

## Supplementary Information for

# 1-Dimensional AgVO<sub>3</sub> Nanowires Hybrid with 2-Dimensional Graphene Nanosheets to Create 3-Dimensional Composite Aerogels and its Improved Electrochemical Property

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### Supporting materials include:

#### Part I. Experimental details

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## Part I. Experimental details

### Preparation

#### Preparation of Graphene Oxide

Graphene Oxide (GO) was synthesized from KS-6 using a modified Hummers method.<sup>1</sup> Briefly, KS-6 (2.0 g) was added to concentrated sulfuric acid (46 mL) under strongly stirring at 0 °C, and then potassium permanganate (6 g) was added slowly to keep the temperature of the suspension lower than 20 °C for 30 min. After this, the reaction system was transferred to a 35 °C water bath with stirring for 2 h, forming a thick paste. Next, 100 mL of water was added slowly to the above solution. Subsequently, the reaction system was transferred to a 95 °C water bath under vigorous agitation for another 15 min. Then, the suspension was diluted by 280 mL of water and treated with 6 mL of H<sub>2</sub>O<sub>2</sub> (30%) to reduce residual permanganate to soluble manganese ions, and the color of solution turned from brown to golden yellow. Finally, the mixture was filtered and washed with 1:10 HCl aqueous solution (1000 mL) to remove metal ions followed by repeated washing with water and centrifugation to remove the acid, and dried in a vacuum oven at 60 °C for 24 h to obtain GO.

#### Preparation of AgVO<sub>3</sub> nanowires/Graphene Composite Aerogels, Pure Graphene Aerogels

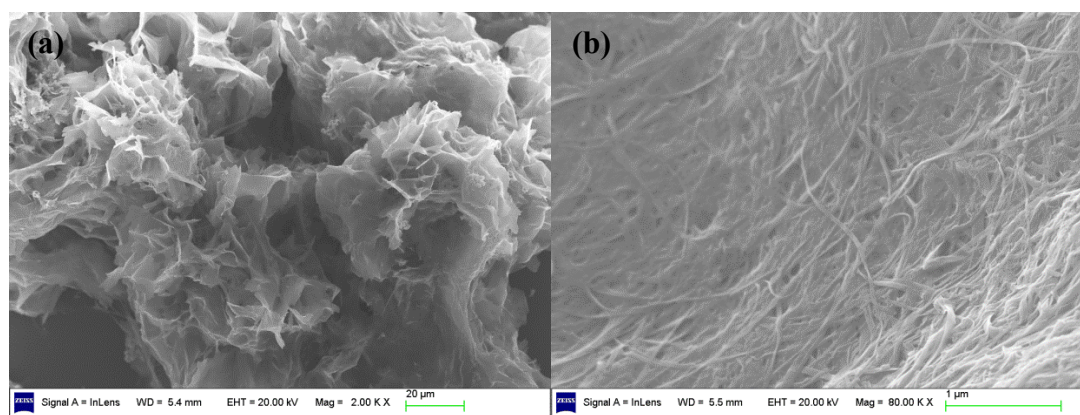
AgVO<sub>3</sub> nanowires/Graphene Composite Aerogels were synthesized by using a hydrothermal method assisted by freeze-drying process. Firstly, GO (120 mg) was dispersed in 40 mL of water by sonication to make a GO aqueous dispersion. Next, NH<sub>4</sub>VO<sub>3</sub> (0.46792g) was added to the GO aqueous dispersion and heated at 80 °C to completely dissolve NH<sub>4</sub>VO<sub>3</sub>. At the same time, AgNO<sub>3</sub> (0.67948 g) was dissolved in another 40 mL of water. After this, the GO aqueous dispersion with NH<sub>4</sub>VO<sub>3</sub> was slowly added into the AgNO<sub>3</sub> solution with strongly stirring. Subsequently, the mixture was sealed in a 100 mL Teflon-lined autoclave and hydrothermally treated at 180 °C for 72 h. Finally, the resulting hybrid hydrogels were dialysis for 3 days in deionized water to remove the residual reducing agents, and freeze-dried ( $5 \times 10^{-2}$  mbar at  $T \leq -46$  °C) for 24 h to obtain AgVO<sub>3</sub> nanowires/graphene composite aerogels. For comparison, we have synthesized pure graphene aerogels. Typically, GO (120 mg) was dispersed in 80 mL of water by sonication, reaching a concentration up to 1.5 mg mL<sup>-1</sup>. The resulting brown dispersion was sealed in an autoclave and heated at 180 °C for 72 h. The amount of GO used was 15% of AgVO<sub>3</sub> by weight, which was theoretically fabricated from 0.67948 g AgNO<sub>3</sub>.

