Electronic Supplementary Material (ESI) for Catalysis Science & Technology.

Supporting Information

Antimony doped tin oxide as an efficient electro-catalyst toward VO^{2+}/VO_2^+ redox couple for vanadium redox flow battery

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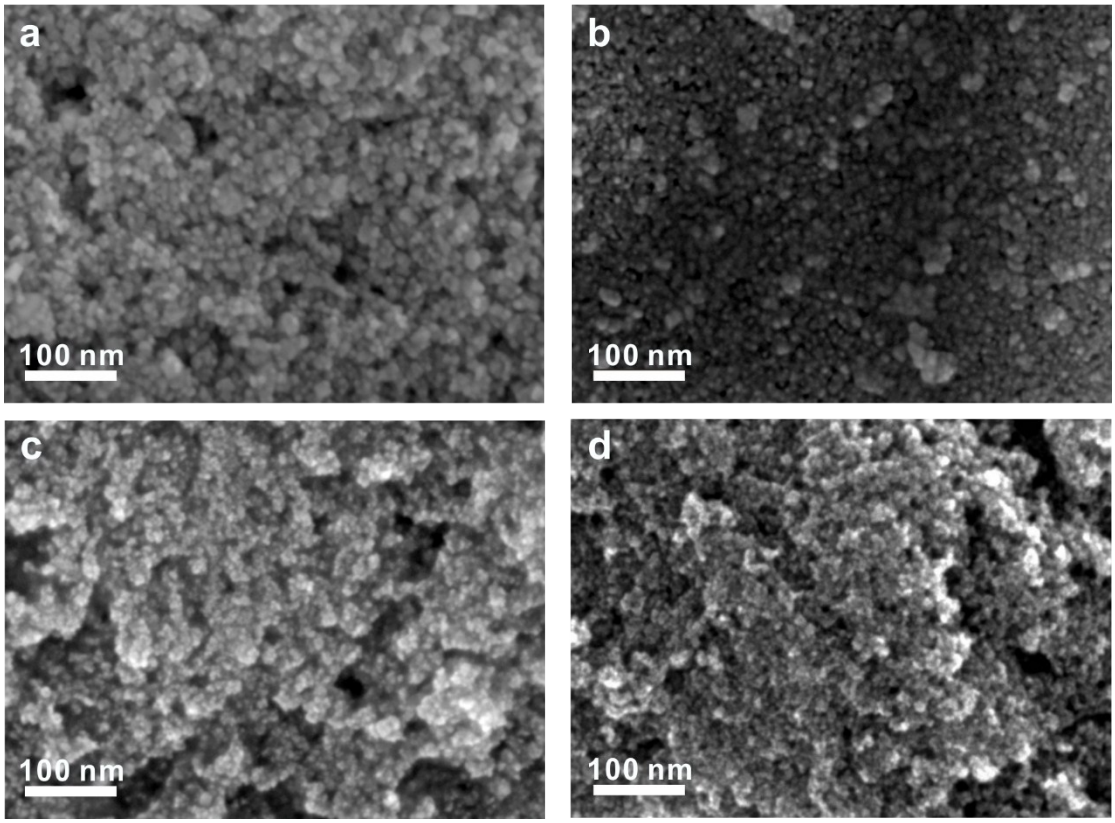

Fig. S1. Scanning electron microscope images of (a) SnO_2, (b) ATO-5, (c) ATO-9 and (d) ATO-15.

