Supporting Information

An Interlaced Silver Vanadium Oxide-Graphene Hybrid with High Structural Stability for Use in Lithium Ion Batteries

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1. Sample preparation

Graphite oxide was prepared from nature flake graphite by a modified Hummers method. As prepared graphite oxide was then dispersed in deionized water to obtain a homogeneous graphene oxide (GO) hydrosol by ultrasonication (200 W, JY92-N, a high-energy bench mounted ultrasonic disintegrator) for 2 h.

The SVO-graphene hybrids were prepared by a facile hydrothermal approach under the reaction of $AgNO_3$ with NH_4VO_3 in the presence of GO in a Teflon-lined autoclave. In a typical procedure, $AgNO_3$ (170 mg) was dispersed in 40 mL GO hydrosol (1 mg mL^{-1}) by a sonication for 1 h to obtain a homogenous mixed dispersion. At the same time, NH_4VO_3 (117 mg) was dissolved in 40 mL deionized water and heated at 80 °C with consecutive stirring until the color of solution became pale yellow. Then, the NH_4VO_3 solution was slowly added to the above mixed dispersion under ultrasonication with the pH value of about 2.5~2.7. In order to mix it uniformly, another one hour sonication was conducted. After that, the final mixture suspension was transferred into a 120 mL autoclave and heated in an oven at 180°C for 12 h, and the obtained product was collected by centrifugation at 8000 rpm for 10 min and washed with ethanol and deionized water for at least 4 times. Finally, the SVO-graphene hybrid (also denoted as SVO-graphene (40)) was obtained after being freeze-dried for 36 h. In order to investigate the influence of GO contents on the structure and electrochemical

performance, the concentration of GO hydrosol was changed to 0.5 mg mL^{-1}, 1 mg mL^{-1}, 2 mg mL^{-1} and 3 mg mL^{-1} , and the obtained samples were denoted as the SVO-graphene (20), SVO-graphene (40) (simply denoted as SVO-graphene in the manuscript), SVO-graphene (80) and SVO-graphene (120) according to the weight of GO added. A control sample was prepared under the same condition without the introduction of GO.

2. Characterization

The morphology and structure of the obtained samples were characterized by field emission scanning electron microscopy (SEM, Hitachi S-4800) equipped with an energy-dispersive X-ray spectroscopy, transmission electron microscopy (TEM, JEOL, JEM-2100F) at an accelerating voltage of 200 kV and X-ray diffraction (XRD, Rigaku D/max 2500/PC using Cu Kα radiation, λ=1.5418Å). Atomic force microscopy (AFM) image was obtained on Dimension Icon (ScanAsyst, Bruker). Raman spectra were recorded with a LabRAM HR800 (Horiba) using 532nm incident radiation. The X-ray photoelectron spectroscopy (XPS) characterization of the products was performed on an Axis Ultra photoelectron spectrometer using an Al Kα (1486.7 eV) X-ray source.

3. Electrochemical measurements

The electrochemical properties of the SVO-graphene hybrids were studied as the active material in coin cells. The cathode electrodes were composed of 80 wt% active material, 10 wt% acetylene black and 10 wt% polyvinylidene fluoride (PVDF). A solution (1 M) of LiPF6 in EC/DEC (1:1 v/v) was used as the electrolyte. The cells were assembled in an argon-filled glove box. Galvanostatic charge/discharge measurement was performed by a multichannel battery testing system (LAND CT2001A) in the voltage range of 1.5 V~3.7 V. Cycling voltammetry (CV) were tested with an electrochemical workstation (VMP3, Bio-Logic, France) with a voltage range from 1.5 V to 3.7 V at a scan rate of 0.1 mV/s. The electrochemical impedance spectroscopy (EIS) was carried out with the frequency range from

100 kHz to 10 mHz on the electrochemical workstation (VMP3, Bio-Logic, France) by applying a 5 mV of AC oscillation. All the measurements were carried out at room temperature.