## Characterization

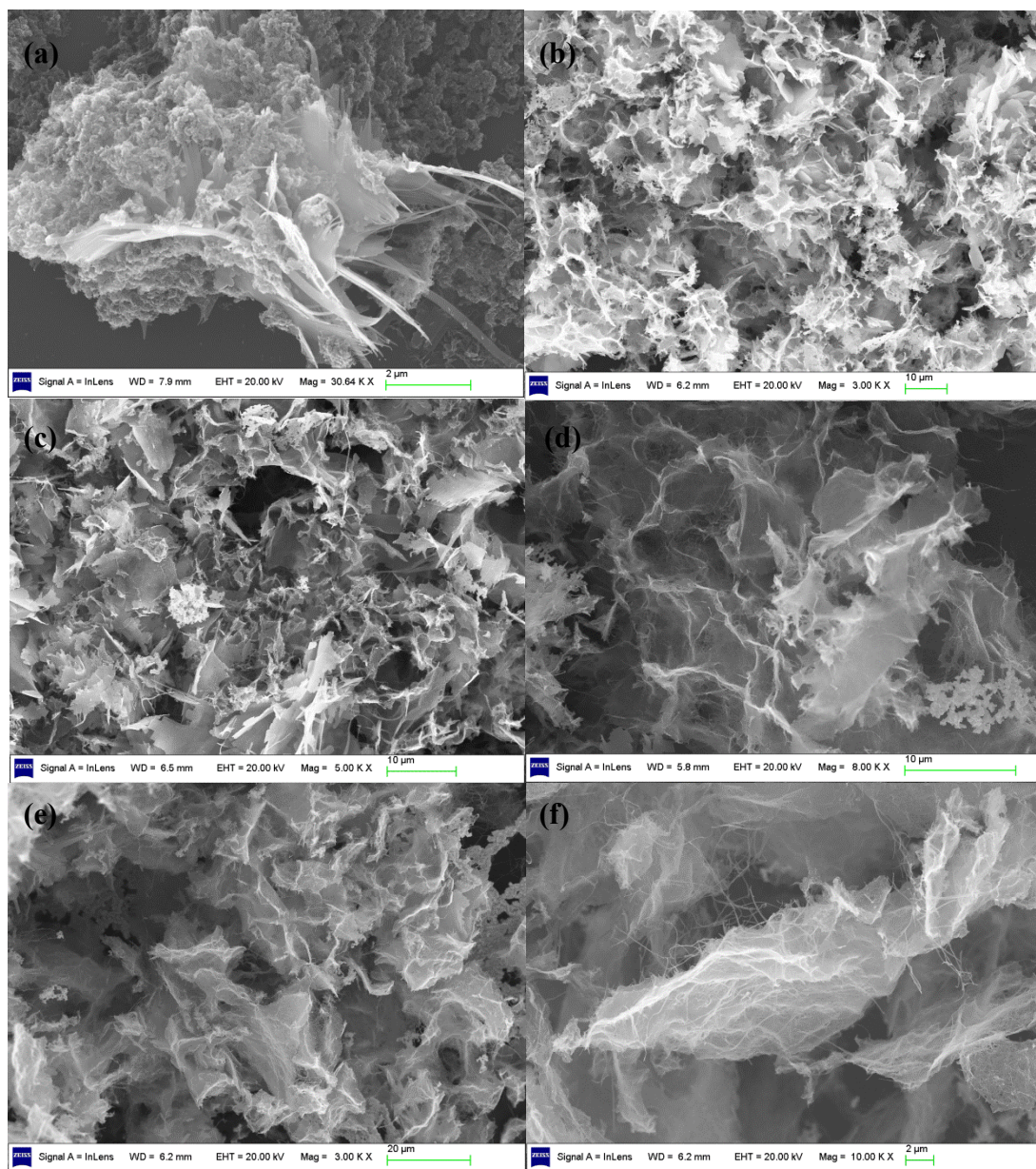
The morphology and crystalline structure of the samples was investigated by field emission scanning electron microscopy (FE-SEM, Zeiss Supra 55) and high resolution transmission electron microscopy (HRTEM, JEM-2100F). X-ray diffraction (XRD) patterns were carried on a Shimadzu XRD-6000 diffractometer using Cu-K $\alpha$  radiation ( $\lambda = 0.15406$  nm). Raman spectra were performed with a Renishaw RM2000 confocal Raman spectrometer with a 532 nm excitation laser. X-ray photoelectron spectroscopy (XPS) measurements were conducted using a Thermo Scientific ESCALAB 250 instrument equipped with Mg-K $\alpha$  X-ray source (1253.6 eV) at a pass energy of 30.0 eV. The binding energies obtained in the XPS analysis were calibrated for specimen charging by referencing the C 1s to 284.6 eV. The specific surface areas and the pore-size distributions were obtained at 77 K using the Brunauer-Emmett-Teller (BET) method with a Micromeritics ASAP2020 surface area and porosity analyzer. Before measurements, the samples were degassed at 80 °C for 12 h. The N $_2$  adsorption-desorption isotherm is fitted based on the Brunauer-Emmett-Teller (BET) model. The pore size distribution analysis is determined by the Barrett-Joyner-Halenda (BJH) method.

