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# Electronic Supplementary Information

## Mesoporous carbon-coated $LiFePO_4$ nanocrystals co-modified by graphene and $Mg^{2+}$ doping as superior cathode material for high-rate lithium ion batteries

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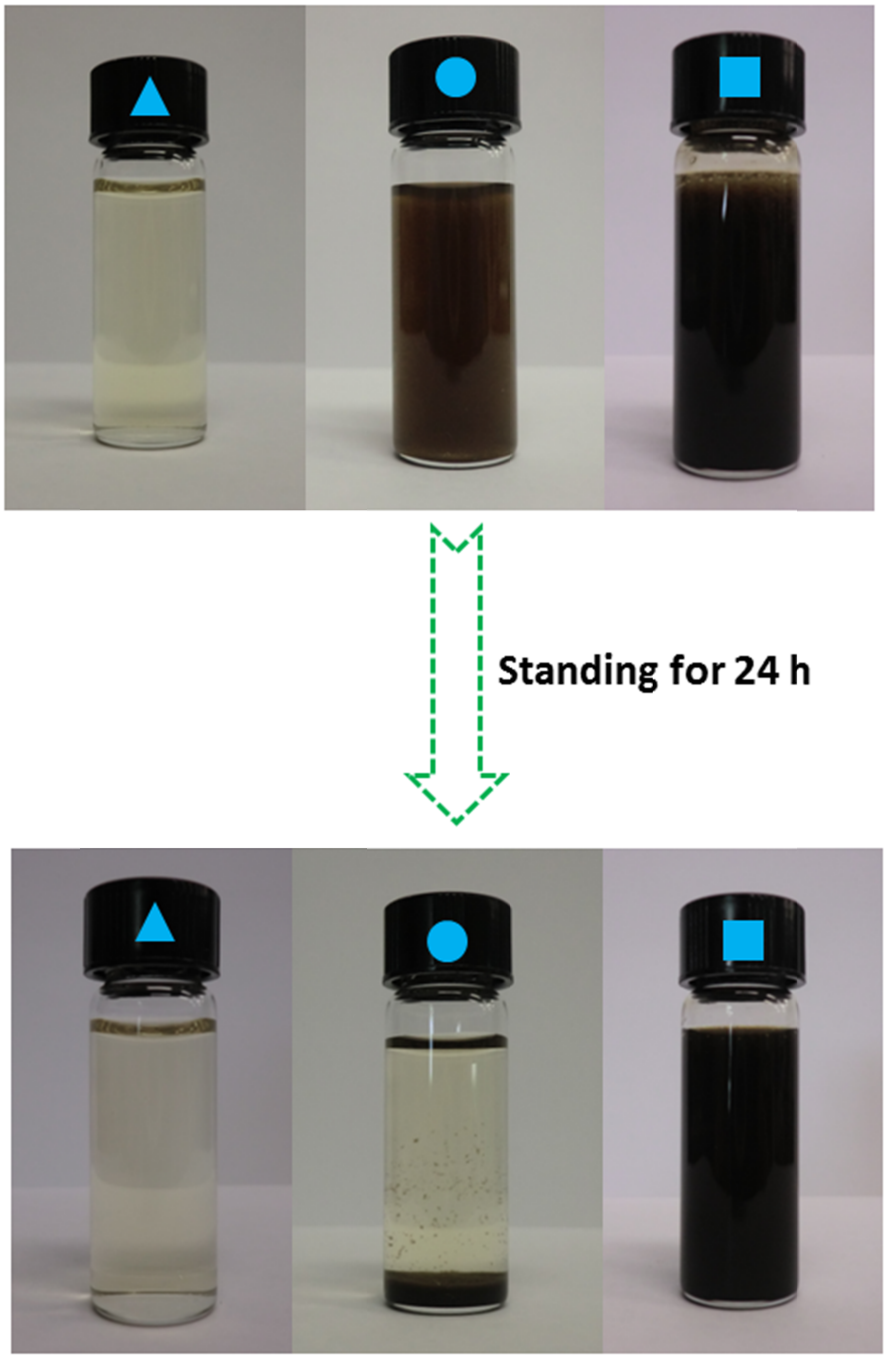


**Fig. S1**† The comparison of the stabilities of ▲ the sucrose/salts solution, ● the GO/sucrose/salts suspension and ■ the GO/sucrose/salts rheological body. Compared with the GO/sucrose/salts suspension, the GO/sucrose/salts rheological body was more superior for the dispersion of GO due to its much higher viscosity, which could keep stable for at least 24 h that was long enough for evaporating the residual water to get a uniform dry mixture.