4. Supplementary Figures

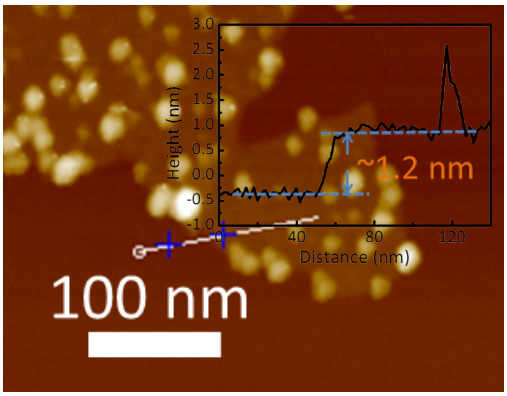

Fig. S1 AFM image of GO sheet after mixed with $AgNO_3$ and the inset height profile shows the thickness of the GO is about 1.2 nm.

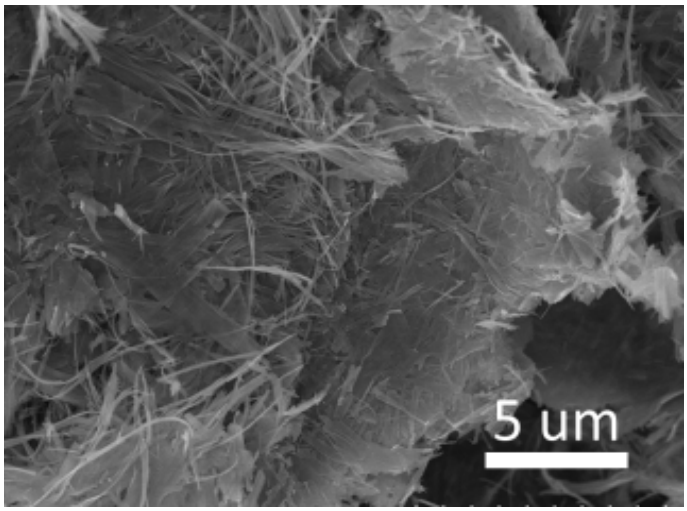

Fig. S2 Typical SEM image of the pure SVO without graphene.

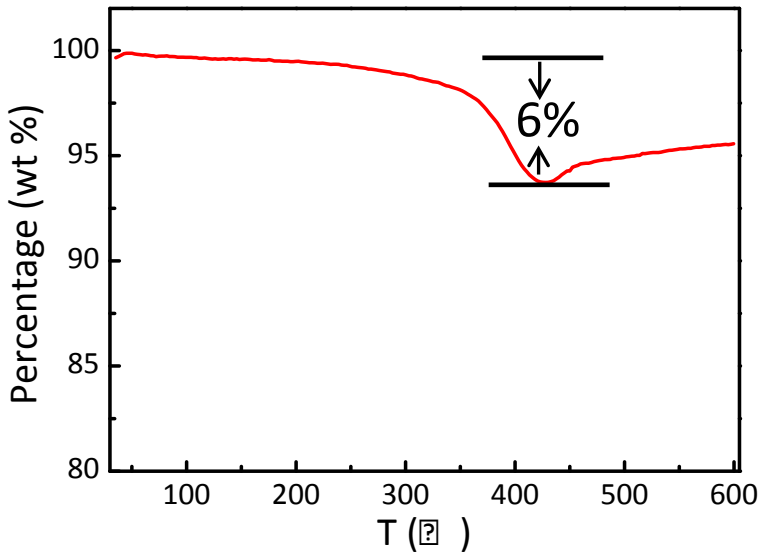

Fig. S3 TG curve of the SVO-graphene (40) hybrid (simply denoted as SVO-graphene in the manuscript).

