Electronic Supplementary Material (ESI) for Chemical Communications

Supporting Information

Superior electrochemical properties of $LiMn_2O_4$ yolk-shell powders prepared by a simple spray pyrolysis process

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This file includes:

• (a) Coulombic efficiencies of yolk-shell $LiMn_2O_4$ powders at various current densities; the charge and discharge curves of (b) Yolk-shell $LiMn_2O_4$ powders post-treated at 650°C, (c) Yolk-shell $LiMn_2O_4$ precursor, and (d) Dense $LiMn_2O_4$ powders post-treated at 650°C at a current density of 3 C.

• SEM images of (a) Yolk-shell $LiMn_2O_4$ powders post-treated at 650℃, (b) Yolk-shell $LiMn_2O_4$ precursor, and (c) Dense $LiMn_2O_4$ powders post-treated at 650°C after 200 cycles at a current density of 3 C.

Detailed experimental procedure:

The precursor powders for $LiMn_2O_4$ yolk-shell materials were prepared by ultrasonic spray pyrolysis. A cylindrical quartz reactor (length, 1200 mm; diameter, 50 mm) was used. The reactor temperature was maintained at 700°C. The flow rate of the air used as the carrier gas was 10 L min^{-1}. An aqueous spray solution was prepared by dissolving lithium nitrate ($LiNO_3$, Junsei) and manganese nitrate hexahydrate [$Mn(NO_3)_2 \cdot 6H_2O$, Junsei] in distilled water. The amount of lithium added to the spray solution was in 3 wt% excess of the stoichiometric amount required to facilitate the formation of $LiMn_2O_4$ powders. The total concentration of the Li and Mn components dissolved in distilled water was 0.2 M. The concentration of sucrose used as the carbon source material was fixed at 0.7 M. The precursor powders obtained by spray pyrolysis were post-treated at 650°C for 3 h in air atmosphere.

The crystal structures of the prepared cathode powders were determined using X-ray diffractometry (XRD, X'pert PRO MPD) with Cu Kα radiation (λ = 1.5418 Å). The morphological characteristics of the powders were investigated using scanning electron microscopy (SEM, JEOL JSM-6060) and high-resolution transmission electron microscopy (HR-TEM, JEOL-2100F).The surface areas of the powders were measured using the Brunauer–Emmett–Teller (BET) method with N_2 as the adsorbate gas.

The capacities and cycle properties of the powders were determined by using a 2032-type coin cell. The cathode electrodes were prepared from a mixture containing 80 wt% active material, 10 wt% activated carbon, and 10 wt% sodium carboxymethyl cellulose (CMC), the latter acting as a binder. Li metal and a microporous polypropylene film were used as the anode electrode and separator, respectively. The electrolyte was 1 M $LiPF_6$ in a 1:1 mixture (by volume) of ethylene carbonate/dimethyl carbonate (EC/DMC).