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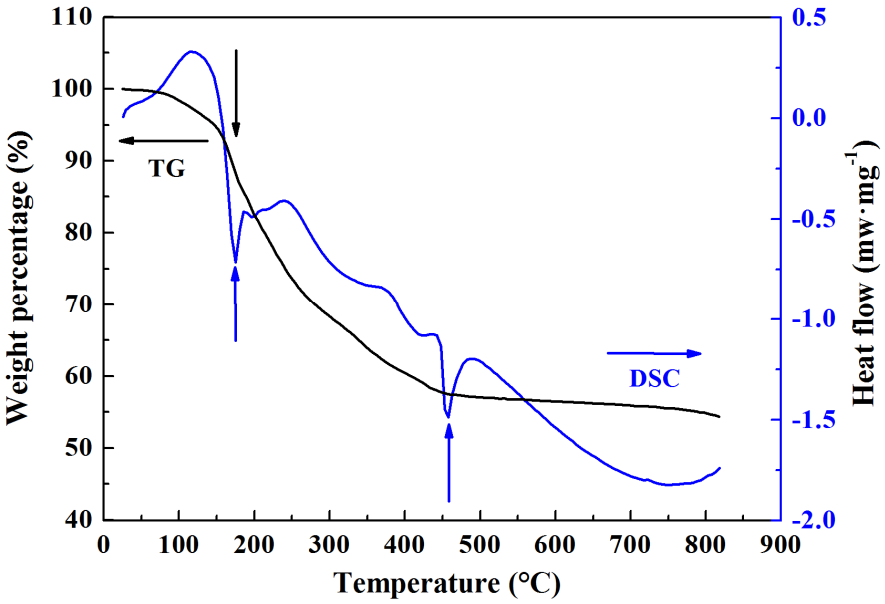


