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Ultrafast Nano-Spherical Single-Crystalline of $LiMn_{0.792}Fe_{0.198}Mg_{0.010}PO_4$ Solid-Solution Confined among Unbundled Interstices of SGCNT

Kazuaki Kisu[1], Etsuro Iwama[1,3], Wataru Onishi[1], Shota Nakashima[1], Wako Naoi[2], and Katsuhiko Naoi*[1,2,3]

[1]*Department of Applied Chemistry, Tokyo University of Agriculture & Technology, 2-24-16 Naka-cho, Koganei, Tokyo 184-8558, Japan*
**E-mail: k-naoi@cc.tuat.ac.jp*

[2]*Division of Arts and Sciences, K & W Inc, 1-3-16-901 Higashi, Kunitachi, Tokyo 186-0002, Japan*

[3]*Advanced Capacitor Research Center, Tokyo University of Agriculture & Technology, 2-24-16 Naka-cho, Koganei, Tokyo 184-8558, Japan*

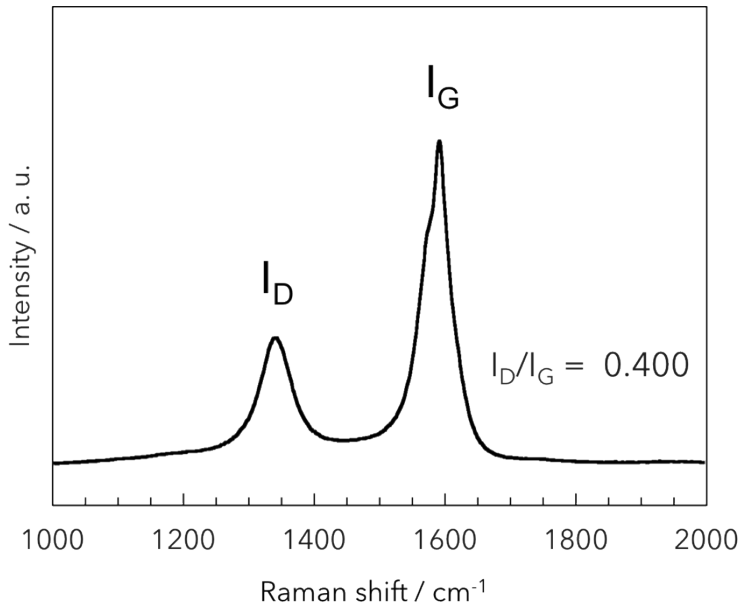

Fig. S1 Raman spectrum for the pristine super growth (single-walled) carbon nanotube (SGCNT) with the $I_D/I_G = 0.40$. The measurement was conducted on the bundled position of SGCNT by Raman spectroscopy systems (Horiba Jobin-Yvon, LabRam HR evolution).