Electrochemical measurements were investigated using coin-cells with lithium metal as the counter and reference electrode. The working electrode was composed of 70% active materials, 20% acetylene black, and 10% polyvinylidene difluoride (PVDF) binder by weight. The above mixture was pressed onto an aluminum foil which served as a current collector. The electrode was dried at 120 °C in vacuum for 12 h. The electrolyte was 1 M LiPF $_6$  in EC-EMC-DMC (1: 1: 1 volume ratio). The cells were assembled in an argon-filled glove box. Galvanostatic discharge-charge measurements were performed at a potential range of 3.7-1.5 V vs. Li $^+$ /Li using a LAND-CT2001A test system (Wuhan, China) at room temperature. Cyclic voltammetry (CV) was carried out at a scan rate of 0.1 mV s $^{-1}$  using a CHI650D work station (Chenhua, Shanghai). The specific capacity and current density were based on the whole composite material.

## Part II. Supplementary Figures

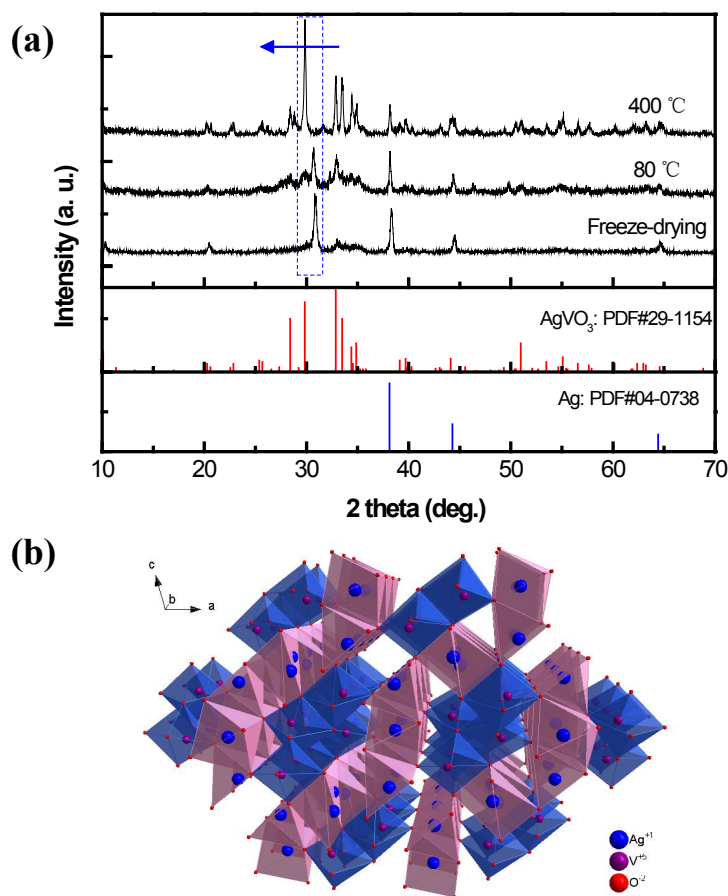


**Fig. S1** SEM images of AgVO<sub>3</sub>/graphene composite hydrogels after hydrothermal self-assembly at 180 °C for 72 h.