**Fig. S2†** TG/DSC curves of LFP precursor after bead milling.

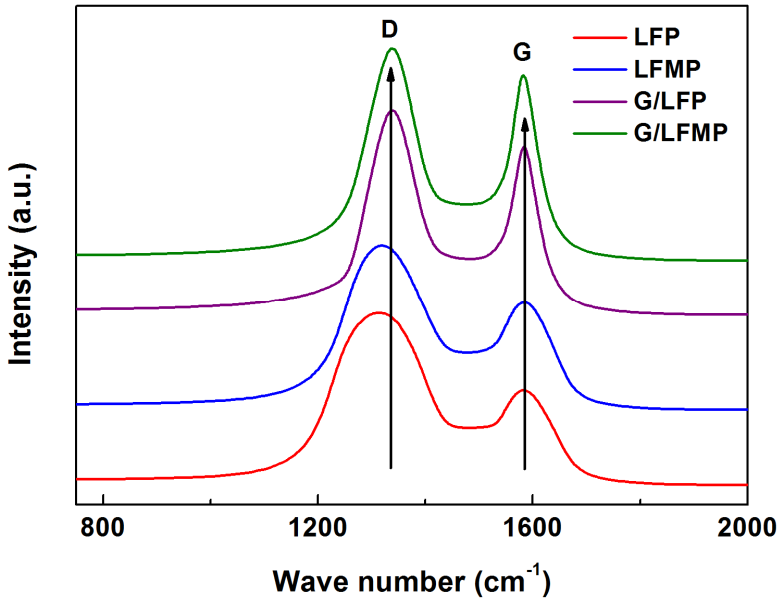


**Fig. S3†** Raman spectra of LFP, LFMP, G/LFP and G/LFMP.

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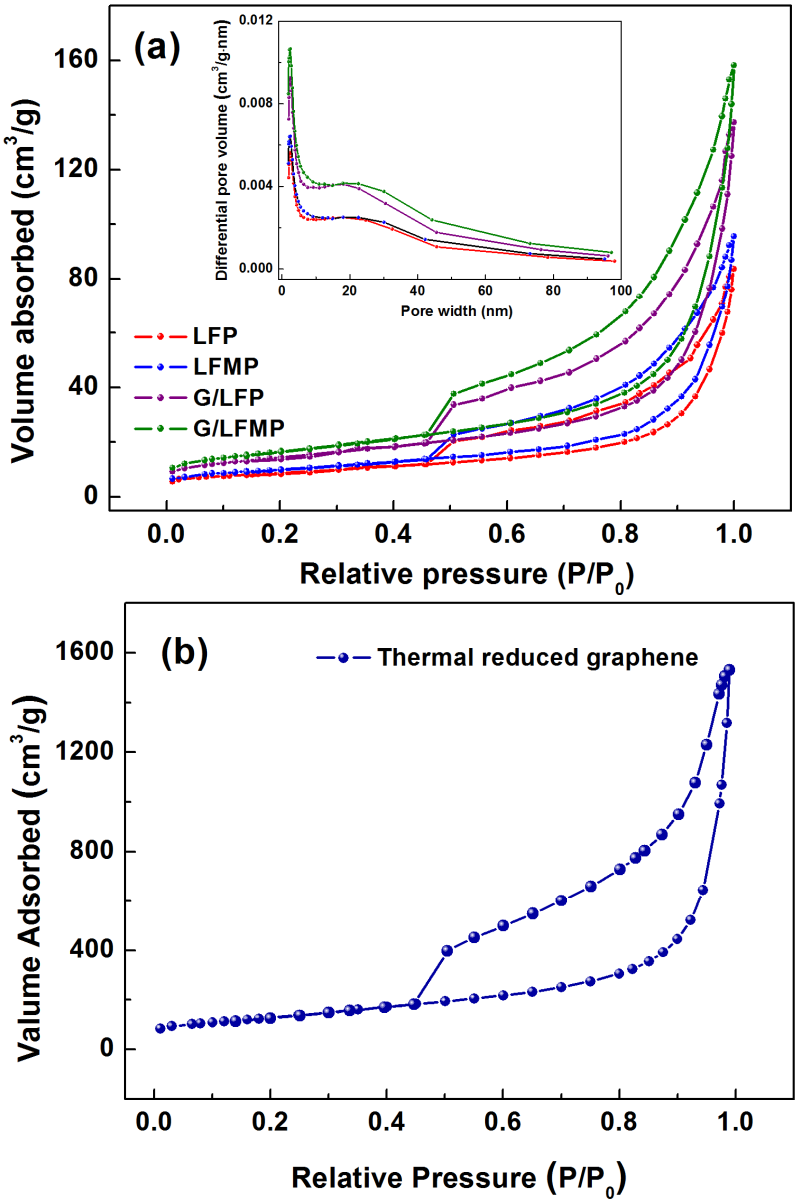


**Fig. S4†** (a) Nitrogen adsorption/desorption isotherms and pore-size distribution curves of LFP, LFMP, G/LFP and G/LFMP, (b) Nitrogen adsorption/desorption isotherms of thermal reduced graphene.