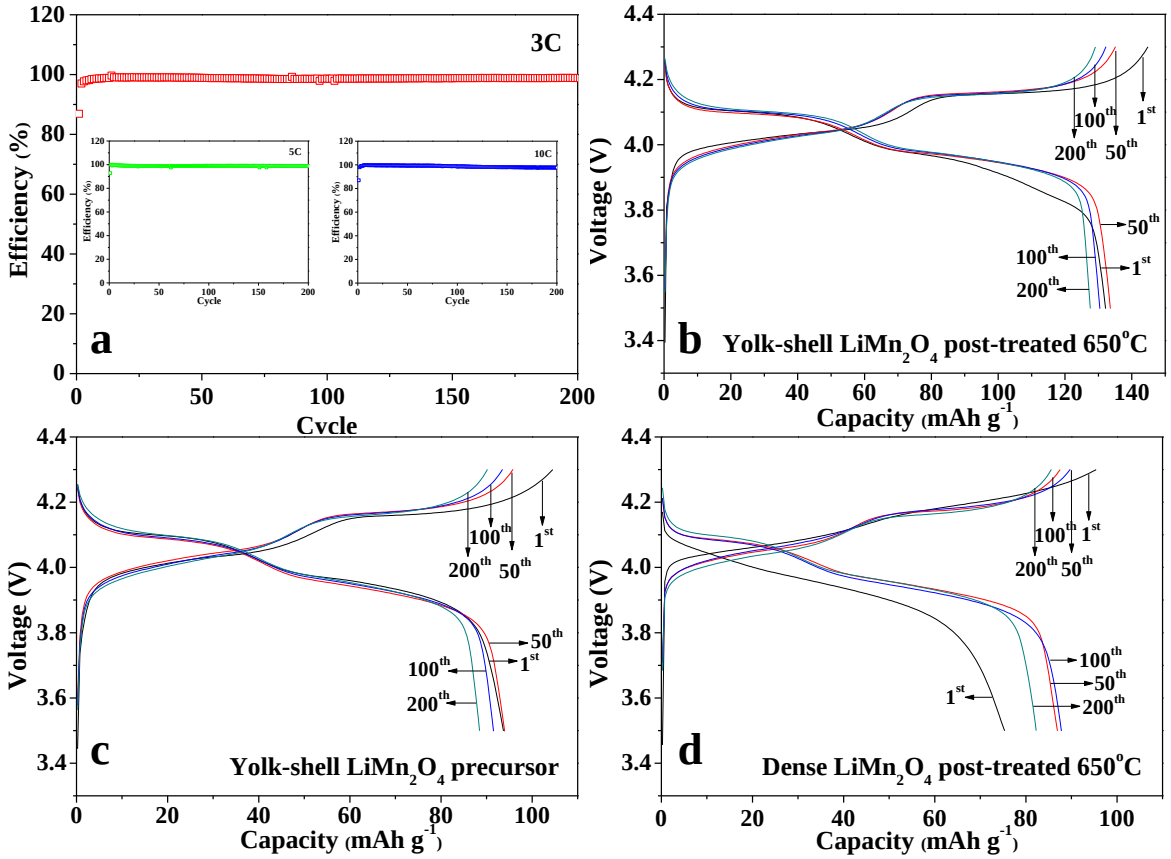

Fig. S1 (a) Coulombic efficiencies of yolk-shell $LiMn_2O_4$ powders at various current densities; the charge and discharge curves of (b) Yolk-shell $LiMn_2O_4$ powders post-treated at 650°C, (c) Yolk-shell $LiMn_2O_4$ precursor, and (d) Dense $LiMn_2O_4$ powders post-treated at 650°C at a current density of 3 C.

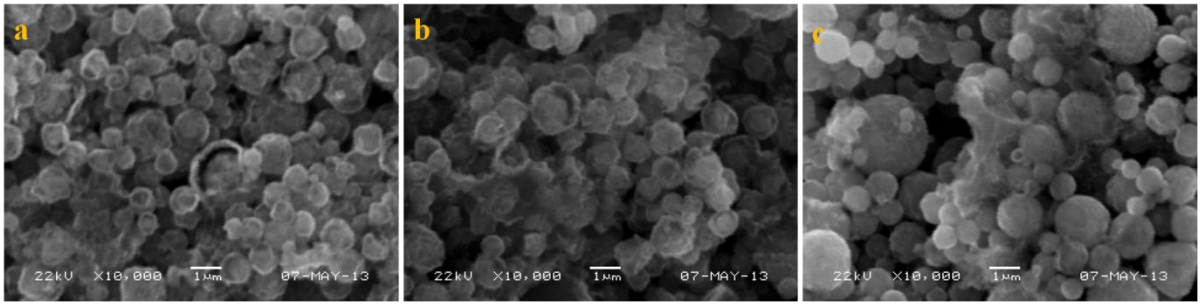

Fig. S2 SEM images of (a) Yolk-shell $LiMn_2O_4$ powders post-treated at 650℃, (b) Yolk-shell $LiMn_2O_4$ precursor, and (c) Dense $LiMn_2O_4$ powders post-treated at 650^{o}C after 200 cycles at a current density of 3 C.