**Fig. S2** SEM images of AgVO<sub>3</sub>/graphene composite aerogels after hydrothermal self-assembly at 180 °C for (a) 12 h, (b) 24 h, (c) 48 h, (d) 72 h, and (e, f) 96 h.

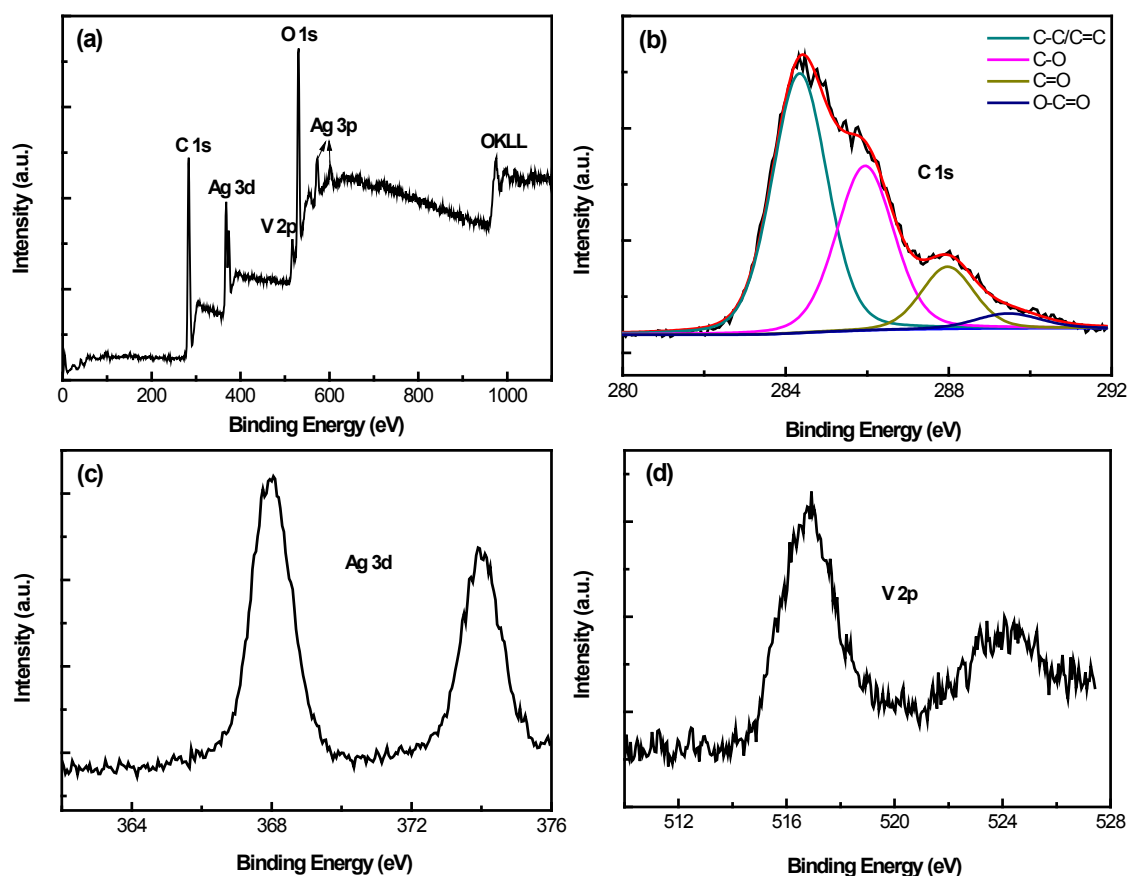




**Fig. S3** (a) XRD patterns of  $\text{AgVO}_3/\text{GAs}$  after freeze-drying,  $80\text{ }^\circ\text{C}$  for 12 h in vacuum, and  $400\text{ }^\circ\text{C}$  for 2 h in air. (b) Crystal structure of  $\beta\text{-AgVO}_3$ .