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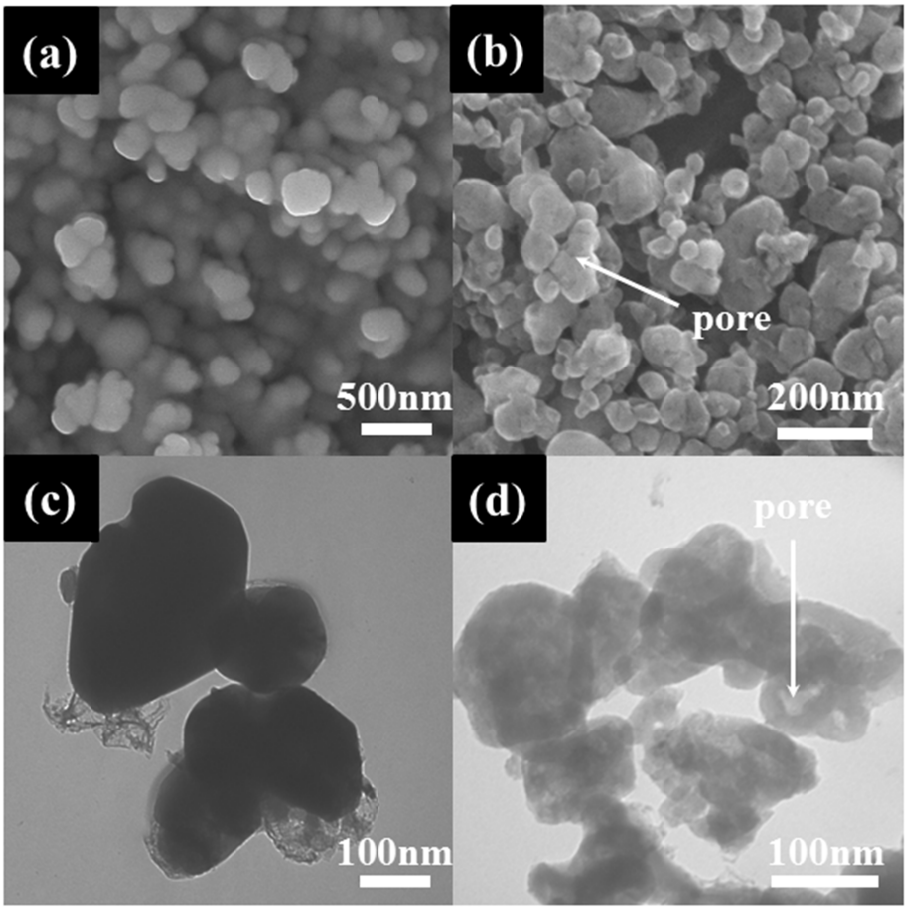


**Fig. S5**† SEM (a) and TEM (c) images of LFP product without bead milling procedure; SEM (b) and TEM (d) images of LFP product experienced bead milling procedure.