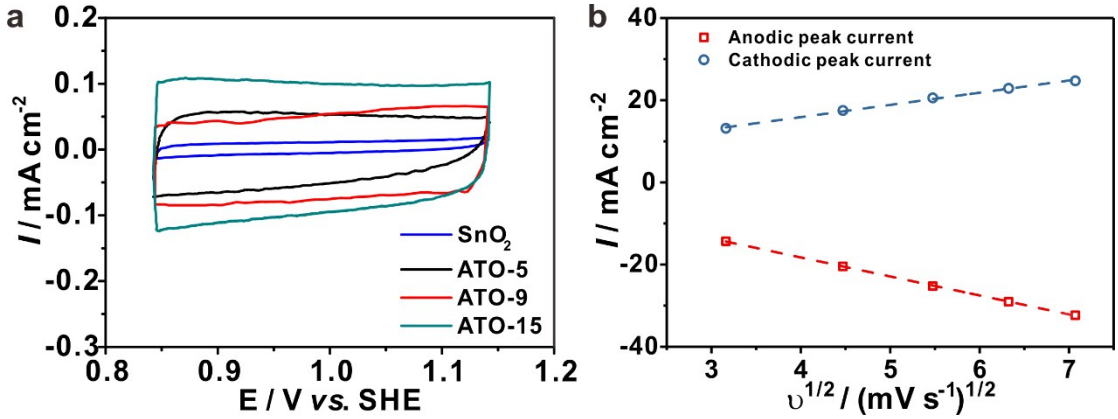

Fig. S2. (a) The cyclic voltammetry curves of SnO_2, ATO-5, ATO-9 and ATO-15 on glassy carbon electrode as working electrode in 1.0 mol L^{-1} H_2SO_4 solution at a scan rate of 10 mV s^{-1}. (b) Variation peak currents as a function of the square root of the scan rates on ATO-9.

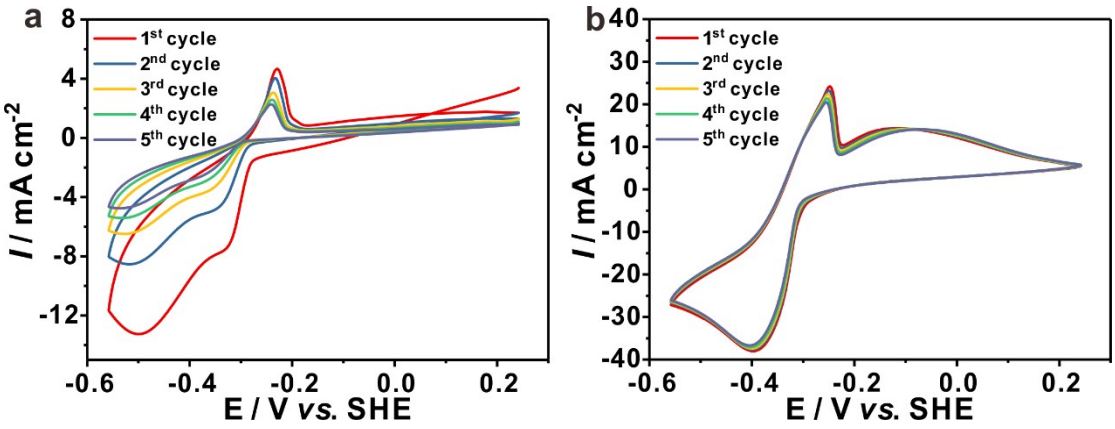

Fig. S3. (a)The cyclic voltammetry curves of ATO-9 on glassy carbon electrode as working electrode in 1.0 mol L^{-1} H_2SO_4 solution at a scan rate of 50 mV s^{-1}. (b) The cyclic voltammetry curves of ATO-9 nanoparticles on glassy carbon electrode as working electrode in 1.0 mol L^{-1} V^{2+} + 3 mol L^{-1} H_2SO_4 solution at a scan rate of 50 mV s^{-1}.

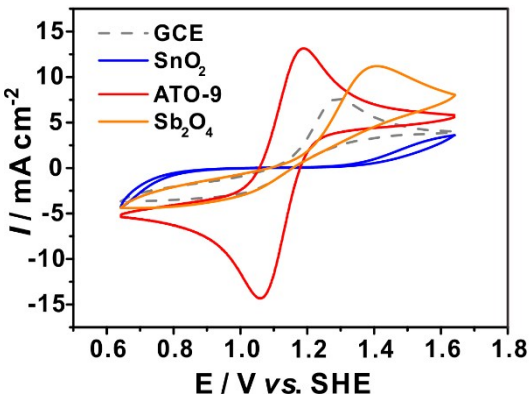

Fig. S4. The cyclic voltammetry curves of SnO_2, Sb_2O_4 and ATO-9 nanoparticles on glassy carbon electrode and bare GCE as working electrode in 1.0 mol L^{-1} $VOSO_4$ + 3.0 mol L^{-1} H_2SO_4 solution at a scan rate of 10 mV s^{-1}. (The Sb_2O_4 nanoparticles, which include two oxidation valence states of Sb (III) and Sb (V), were prepared according to the reported reference.[1])

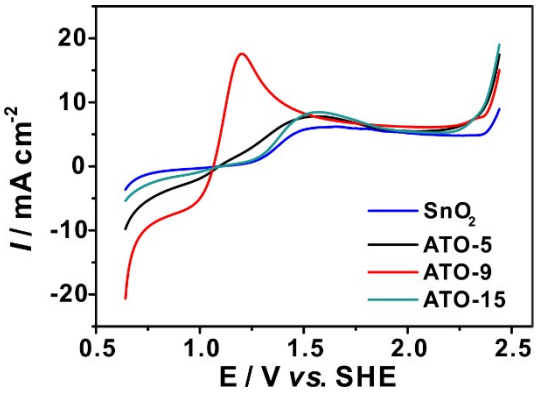

Fig. S5. LSV curves of SnO_2, ATO-5, ATO-9 and ATO-15 nanoparticles on glassy carbon electrode as working electrode in 1.0 mol L^{-1} $VOSO_4$ + 3.0 mol L^{-1} H_2SO_4 solution at a scan rate of 10 mV s^{-1}.