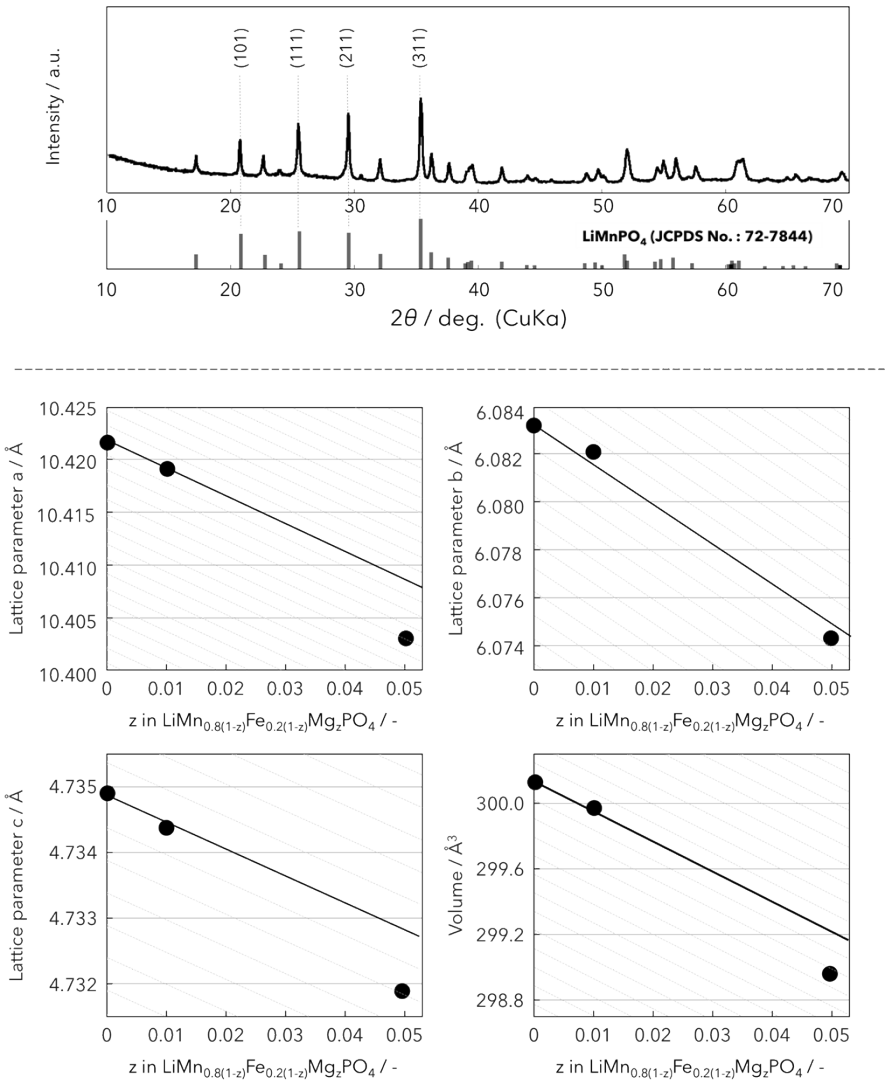

Fig. S2 [**TOP**] XRD patterns for $LiMn_{0.76}Fe_{0.19}Mg_{0.05}PO_4$/SGCNT composite. The major diffraction peaks of these composites ((101), (111), (211), and (311)) are well indexed to the orthorhombic structure of $LiMnPO_4$ and no peaks for possible impurities were found, as same as other two $LiMn_{0.8}Fe_{0.2}PO_4$/SGCNT and $LiMn_{0.792}Fe_{0.198}Mg_{0.010}PO_4$/SGCNT (shown in Fig.1 right A and B). [**BOTTOM**] Plots of three refined lattice (a-, b-, and c-) parameters and the volume of $LiMn_{0.8(1-z)}Fe_{0.2(1-z)}PO_4$ with respect to Mg dosage (z = 0-0.05). The lattice parameters and volume were calculated from the Rietveld analysis on XRD patterns shown in Fig. 1 Right (A), (B), and Fig. S2 top. A decrease in each three parameters and volume with an increase of Mg dosage is due to the smaller lattice size of $LiMgPO_4$ than other phosphates; $LiFePO_4$ and $LiMnPO_4$. The obtained linearity in each four figures suggests that the Mg atom was successfully doped into the $LiMn_{0.8}Fe_{0.2}PO_4$/SGCNT nano-crystals.