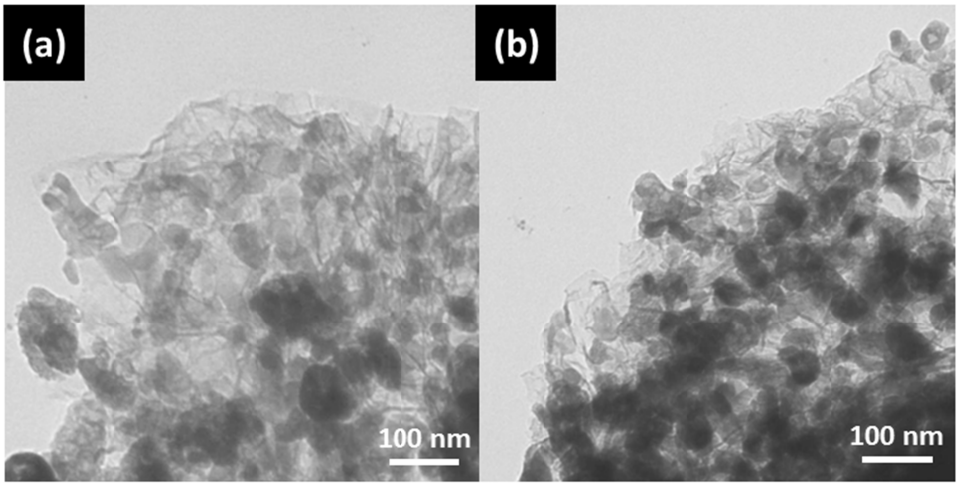


**Fig. S6**† The TEM images of (a) G/LFP and (b) G/LFMP.

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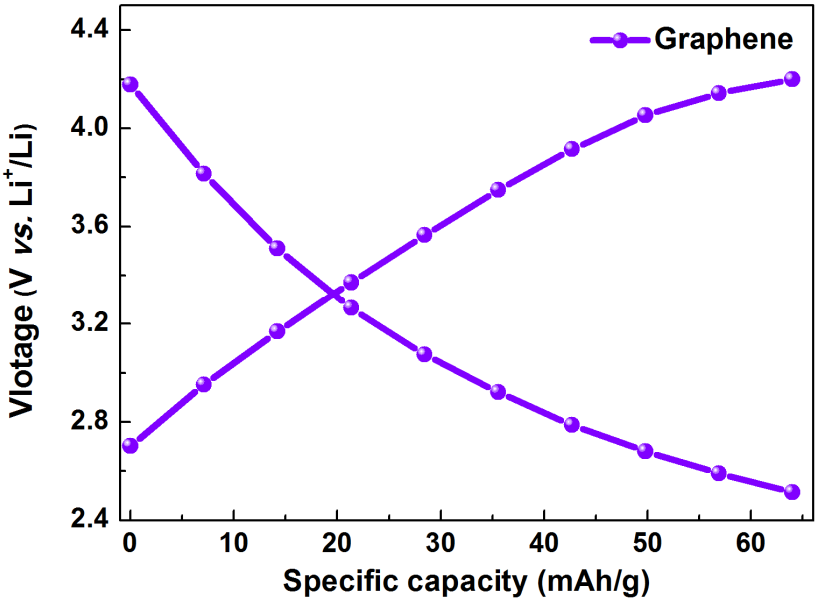


**Fig. S7**† Charge/discharge profiles of graphene electrode at 0.2*C*-0.2*D*.

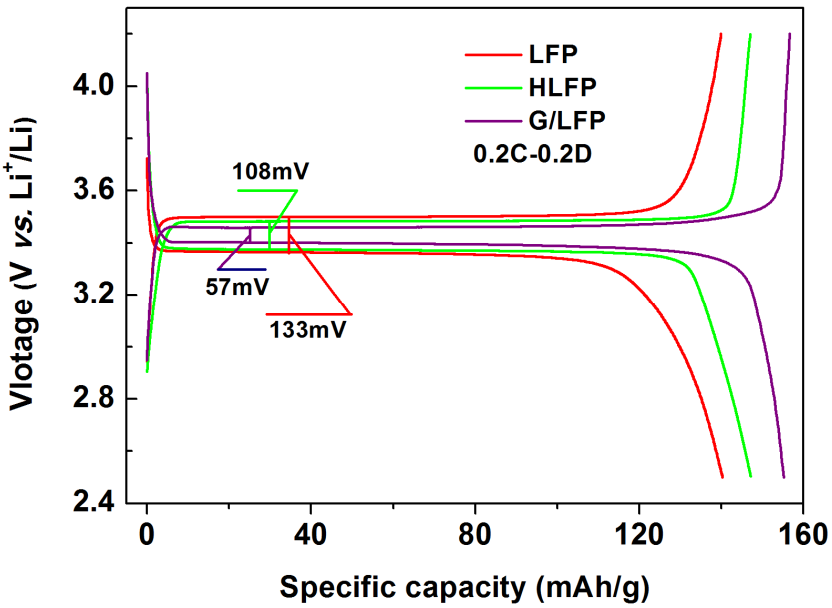


**Fig. S8**† The charge/discharge profiles of LFP, HLFP and G/LFP at current rates of 0.2*C*-0.2*D*.

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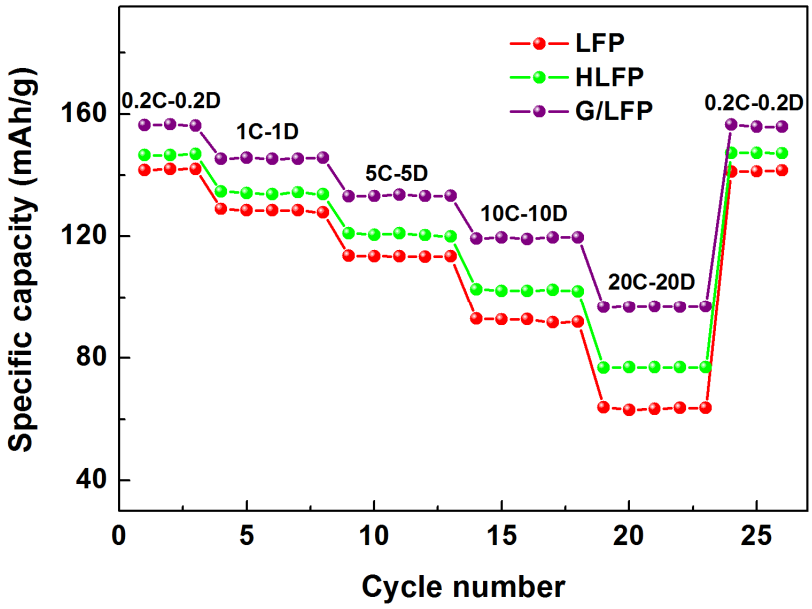


