

# In situ synthesis of $\text{LiV}_3\text{O}_8$ nanorods on graphene as high Rate-Performance cathode materials for rechargeable lithium batteries

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## Experimental Section

### Synthesis of graphene oxide (GO)

GO was prepared from graphite flakes by a modified Hummers method.<sup>1,2</sup> 1.0 g of graphite flakes, 1.0 g of  $\text{NaNO}_3$  and 46 mL of concentrated  $\text{H}_2\text{SO}_4$  were mixed together in an ice bath for 4 h. Then 6.0 g of  $\text{KMnO}_4$  was added slowly into the solution. Afterwards, the ice bath was removed and the suspension was stirred for another 4 days. Then the suspension was further treated with 200 mL of warm water ( $\sim 60^\circ\text{C}$ ) and 10 mL of  $\text{H}_2\text{O}_2$  (30%). The mixture was centrifuged at 4000 rpm and washed with diluted HCl and water to neutral. Finally, a homogeneous GO aqueous dispersion ( $1\text{ mg mL}^{-1}$ ) was obtained for further use.

### Synthesis of G-LVO NRs composites

The composites of  $\text{LiV}_3\text{O}_8$  nanorods on rmGO were synthesized simply by two-step solution-phase reaction. In the first step of synthesis, 160 mg of  $\text{V}_2\text{O}_5$  and oxalic acid 240 mg were dissolved into 30 mL of  $1\text{ mg mL}^{-1}$  GO aqueous dispersion and was vigorously stirred for 1 h. After that, the as-made composite was collected by centrifuge. In the second step of synthesis, the as-made composite from the first step of synthesis was dispersed in 30 mL of aqueous, to which a stoichiometric amount of LiOH aqueous solution (260 mg  $\text{LiOH}\cdot\text{H}_2\text{O}$ ) was added. The mixture was then sealed in a 40 mL Teflon lined stainless steel autoclave for hydrothermal reaction at  $160^\circ\text{C}$  for 12 hours. The resulted product was washed with water and then centrifuged at 5000 g for 1 min, which was repeated for 6 times to remove side products. Pure  $\text{LiV}_3\text{O}_8$  nanorods were also prepared by the similar procedure without any GNs.

### Material Characterizations

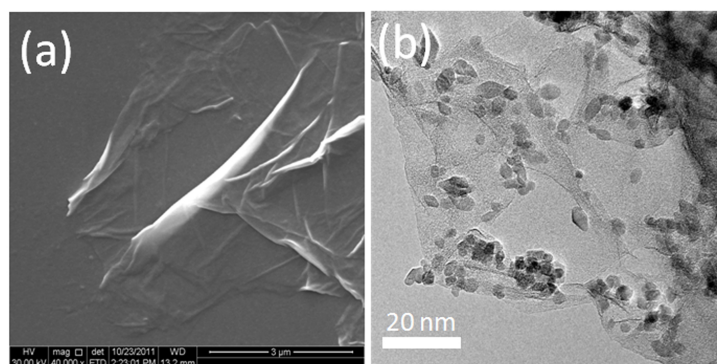
The resulting sample was characterized by means of X-ray diffraction (XRD, Rigaku D/max- $\gamma$ B) with monochromated  $\text{Cu K}\alpha$  radiation at a scanning rate of  $2^\circ\text{ min}^{-1}$  in the range of  $10$ – $50^\circ$ . morphology of products was characterized by scanning electron microscopy (SEM, Hitachi S4800) and high resolution transmission electron microscopy (HRTEM, JEM-2100) with an accelerating voltage of 200 KV. TG analysis was carried out with a TG/DTA6200 instrument. Additionally, Raman spectra were recorded at room temperature by employing an InVia Raman spectrometer using 633 nm red laser with 10% intensity to determine the extent of graphitic disorder.