The structure of  $\text{AgVO}_3/\text{GAs}$  was confirmed by X-ray diffraction (XRD). Fig. S3a displays XRD patterns of  $\text{AgVO}_3/\text{GAs}$  at different post treatment conditions, which are freeze-drying,  $80\text{ }^\circ\text{C}$  for 12 h in vacuum, and  $400\text{ }^\circ\text{C}$  for 2 h in air, respectively. The composite aerogels after freeze-drying consist of part of low crystallinity of  $\text{AgVO}_3$  nanowires and some Ag particles (JCPDS card no. 04-0738), in which these Ag particles were incompletely used to prepare  $\text{AgVO}_3$ . However, with the improved treatment temperatures, the diffraction peaks intensity of Ag particles is gradually weakening, in contrast, the peaks of  $\text{AgVO}_3$  become increasing sharp and intense, and all peaks can be readily indexed to the monoclinic  $\beta\text{-AgVO}_3$  (JCPDS card no. 29-1154). No apparent diffraction peak of graphene is attributed to the small amount (13%) in the composite aerogels. Meanwhile, it is worth

noting that the diffraction peak at  $29.837^\circ$  for JCPDS card no. 29-1154 shifts to larger degree after freeze-drying, due to the decreased distance between the vanadium oxide sheets. With respect to  $\beta$ - $\text{AgVO}_3$  crystal structure (Fig. S3b), the silver interlayer is between the vanadium oxide sheets, and hence the shortage of Ag in silver interlayer of  $\text{AgVO}_3$  leads to the shrunken layer distance after freeze-drying.



**Fig. S4** (a) XPS survey spectrum of  $\text{AgVO}_3/\text{GAs}$  after freeze-drying. (b), (c), and (d) XPS core level spectra of C 1s, Ag 3d, and V 2p regions.

The chemical attribute of  $\text{AgVO}_3/\text{GAs}$  has been investigated by X-ray photoelectron spectroscopy (XPS) as shown in Fig. S4. No peaks of other elements except C, O, Ag, and V were observed in the survey spectrum (Fig. S4a), indicating the high purity of the composite aerogels. Fig. S4b shows C 1s XPS peaks at 284.34, 285.95, 287.97, and 289.46 eV, corresponding to C=C/C-C in aromatic rings, C-O (epoxy and alkoxy), carbonyl, and carboxyl groups, respectively. The corresponding components of Ag 3d and V 2p can be found in our previous work.<sup>2</sup>



**Table S1 The comparison of electrochemical properties of different SVOs**

Composition	Current density	Capacity (mAh g <sup>-1</sup> ) (cycle number)	Capacity retention (cycle number)
$\beta$ -AgVO <sub>3</sub> nanowires <sup>3</sup>	0.01 mA	302.1 (1)-90.6 (20)	30% (20)
Nanocrystalline Ag <sub>2</sub> V <sub>4</sub> O <sub>11</sub> <sup>4</sup>	2C	305 (1)-100 (30)	32.8% (30)
Ag <sub>2</sub> V <sub>4</sub> O <sub>11</sub> /Ag nanobelts <sup>5</sup>	20 mA g <sup>-1</sup>	276 (1)-30 (20)	10.9% (20)
$\beta$ -Ag <sub>0.33</sub> V <sub>2</sub> O <sub>5</sub> nanoparticles <sup>6</sup>	100 mA g <sup>-1</sup>	175 (1)-125 (30)	71.4% (30)
$\beta$ -AgVO <sub>3</sub> nanorods <sup>7</sup>	100 mA g <sup>-1</sup>	228.8 (1)-106 (30)	46.3% (30)
	400 mA g <sup>-1</sup>	202.7 (1)-65 (30)	32.1% (30)
$\beta$ -AgVO <sub>3</sub> /PANI nanowires <sup>8</sup>	30 mA g <sup>-1</sup>	211 (1)-131 (20)	62% (20)
$\beta$ -AgVO <sub>3</sub> nanowire clusters <sup>9</sup>	100 mA g <sup>-1</sup>	220 (1)-96 (50)	43.6% (50)
	<b>50 mA g<sup>-1</sup></b>	<b>195.8 (1)-118.8 (50)</b>	<b>60.9% (50)</b>
	<b>100 mA g<sup>-1</sup></b>	<b>185 (1)-118.9 (50)</b>	<b>62.9% (50)</b>
	<b>400 mA g<sup>-1</sup></b>	<b>166.5 (1)-106.4 (50)</b>	<b>63.9% (50)</b>
	<b>800 mA g<sup>-1</sup></b>	<b>159.1 (1)-106.1 (50)</b>	<b>66.7% (50)</b>
<b>This work</b>	<b>1000 mA g<sup>-1</sup></b>	<b>143.9 (1)-116.4 (50)</b>	<b>80.9% (50)</b>

## References

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