Dendrite-Free and High-Efficiency Rechargeable Lithium Metal Batteries

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Rechargeable lithium (Li) metal batteries are considered as the "holy grail" of energy storage systems because Li metal anode has a significantly high theoretical capacity of 3860 mAh/g (10 times as large as that of graphite) and the lowest electrochemical potential at -3.040 V vs. standard hydrogen electrode. However, the development and application of recharge Li metal batteries has been hindered in the past four decades due to two major issues—one is the Li dendrite growth on Li anode during repeated charge/discharge processes leading to serious safety hazards and another is the low Coulombic efficiency of Li anode since Li metal is reactive to organic solvents and salt anions. With the demand for high energy rechargeable batteries for plug-in hybrid electric vehicles and pure electric vehicles in recent years, the research and development of Li metal as anode material for rechargeable Li metal batteries has been revived. If the stability of Li metal anode could be significantly improved, it can considerably reduce the volume and mass of the batteries and allow many un-lithiated cathode materials with high capacities to be used in the system, thus greatly improve the energy density of these batteries over the state-of-the-art Li ion batteries.

Recently, we developed a novel self-healing electrostatic shield (SHES) mechanism that fundamentally alters Li dendrite formation occurred in all traditional approaches.[1] With the help of the SHES additives added in the conventional Li-ion battery electrolytes, Li dendrite formation and growth has been significantly suppressed (see Figure 1). By optimizing electrolyte solvents, lithium salts and other additives, the lithium Coulombic efficiency has also been greatly improved to >97% from ca. 76%. The long-term cycling stability over 650 cycles and dendrite-free Li anode were achieved for Li|$Li_4Ti_5O_{12}$ cells (Figure 2). Further development of this approach will lead to long term safe operation of rechargeable Li metal batteries with other cathode materials. The details of these new developments will be reported.

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References

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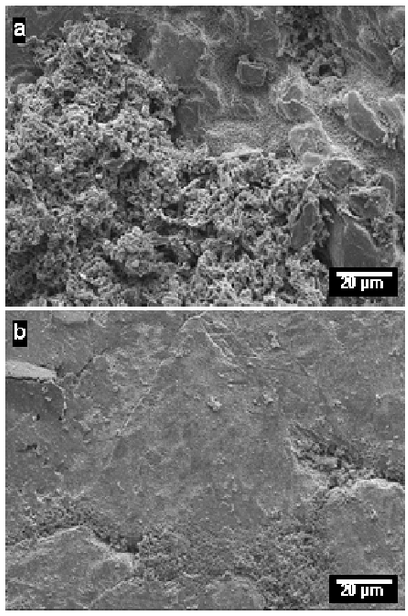

Figure 1. Morphologies of Li electrodes after 100 charge/discharge cycles in coin cells of Li|$Li_4Ti_5O_{12}$ containing electrolyte of electrolyte of 1M $LiPF_6$/PC (a) without and (b) with 0.05 M $CsPF_6$ additive.

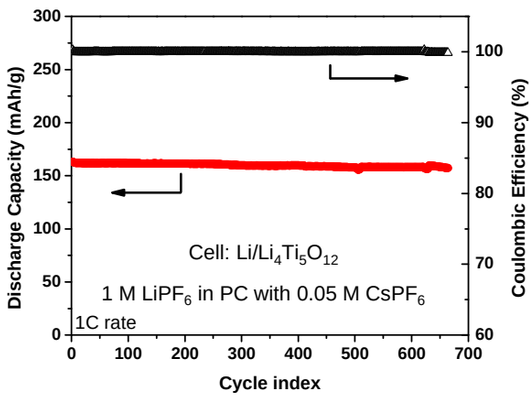

Figure 2. Long-term cycling stability and Coulombic efficiency of Li|$Li_4Ti_5O_{12}$ cell containing electrolyte of 1M $LiPF_6$/PC with 0.05 M $CsPF_6$ additive.