### Electrochemical measurements

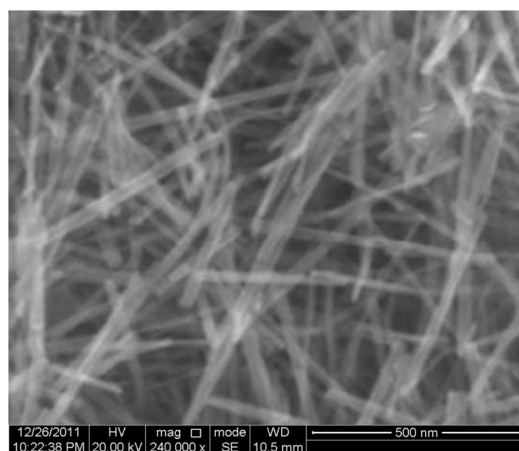
The  $\text{LiV}_3\text{O}_8/\text{rmGO}$  active material powder ( $\sim 120\text{mg}$ ) was annealed at  $450^\circ\text{C}$  in Ar for 1h and mixed with Super P carbon black and polyvinylidene fluoride (PVDF, Kynar HSV 900), with weight ratio of 80:10:10, in N-Methylpyrrolidone (NMP) solvent to produce an electrode slurry. The mass of active materials was calculated at ca. 3.8 mg and integrated into two-electrode CR2025-type coin cells for electrochemical measurements, with G-LVO NRs composite electrode as cathode, metallic lithium foil as anode, two porous polypropylene films as separator; electrolyte was 1.0 M  $\text{LiPF}_6$  dissolved in ethylene carbonate (EC) and dimethyl carbonate (DMC) and diethyl carbonate (DEC) at a volumetric ratio of 1:1:1. The discharge-charge tests were conducted at various rates within a voltage window from 1.5 V to 4.0 V (vs.  $\text{Li}^+/\text{Li}$ ) on the BTS battery testing system (Neware, Shenzhen, China). Electrical impedance spectroscopy (EIS) experiments were carried out on a Parstat 2273 advanced electrochemical systems in the frequency range mainly from 100 kHz to 10 mHz with the a.c. signal amplitude of 5 mV.

	$R_s (\Omega)$	$R_f (\Omega)$	$R_{ct} (\Omega)$
LVO NRs	7	94	33
G-LVO NRs	5	32	24

**Table S1.** Impedance parameters calculated from equivalent circuit



**Figure S1.** (a) SEM image of GO. (b) TEM images of vandyl oxalate hydrate nanoparticles on GO.



**Figure S2.** SEM images of  $\text{LiV}_3\text{O}_8$  nanorods synthesized without the addition of GO.

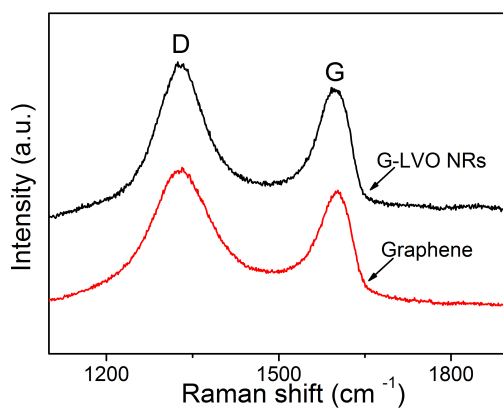


Figure S3. Raman spectra of Graphene and G-LVO NRs in the wave length range of 1100-2000  $\text{cm}^{-1}$ .

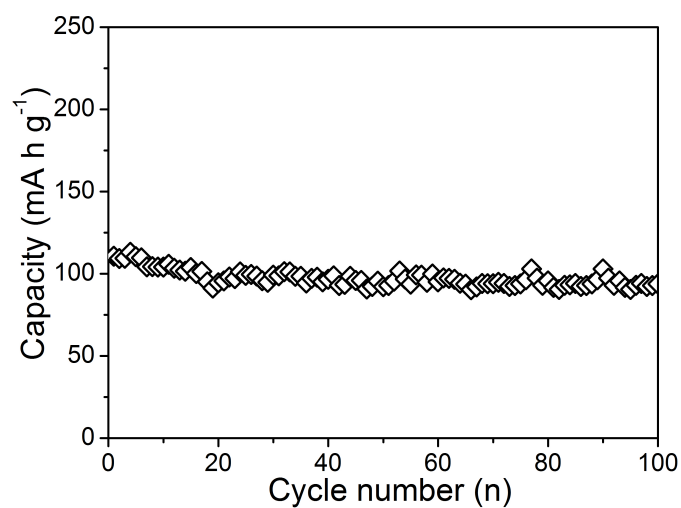


Figure S4. Cycling stability of G-LVO NRs cathode at 1500  $\text{mA g}^{-1}$  at room temperature.

#### Reference

- 1 Y. Chen, X. Zhang, P. Yu and Y. W. Ma, *Chem. Commun*, 2009, 4527.
- 2 C. H. Xu, J. Sun and L. Gao, *J.Mater. Chem*, 2011, **21**, 11253.