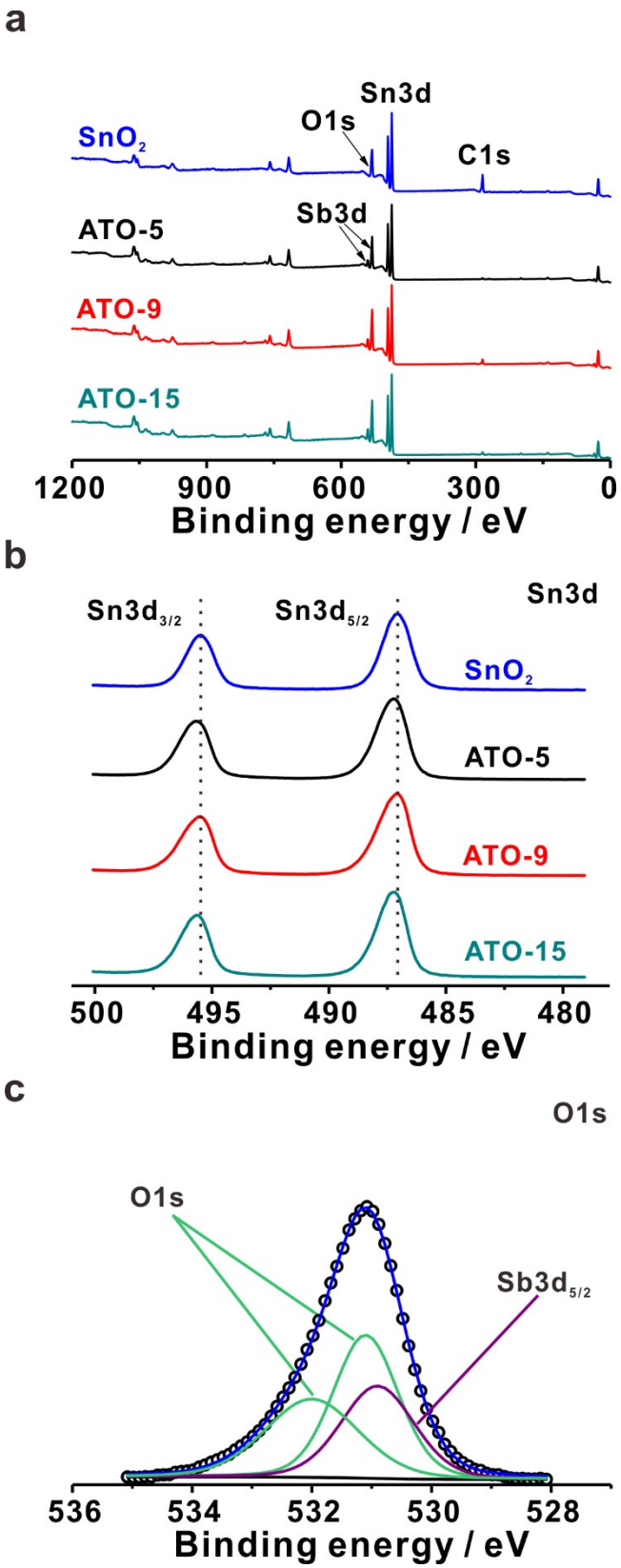

Fig. S6. (a) XPS spectra of SnO_2, ATO-5, ATO-9 and ATO-15. (b) Sn3d XPS spectra of SnO_2, ATO-5, ATO-9 and ATO-15. (c) O1s XPS spectra of ATO-9. The blue, green line represents the fitted peaks of O1s and $Sb3d_{5/2}$ spectra. Black circles exhibit the original peak and blue line is the total fitted line.

