# Liquid-phase Synthesis of Uniformly Nano-sized $LiMnPO_4$ Particles and Their Electrochemical Properties for Lithium-ion Batteries

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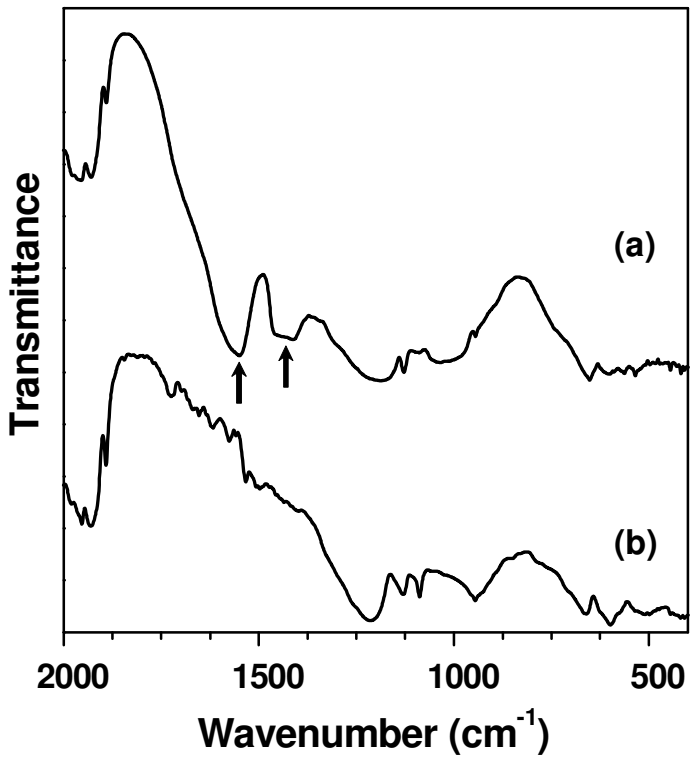


Fig. 1S. FT-IR spectra of (a) $LiMnPO_4$ particles prepared at 280 $^oC$ and (b) $LiMnPO_4$ powder prepared by a conventional solid-phase synthesis.

The $LiMnPO_4$ powder was prepared by a conventional solid-phase synthesis as follows: a mixture of lithium carbonate (98 %), dimanganese trioxide (99.9 %) and diphosphorus pentaoxide (98 %) in a Li/Mn/P ratio of 1/1/1 was fired at 500 $^oC$ for 15 h in air. The resultant powder was ground and sintered at 800 $^oC$ for 36 h in air. The particle size of the $LiMnPO_4$ powder was ca. 30 μm. FT-IR spectra of the particles were obtained by accumulating 200 iterations with a resolution of 4 $cm^{-1}$ using a spectrometer (FT-IR, FT/IR-680plus, Jasco). The nano-sized $LiMnPO_4$ particles gave a spectrum very similar to that of the $LiMnPO_4$ powder, except for two peaks at around 1450 and 1550 $cm^{-1}$. Based on the literature, these two bands were identified as symmetric and antisymmetric stretching bands of a carboxyl group, respectively.[17] The gap between these two bands was about 100 $cm^{-1}$, indicating that oleic acid was attached to the $LiMnPO_4$ particles.

