Electronic Supplementary Information (ESI) for

RuSe/reduced graphene oxide: an efficient electrocatalyst for VO^{2+}/VO_2^+ redox couples in vanadium redox flow batteries

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Experimental

GO was prepared using a modified Hummers' method [1]. The RuSe/rGO catalyst was prepared by the following method: typically, GO (240 mg) was added into 100 mL ethylene glycol (EG) and ultrasonicated for 2h. Ruthenium trichloride (Sigma, 143 mg) in 80 mL EG and 17 mg Na_2SeO_3 in 10 mL water were added into the above suspension. The solution was then magnetically stirred for 30 min and followed by an ultrasonication for 30 min. 1 mol L^{-1} NaOH solution was dropped into the above solution to adjust the pH value to 8. The homogeneous solution was placed in the flask and refluxed in an oil bath. Subsequently, the solution was bubbled with Ar gas for 20 min and treated at 160 ^oC for 3h. Then it was centrifuged and washed with deionized water and dried in a vacuum oven at 50 ^oC overnight. The final product of RuSe/rGO nanocomposite was obtained.

Structural information of RuSe/rGO nanocomposite was recorded by transmission electron microscopy (TEM, JEOL 2100F) and X-ray diffraction (XRD, D/max 2200/PC, Rigaku). X-ray photoelectron spectroscopy (XPS) data was obtained with an ESCALab220i-XL electron spectrometer from VG Scientific using a 300 W Al Ka radiation.

Cyclic voltammetry (CV) and electrochemical impedance spectroscopy (EIS) were performed using an Electrochemical Workstation (ZAHNER-Elektrik GmbH & Co. KG, Germany) with a traditional three-electrode system. A sample of 5 mg active materials (rGO or RuSe/rGO) was dispersed in 1 mL ethanol containing Nafion (5

wt%) to prepare a homogeneous ink, and 5 μL drop of ink was put onto a glassy-carbon disk electrode to obtain a working electrode. So, the active material loaded on the glassy-carbon disk electrode is 0.025 mg. A saturated calomel electrode and a platinum wire were applied as the reference and counter electrodes, respectively. The potentials mentioned in this paper were referred to the standard hydrogen electrode. The electrolyte was 2 mol L^{-1} $VOSO_4$ solution containing 2 mol L^{-1} H_2SO_4.

The performances of the VRFB cells (size: 40mm×70mm) with rGO or RuSe/rGO as the cathode electrocatalyst and the thermally treated graphite felt as the anode were tested on a LAND battery testing system. The electrolytes were circulated through the corresponding cell at a flow rate of 20 mL $mins^{-1}$. Charge-discharge measurements were carried out galvanostatically at various current densities over a voltage range of 0.8-1.6 V. Nafion 117 proton-exchange membrane was used as separator.

References

[1] W.S. Hummers and R.E. Offeman, *J. Am. Chem. Soc.*, 1958, **80**, 1339.

Table S1. Peak current densities of VO^{2+}/VO_2^+ redox couples under different scan rate.

Samples	Peak current densities [A mg^{-1}]											
	2 mV s^{-1}			5 mV s^{-1}			10 mV s^{-1}			20 mV s^{-1}		
	I_{pa}	I_{pc}	$\lvert I_{pa}/ I_{pc}\rvert$	I_{pa}	I_{pc}	$\lvert I_{pa}/ I_{pc}\rvert$	I_{pa}	I_{pc}	$\lvert I_{pa}/ I_{pc}\rvert$	I_{pa}	I_{pc}	$\lvert I_{pa}/ I_{pc}\rvert$
rGO	0.0248	-0.002	12.4	0.0284	-0.0052	5.46	0.0376	-0.008	4.70	0.0456	-0.0112	4.07
RuSe/rGO	0.0848	-0.026	3.26	0.1212	-0.0492	2.46	0.1568	-0.0844	1.85	0.2048	-0.1232	1.66

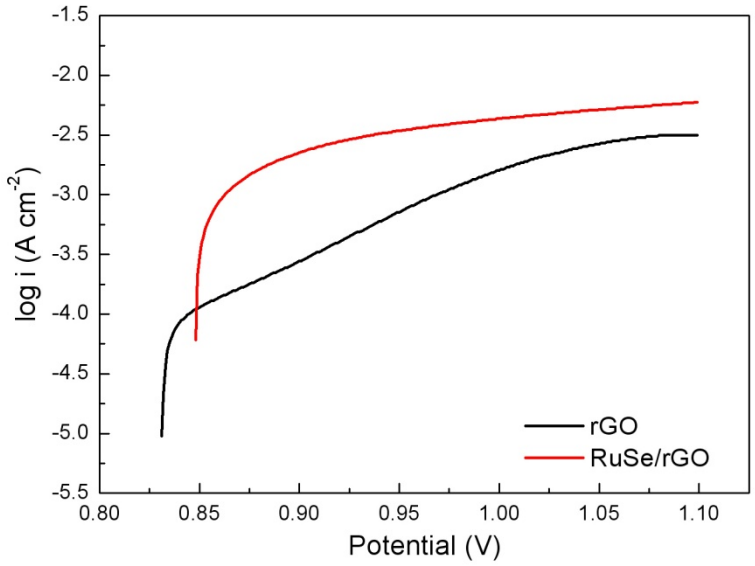

Fig. S1 Tafel polarization curve of rGO and RuSe/rGO in the solution of 2 mol L^{-1} $VOSO_4$ solution containing 2 mol L^{-1} H_2SO_4 with scan rate of 5 mV s^{-1}.