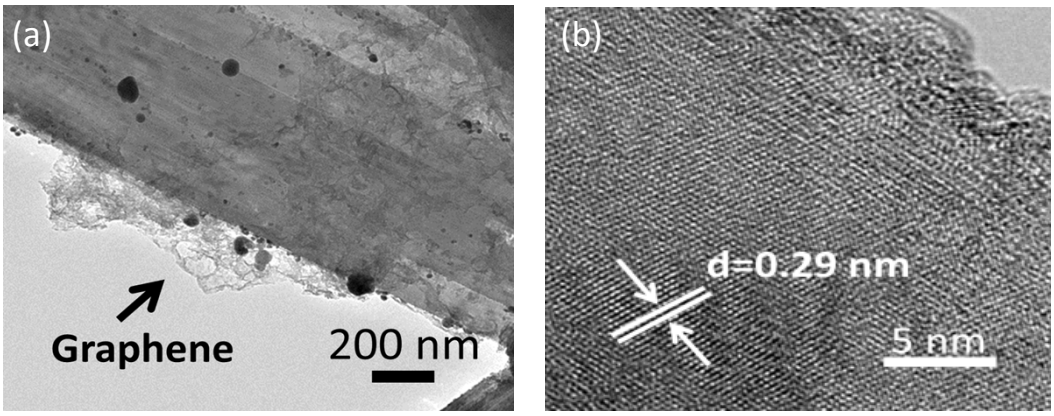

Fig. S4 TEM and HRTEM image of the SVO-graphene (40) hybrid synthesized in 12 h. The HRTEM of SVO-graphene (40) hybrid shows a well-defined crystalline structure with a lattice space of 0.29 nm, corresponding to the (003) plane of $Ag_{1-x}V_2O_5$.

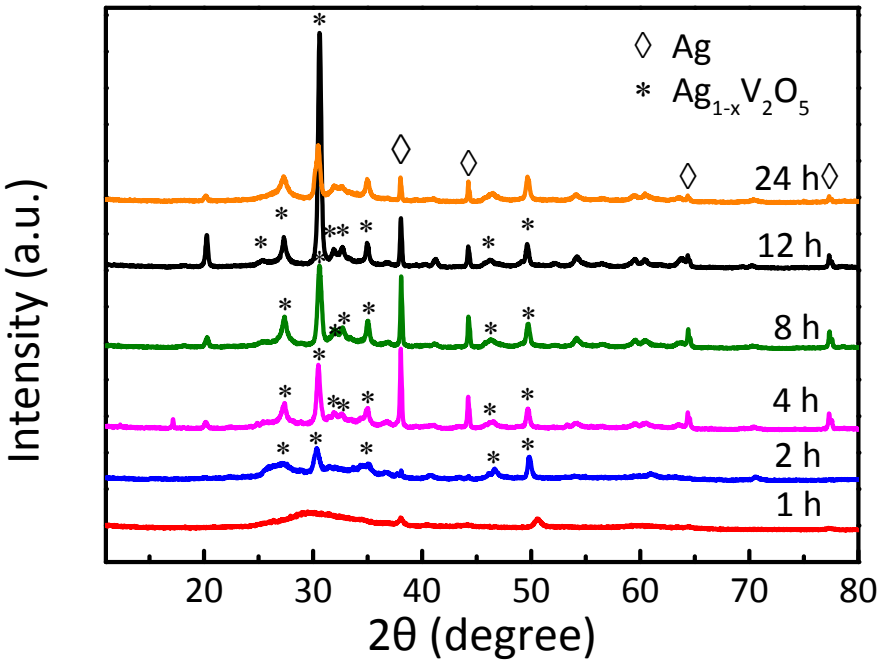

Fig. S5 XRD patterns of the SVO-graphene (40) hybrids hydrothermally treated with different time.