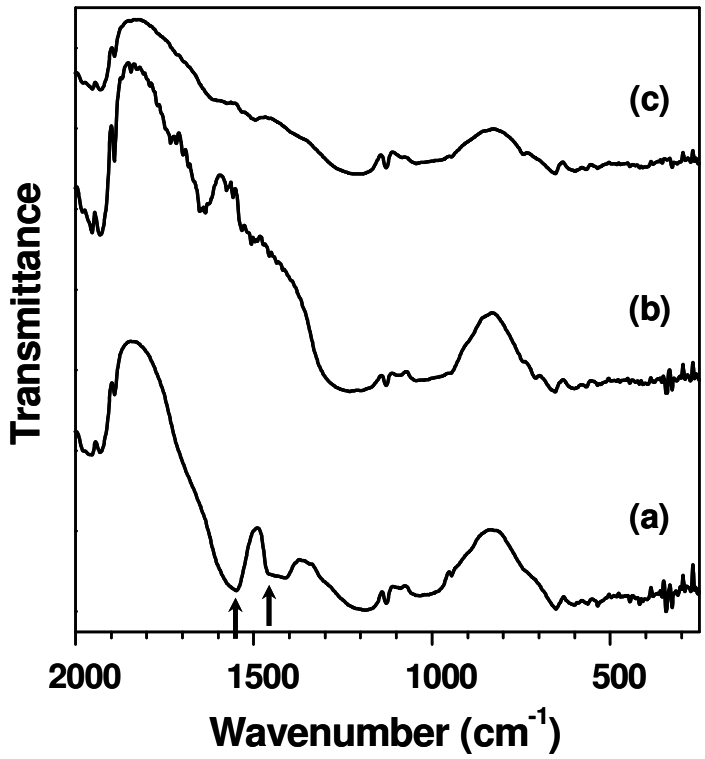


Fig. 2S. FT-IR spectra of $LiMnPO_4$ particles (a) before and after heat treatment in (b) $O_2$ or (c) Ar at 500 $^oC$ for 1 h.

The peaks at around 1450 and 1550 $cm^{-1}$, which are assigned to carboxyl groups of oleic acid, disappeared with heat treatment at 500 $^oC$ for 1h in Ar and $O_2$; a peak at around 1650 $cm^{-1}$ was observed after heat treatment in $O_2$, likely due to $Li_3PO_4$. Thus, oleic acid molecules attached to $LiMnPO_4$ particles could be removed by heat treatment.

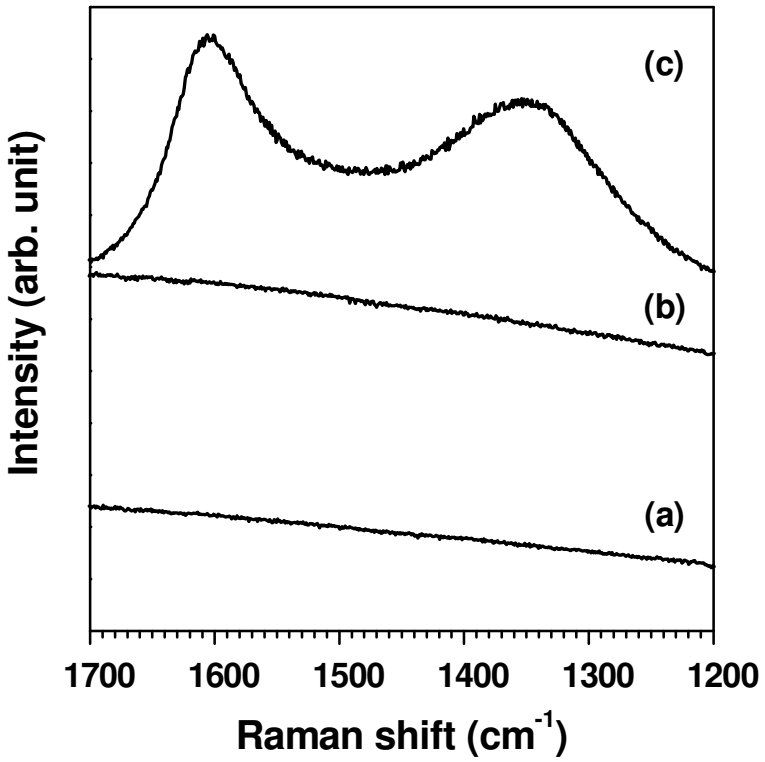


Fig. 3S. Raman spectra of $LiMnPO_4$ particles (a) before and after heat treatment in (b) $O_2$ or (c) Ar at 500 $^oC$ for 1 h.

Raman spectra were excited using the 514.5 nm line (100mW) of an argon ion laser for 60 s, and the scattered light was collected in a quasi-backscattering geometry (NRS-2100, Jasco). Two broad peaks appeared at around 1360 and 1600 $cm^{-1}$ after heat treatment in Ar (Fig. S3c), while no peak was observed after heat treatment in $O_2$ (Fig. S3b). These results indicate that carbonaceous materials with low crystallinity were formed from oleic acid by heat treatment in Ar.