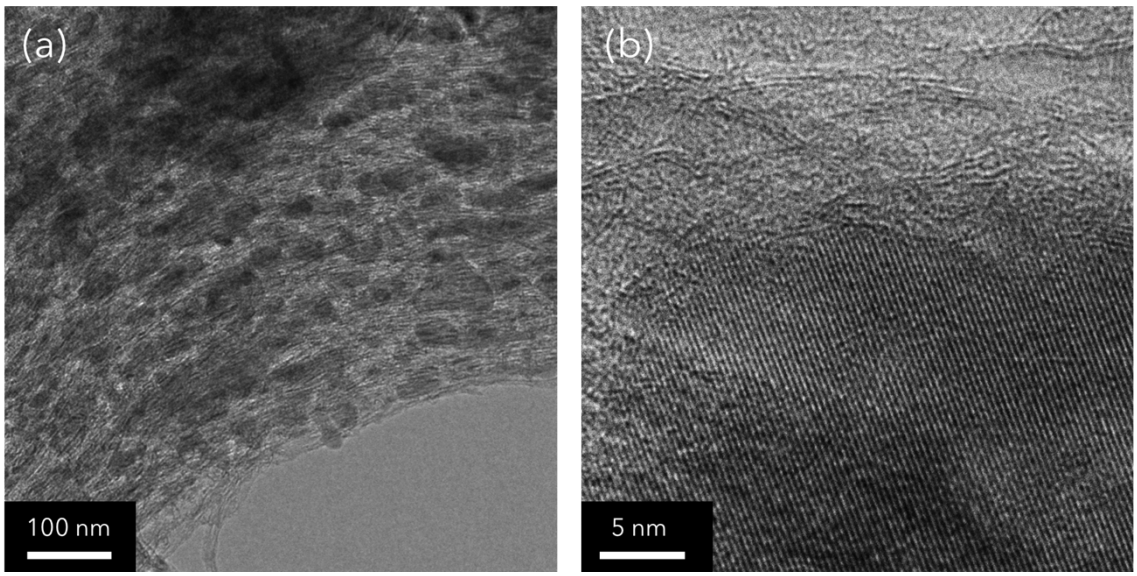

Fig. S3 HRTEM images for the synthesized $LiMn_{0.8}Fe_{0.2}PO_4$/ supergrowth (single-walled) carbon nanotubes (denoted as SGCNT) composite, which was prepared under ultra-centrifuging (UC) treatment with the same dosage condition of Mn/Fe (= 4) for the $LiMn_{0.792}Fe_{0.198}Mg_{0.01}PO_4$/SGCNT except Mg doping (see experimental section). (a) Lower magnification HRTEM image shows that the spherical $LiMn_{0.8}Fe_{0.2}PO_4$ (10-40 nm of diameter), which is highly dispersed and encapsulated within the SGCNT interstices. (b) Higher magnification HRTEM image of the $LiMn_{0.8}Fe_{0.2}PO_4$ nanoparticle with clear lattice fringes. These images ($LiMn_{0.8}Fe_{0.2}PO_4$/SGCNT composite) and Fig. 2a-d ($LiMn_{0.792}Fe_{0.198}Mg_{0.010}PO_4$/SGCNT composite) clearly indicate that the UC treatment enables the *in-situ* synthesis of nano-crystalline $LiMn_{0.8}Fe_{0.2}PO_4$ or $LiMn_{0.792}Fe_{0.198}Mg_{0.010}PO_4$ particles in the presence of SGCNT, simultaneously achieving such a highly unbundled state of the SGCNT.