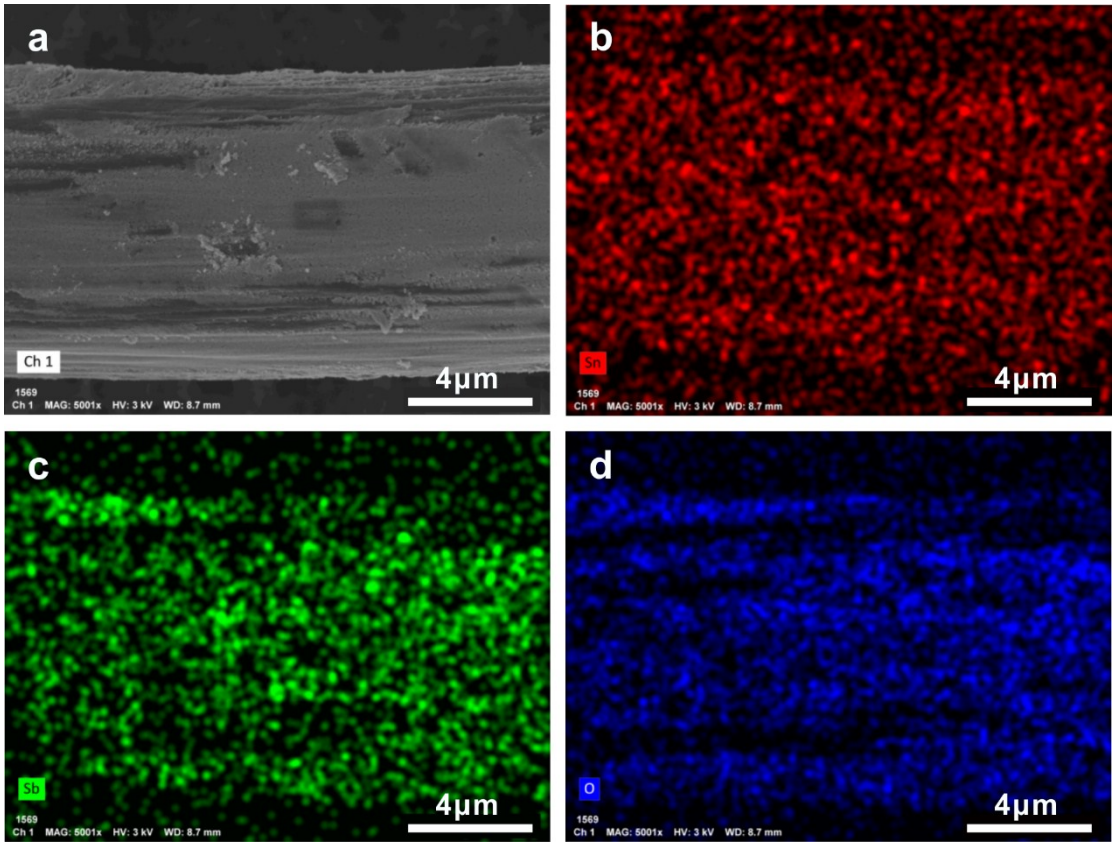

Fig. S7. SEM image (a) and EDS element mapping of ATO-9 coated on graphite felt: element Sn (b), element Sb (c) and element O (d).

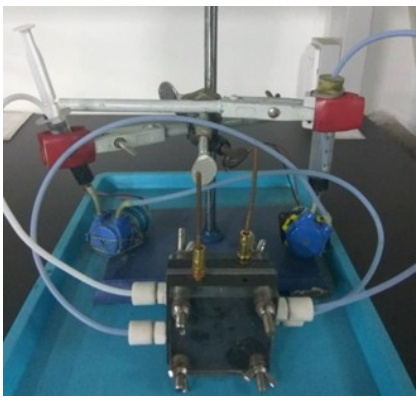

Fig. S8. The photograph of a vanadium redox flow battery.

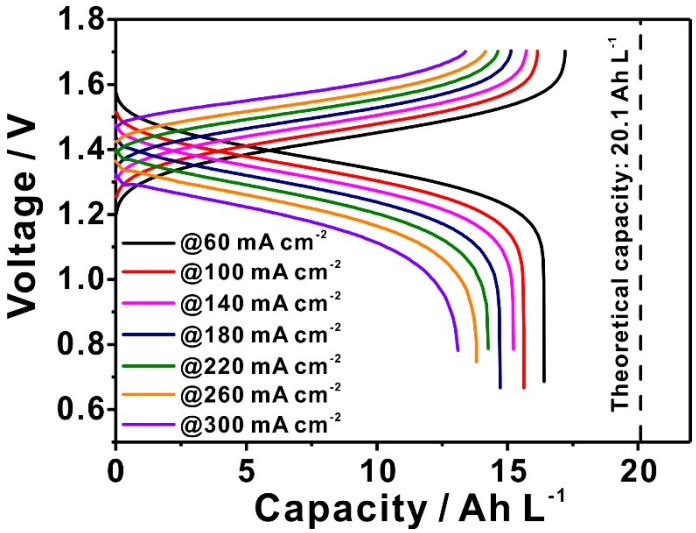

Fig. S9. Charge-discharge curves of VRFB employing with optimized ATO-9@GF at different current densities.