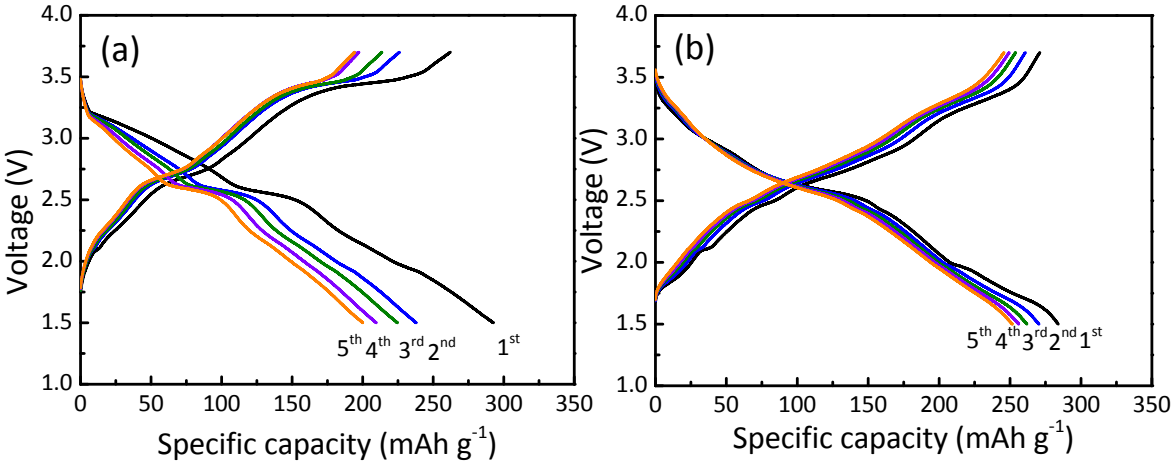

Fig. S6 The first 5 discharge-charge curves of (a) the pure SVO without graphene and (b) the SVO-graphene (40) hybrid at 50 mA g^{-1} over a potential window of 1.5 V-3.7 V vs. Li/ Li^+.

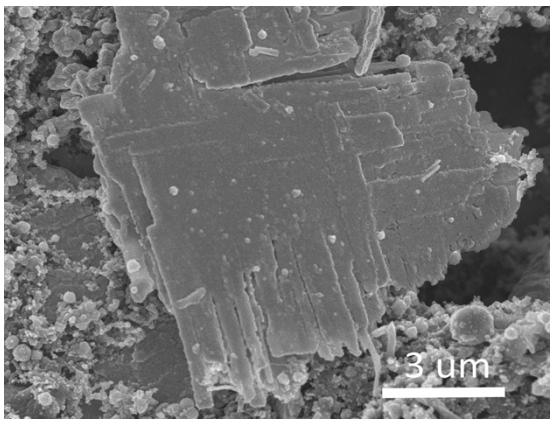

Fig. S7 Typical SEM image of the SVO-graphene (40) hybrid electrode material after 50 cycles.

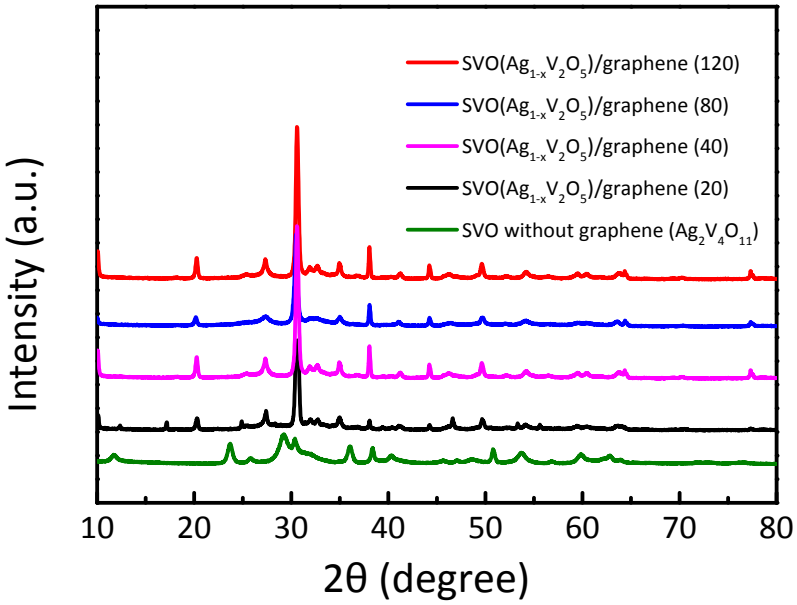

Fig. S8 XRD patterns of the pure SVO without graphene and the SVO-graphene hybrids with different contents of GO. The formation of $Ag_{1-x}V_2O_5$ after graphene added is possibly due to some Ag^+ were reduced into Ag, resulting in the amount of Ag^+ that participates in the formation of SVO is insufficient.