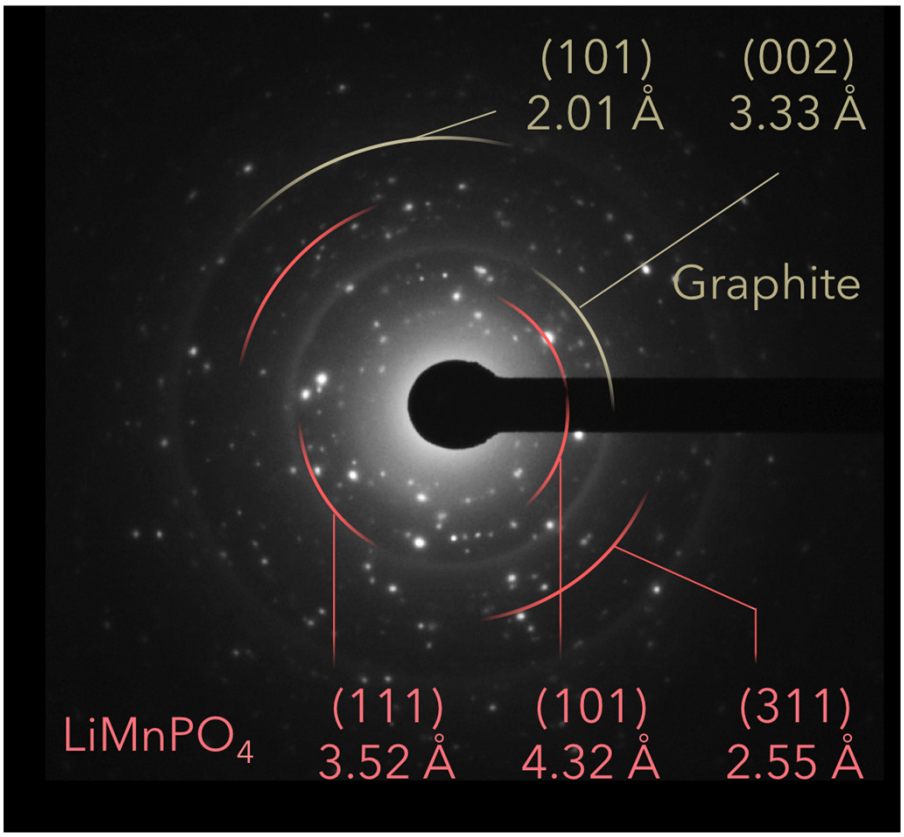

Fig. S4 Electron diffraction patterns for $LiMn_{0.792}Fe_{0.198}Mg_{0.010}PO_4$/SGCNT (their HRTEM images are shown in Fig. 2), indicating that those patterns are identical to $LiMnPO_4$ and graphite attributed to the basal plane of SGCNT.

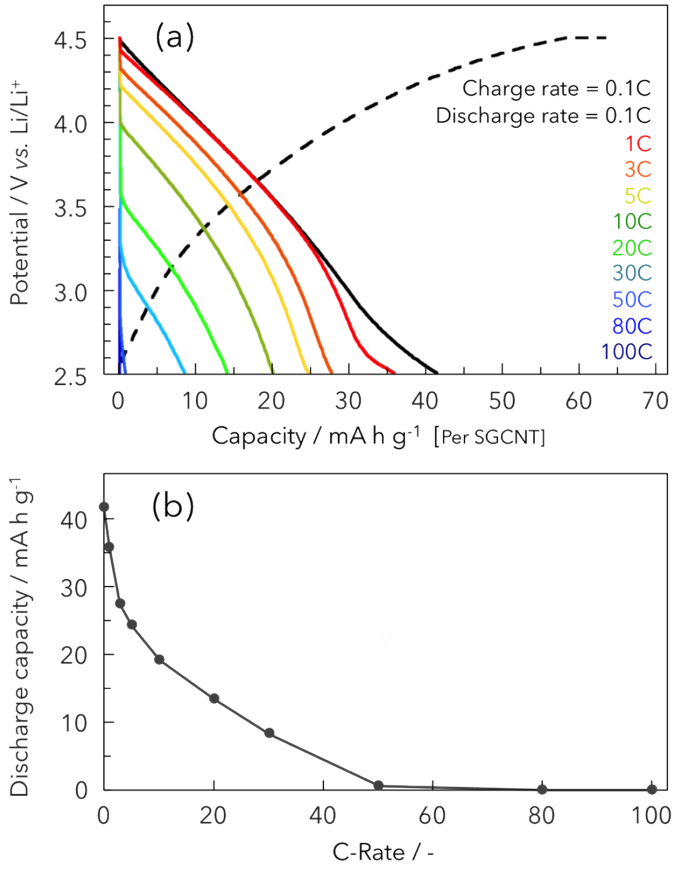

Fig. S5 (a) Charge-discharge curves for pure SGCNT electrode. Charge-discharge tests were performed using a 2032-typed coin cells composed of Li metal and SGCNT electrodes. Used electrolyte composition was 1M $LiPF_6$ /EC + DEC (EC/DEC =50/50, v/v). Charge-discharge performance was conducted under the CC-CV (charge) and CC (discharge) mode between 2.5 and 4.5 V, at constant charge current density of 0.1C and at different discharge current densities ranging from 0.1C to 100C (assuming 1C = 40 mA g^{-1}. The electrode composition was 90 wt% of SGCNT and 10 wt% of polyvinylidene difluoride. (b) Summarized results of Fig S5a: discharge capacity for SGCNT electrode with respect to current density.