Application of Mesoporous Silica Thin Film in Anode-Free Lithium Metal Batteries

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Abstract

Replacing the traditional anode material, graphite, by Li metal with higher theoretical capacity has been increasingly explored over decades. However, the uneven surface deposition would cause "dead lithium" which is mainly due to the uneven electric field during stripping. Plating hostless Li results in easy and safe manufacturing, and better controls in dendritic structure. Our strategy is to synthesize mesoporous silica thin film (MSTF) with perpendicular and order tunnels on the stainless steel (SS). The uniform Li-ion flux will be obtained during battery operation and the stability of Li metal will be enhanced dramatically. Thus, these vertical and ordered mesoporous tunnels, which are well-defined pore diameter (~5nm), provide uniform pathways between anode and cathode for Li-ion, leading to efficient Li plating/stripping. The homogeneous Li-ion distribution occurred during Li plating/stripping results in high Coulombic efficiency (CE) (>99%) in the liquid electrolyte at half-cell for 200 cycles.

Of greater consequence, we use this novel current collector to develop anode-free Li metal batteries, and MSTF current collector shows dramatically reversibility of plating/stripping at 1st cycle so that it can retain more than 100 mAh/g of discharge capacity after the 50th cycle. Through SEM observation, morphologies of Li plating at preliminary cycles are pretty flat with MSTF current collector due to homogenous Li-ion flux but not with a commercial one. To obtain more crucial information on how the MSTF enhances CE, we use GIWAXS to observe the crystalline of Li film. The semi-ring pattern (white arrow) of Li (110) peak can be perspicuously seen from the 2D GIWAXS pattern in the SS sample, indicating the random orientation of lithium deposition. However, the 2D GIWAXS pattern obtained by lithium deposition on the MSTF⊥SS depicts strongly sharp spots, meaning MSTF is able to confine the orientation of Li deposition and form larger grains. Therefore, lithium deposited on the MSTF⊥SS electrode is extremely order and dense lead to superb reversibility of Li deposition/ dissolution.

Keywords – Mesoporous Silica Materials., Anode-Free Lithium Metal Batteries, Grazing Incidence Wide Angle X-ray Scattering