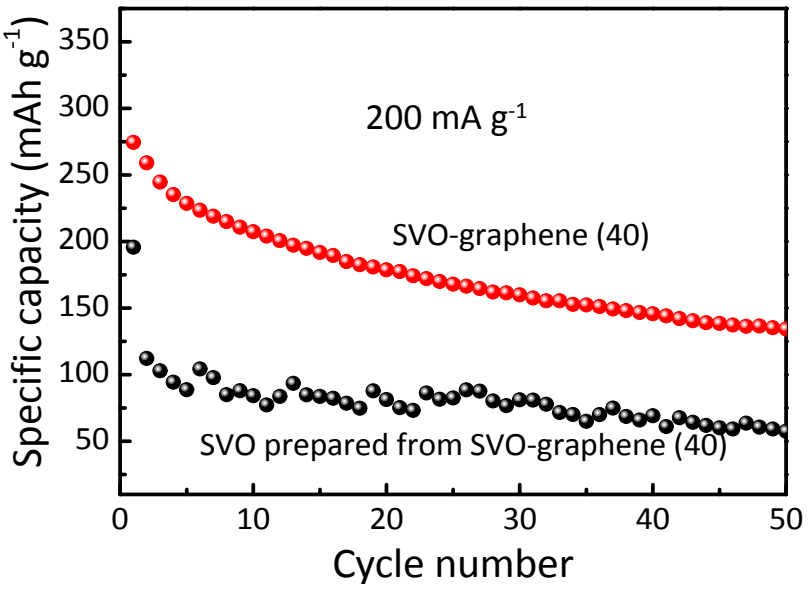

Fig. S9 The comparison of the electrochemical performance of SVO-graphene (40) and SVO prepared by the removal of graphene from SVO-graphene (40) through calcining it in air at 450 °C for 2 h.

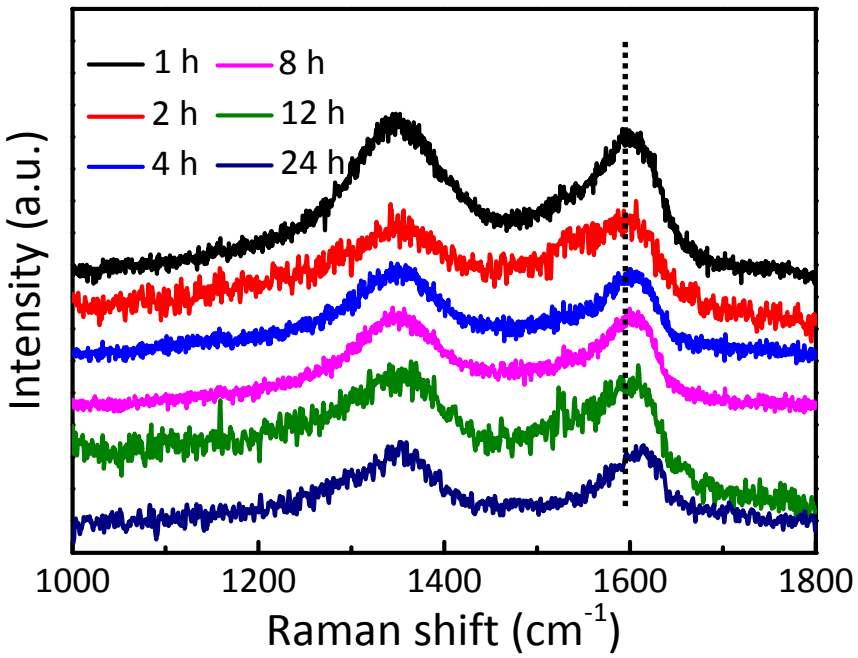

Fig. S10 Raman spectra of the SVO-graphene (40) hybrid prepared in different hydrothermal treatment time.