**Fig. S9**† The rate performance of LFP, HLFP and G/LFP from 0.2*C*-0.2*D* to 20*C*-20*D*.

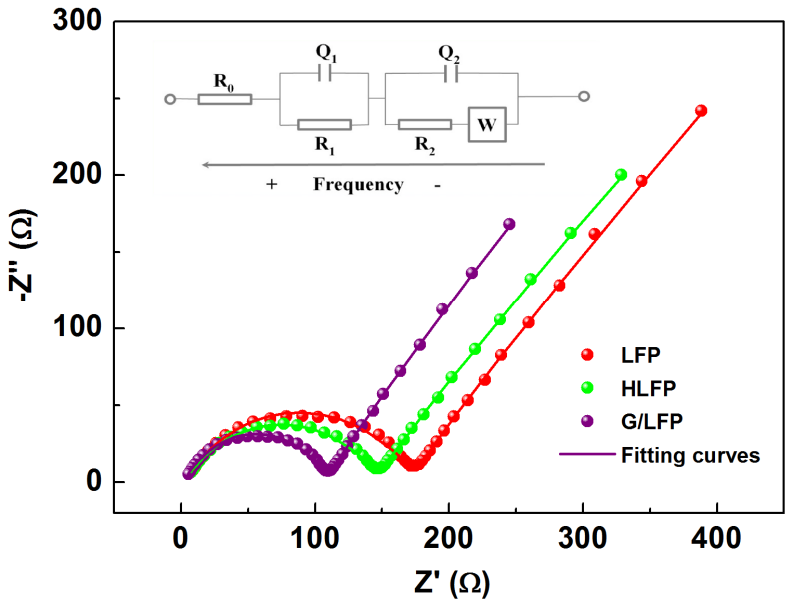


**Fig. S10**† The EIS plots and equivalent circuit of LFP, HLFP and G/LFP.

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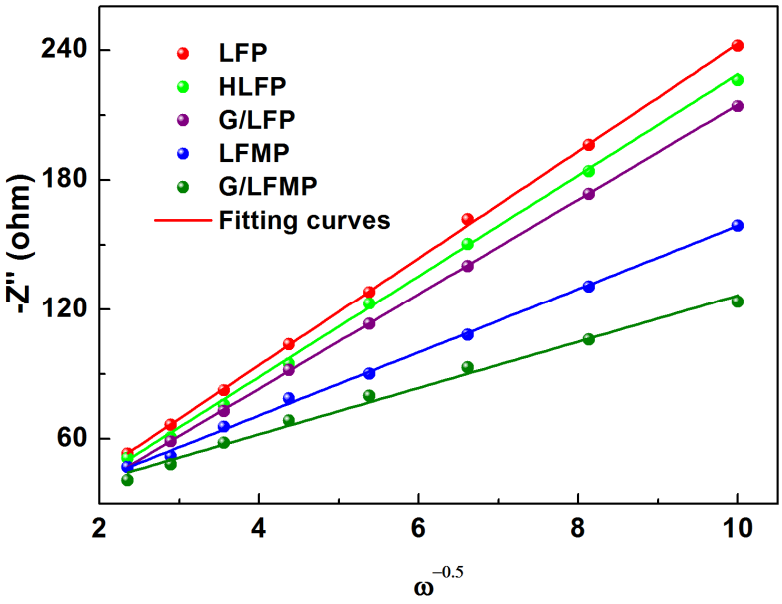


**Fig. S11†** The fitting curves of $-Z''$ and reciprocal square root of the angular frequency at low frequency region of LFP, HLFP, LFMP, G/LFP and G/LFMP.

