithium intercalation and deintercalation strongly depends on the crystalline phase, microstructure and micromorphology of the carbonaceous materials. The intercalation and deintercalation processes can be expressed in:

$$6C + xLi+ xe^- \Leftrightarrow Li_xC_6$$

Here x is the stoichiometric factor in Li_xC_6. Generally, the carbonaceous materials can be divided into graphitic carbon, with a perfect stacking order of crystallographic layers structure in c-direction, and non-graphitic carbon without crystallographic in c-direction. For graphitic carbon, lithium ions intercalating into graphitic carbon is almost reversible, and the stoichiometric factor x in Li_xC_6 for graphitic carbon is about 1.0. But, the non-graphitic carbon, which is synthesized at rather low temperature from 500°C-1000°C, can be also classified into "lower specific carbon", where x is about 0.5 to 0.8 for in Li_xC_6, and "high specific carbon", where x is about 1.2 to 5.0 for in Li_xC_6. Although the high specific carbon provides a remarkable high specific energy capacity, the fatal problems hinder practical application in the lithium rechargeable battery; (1) high irreversible specific charge existing in not only the initial insertion-extraction cycle but also higher cycle numbers, (2) poor cycling performance and (3) too low intercalating potential which is near to 0V or exceeding 0V (vs. Li^+/Li) for several hundreds mAh/g intercalated.

Recently, as a potential high specific charge carbonaceous material, multi walled (MWNT) and single walled (SWNT) carbon nanotube attracts more attention for their electrochemical storage of lithium by intercalation and deintercalation process. However, a high irreversible capacity C_{irr} (460-1080mAh/g) comparing with a relative low reversible capacitor C_{re} (400-100mAh/g) have been observed. A high hysteresis between the initial intercalation and deintercalation processes has been also observed just as other traditional high specific charge carbonaceous material. Now much more efforts are to find and synthesize high specific charge carbonaceous material with high reversible capacity and excellent cycle performance.

Here, we first, according to our knowledge, report a high reversible specific capacity (850mAh/g-1150mAh/g) from self-ordered mesoporous carbon (CMK-3) with good discharge (reduction) and charge (oxidation) cycle performance, which is synthesized by using self-ordered silica SBA-15 as a template. Self-ordered mesoporous carbon, first reported by Ryoo et al in 1999 through carbonizing sucrose inside the pores of the mesoporous silica template, has attracted much attention in potential application as hydrogen storage, adsorbents, catalyst supports in addition to electrochemical double-layer capacitors (EDLC).

We first observed a high specific energy capacity about 1100mAh/g (Li_3C_6) for lithium storage in the self-ordered mesoporous carbon CMK-3. After the 1st cycle, the discharge and charge remain at a reversible capacity level (Li_xC_6: x = 2.5 to 3.0) with an good cycle performance.