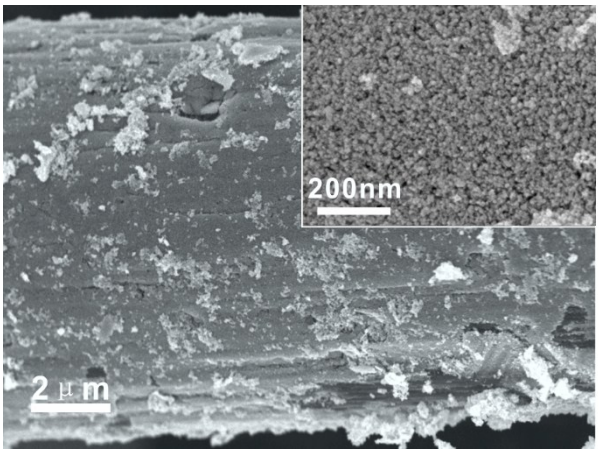

Fig. S10. SEM images of ATO-9 coated on graphite felt after cell cyclic measurement.

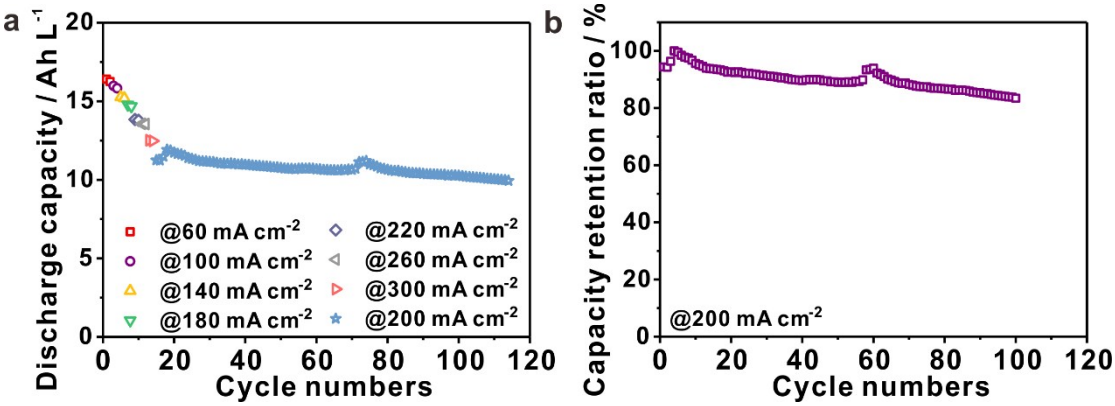

Fig. S11. (a) The discharge capacity of VRFB with ATO-9@GF at different cycles. (b) Capacity retention ratio of VRFB with ATO-9@GF at 200 mA cm^{-2}.

Table S1. Sb doping level and resistivity of SnO_2, ATO-5, ATO-9 and ATO-15.

Catalyst	Sb doping level (%)[a]	Resistivity (Ω cm)
SnO_2	0	16512.32
ATO-5	6.70	14.59
ATO-9	9.77	7.66
ATO-15	13.71	36.76

[a] Determined by ICP-MS.

Table S2. Comparison of various metallic oxides electrodes for vanadium redox flow battery application.

Catalyst	ΔE_p (mV)	Scan rate (mV s^{-1})	Current density (mA cm^{-2})	CE (%)	VE (%)	EE (%)	Ref
Mn_3O_4	~560	20	40	85.40	90.20	77.00	[2]
WO_3	106	10	60	95.10	81.80	78.10	[3]
TiO_2	~125	5	200	90.00	73.00	65.40	[4]
ZrO_2	224	1	200	93.70	71.90	67.40	[5]
SnO_2/CF	766	10	150	97.40	79.30	77.30	[6]
ATO-9	133	10	140	97.92	87.80	85.97	This work
			220	97.98	81.32	79.68	
			300	98.06	74.53	73.09	

References

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