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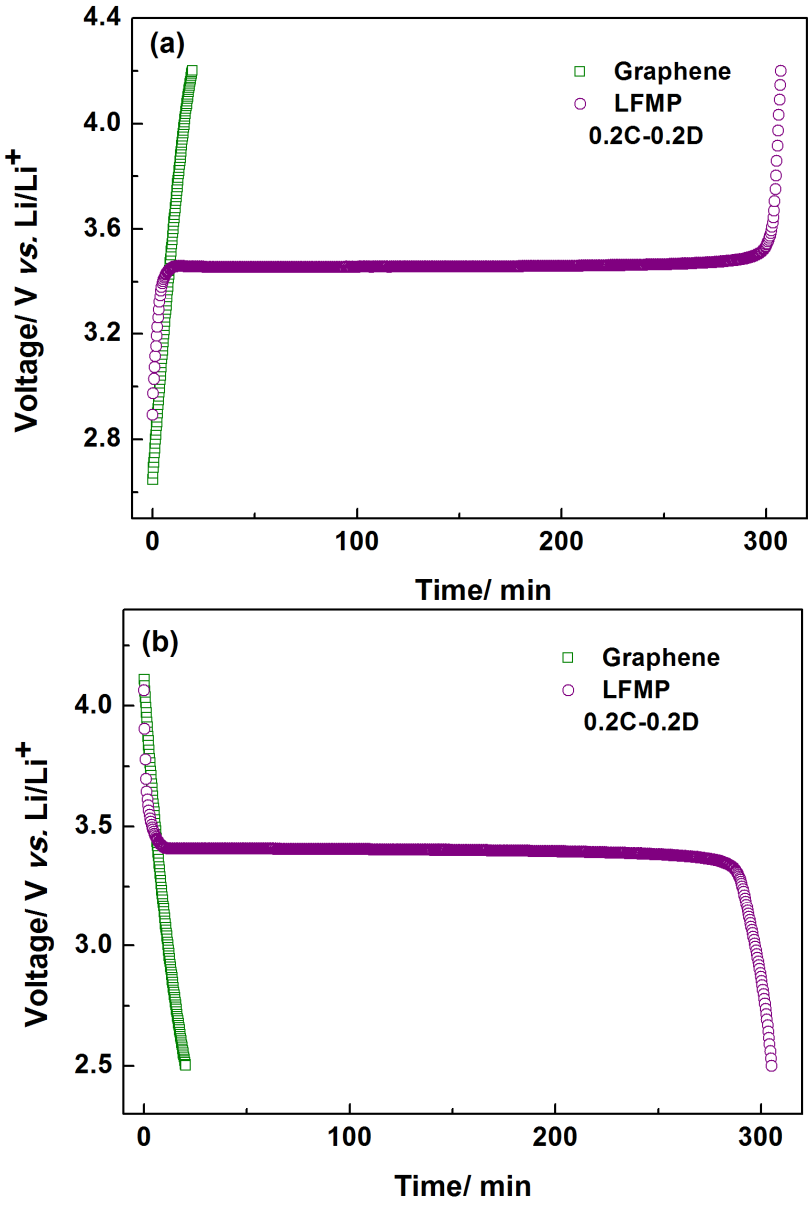


**Fig. S12**† Potential as a function of time of graphene electrode and LFMP electrode at 0.2*C*-0.2*D* for both charge (a) and discharge (b) processes.

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**Table S1†** Results of structural analysis obtained from XRD Rietveld refinement of samples LFP, LFMP, G/LFP and G/LFMP.