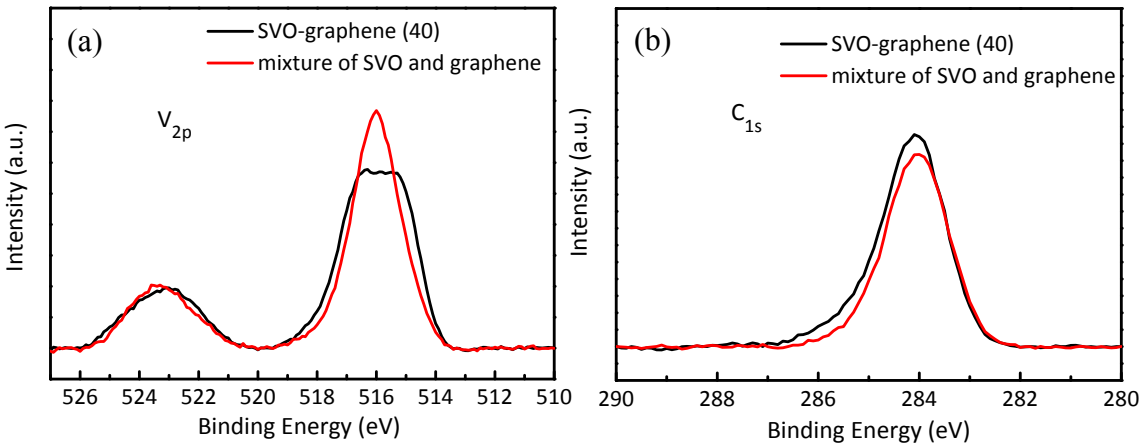

Fig. S11 (a) V_{2p} and (b) C_{1s} XPS profiles of SVO-graphene (40) hybrid and a simple mixture of SVO and graphene.

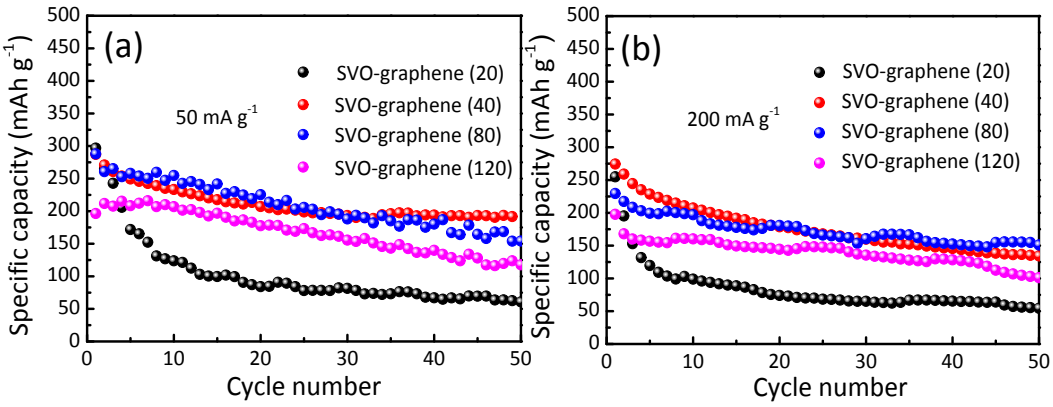

Fig. S12 The comparison of the cycling behavior of the SVO-graphene hybrids added with different content of GO: 20 mg, 40 mg, 80 mg, 120 mg at (a) 50 mA g^{-1}, (b) 200 mA g^{-1} with a potential window of 1.5V-3.7 V vs. Li/ Li^+ .