| Samples | LFP | LFMP | G/LFP | G/LFMP |
|---|---|---|---|---|
| **Doped ion radius/Å** | 0.74 ($Fe^{2+}$) | 0.65 ($Mg^{2+}$) | 0.74 ($Fe^{2+}$) | 0.65 ($Mg^{2+}$) |
| **Lattice constant/Å** | | | | |
| ***a*/Å** | 10.3316 | 10.3286 | 10.3311 | 10.3275 |
| ***b*/Å** | 6.0097 | 6.0064 | 6.0089 | 6.0052 |
| ***c*/Å** | 4.6918 | 4.6895 | 4.6913 | 4.6883 |
| ***v*/Å$^3$** | 291.3130 | 290.9258 | 291.2291 | 290.7263 |
| **Lattice bond/Å** | | | | |
| **Fe-O(1)×1** | 2.2083 | 2.2016 | 2.2079 | 2.2007 |
| **Fe-O(2)×1** | 2.1026 | 2.0975 | 2.1024 | 2.0967 |
| **Fe-O(3)×2** | 2.0605 | 2.0561 | 2.0607 | 2.0571 |
| **Fe-O(3)×2** | 2.2576 | 2.2436 | 2.2563 | 2.2432 |
| **Fe-O average** | 2.1573 | 2.1497 | 2.1568 | 2.1494 |
| **P-O(1)×1** | 1.4403 | 1.4206 | 1.4396 | 1.4235 |
| **P-O(2)×1** | 1.4935 | 1.4924 | 1.4941 | 1.4908 |
| **P-O(3)×2** | 1.4556 | 1.4562 | 1.4543 | 1.4537 |
| **P-O average** | 1.4631 | 1.4564 | 1.4627 | 1.4560 |
| **Li-O(1)×2** | 2.1541 | 2.1579 | 2.1539 | 2.1573 |
| **Li-O(2)×2** | 2.0879 | 2.0962 | 2.0881 | 2.0953 |
| **Li-O(3)×2** | 2.1806 | 2.1836 | 2.1782 | 2.1829 |
| **Li-O average** | 2.1409 | 2.1459 | 2.1407 | 2.1452 |
| **Reliability factors/%** | | | | |
| $R_{wp}$ | 6.63 | 5.96 | 6.35 | 5.81 |
| $R_p$ | 4.67 | 3.96 | 4.03 | 4.56 |
| $\chi^2$ | 1.96 | 1.83 | 2.15 | 1.69 |

**Table S2†** The contents of LF(M)P, total carbon including sucrose-pyrolytic carbon and graphene, as well as electronic conductivities of the samples.

| Samples | LF(M)P /wt.% | Total carbon/wt.% | Sucrose-pyrolytic carbon/wt.% | Graphene /wt.% | Electronic conductivity/S·cm$^{-1}$ |
|---|---|---|---|---|---|
| **LFP** | 97.06 | 2.94 | 2.94 | — | $6.79\times10^{-6}$ |
| **HLFP** | 93.87 | 6.13 | 6.13 | — | $1.73\times10^{-4}$ |
| **LFMP** | 96.94 | 3.06 | 3.06 | — | $8.26\times10^{-4}$ |
| **G/LFP** | 94.04 | 5.96 | ~ 2.94 (similar to LFP) | ~ 3.02 | $3.65\times10^{-3}$ |
| **G/LFMP** | 93.98 | 6.02 | ~ 3.06 (similar to LFMP) | ~ 2.96 | $6.36\times10^{-2}$ |

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**Table S3†** Elemental composition of the $Mg^{2+}$ doping samples determined using ICP* (the other elements ware not calculated).

| Samples | Li | Fe | Mg | P |
|---|---|---|---|---|
| **LFMP** | 0.99(2) | 0.95(3) | 0.04(7) | 1 |
| **G/LFMP** | 0.99(4) | 0.94(6) | 0.05(2) | 1 |

* Molar ratio based on element P as 1.

**Table S4†** The circuit parameters, $D_{Li}$, and σ of the samples.

| Samples | $R_0$/Ω | $R_1$/Ω | $R_2$/Ω | $D_{Li}$/ $cm^2 \cdot s^{-1}$ | $\sigma$/ $\Omega \cdot s^{-1/2}$ |
|---|---|---|---|---|---|
| **LFP** | 5.64 | 39.27 | 135.83 | $4.11\times10^{-13}$ | 24.79 |
| **HLFP** | 5.31 | 36.14 | 124.39 | $4.63\times10^{-13}$ | 23.36 |
| **LFMP** | 5.06 | 33.68 | 120.67 | $1.17\times10^{-12}$ | 14.66 |
| **G/LFP** | 3.87 | 28.93 | 91.85 | $5.25\times10^{-13}$ | 21.92 |
| **G/LFMP** | 3.69 | 26.75 | 52.76 | $2.19\times10^{-12}$ | 10.73 |