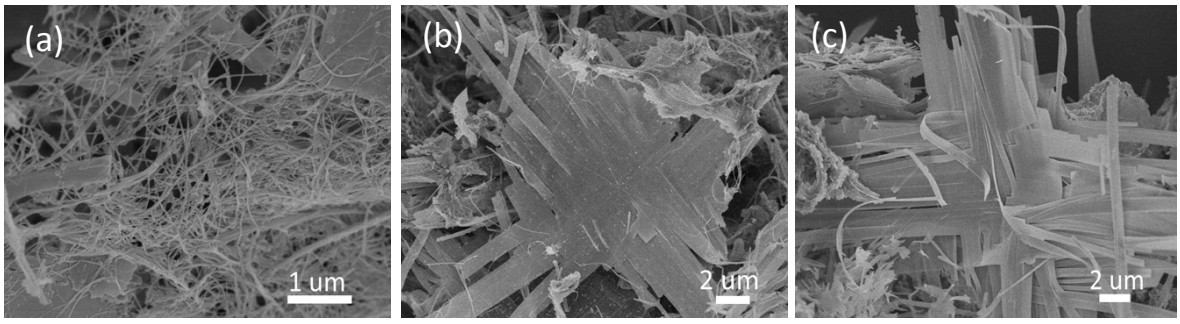

Fig. S13 Typical SEM images of the SVO-graphene hybrids prepared by adding different contents of GO: (a) 20 mg, (b) 80 mg, (c) 120 mg.

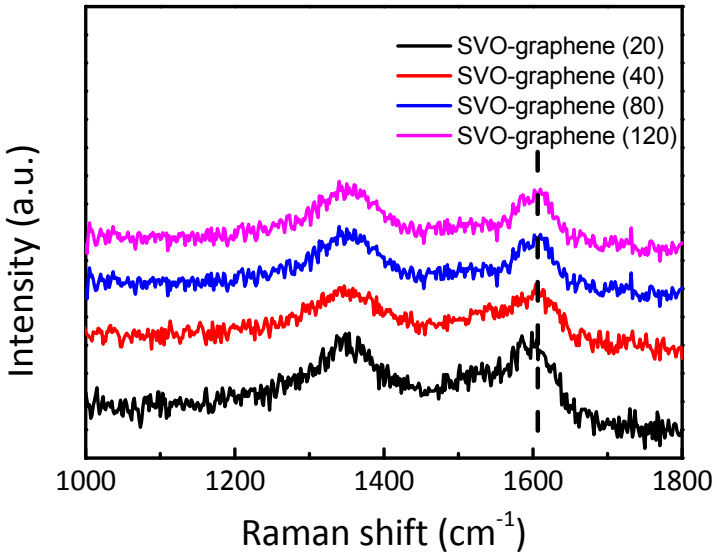

Fig. S14 Raman spectra of the SVO-graphene hybrids with different contents of GO**.**

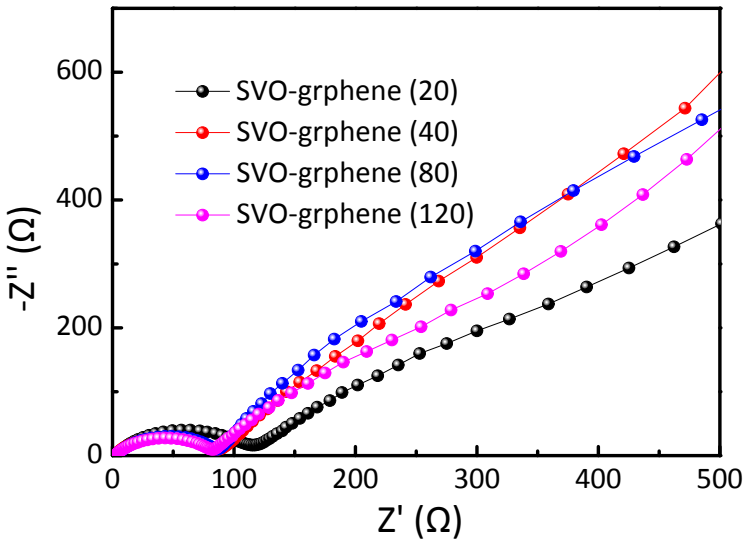

Fig. S15 EIS profiles of the SVO-graphene hybrids with different contents of GO.