Electronic Supplementary Information

Oxygenated copper vanadium selenide composite nanostructures as a cathode material for zinc-ion batteries with high stability up to 10 000 cycles

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1. Experimental procedure

1.1. Materials

Following chemicals, such as copper (II) nitrate trihydrate ($CuH_6N_2O_9$, Sigma Aldrich, 99%), selenious acid ($Se_2H_2O_3$, Sigma Aldrich, 99%), 2-methylimidazole ($C_4H_6N_2$, Sigma Aldrich, 99%), ammonia meta vanadate (NH_4VO_3, Sigma Aldrich, 99%), metallic Zn (Sigma Aldrich, 0.1 cm thickness), zinc trifluoromethanesulfonate ($Zn(CF_3SO_3)_2$, Sigma Aldrich, 98%), and ZnCF (Sigma Aldrich, 98%), were utilized without further purification. The carbon fiber cloth (CFC) textile was received from the Nara Cell-Tech Corp., South Korea. Distilled water was produced in our laboratory by using a Milli-Q water equipment.

1.2. Material characterizations

The phase confirmation of the prepared samples was analyzed by X-ray diffraction (XRD; Rigaku MiniFlex 600 X-ray diffractometer with Cu K_α radiation). The morphology and fine structure of the powder sample were characterized by using a field-emission scanning electron microscope (FE-SEM; JEOL JSM-7500F) and a transmission electron microscope (TEM, JEOL- JEM). The valance states of the sample were examined by X-ray photoelectron spectroscopy (XPS; PHI 5000 VersaProbe ESCALAB 250xi).

1.3. Electrochemical measurements

The O-CuVSe cathode material slurry was prepared by mixing 70 wt% of active material, 15 wt% polyvinylidene fluoride, and 15 wt% of super P carbon in N-methyl 2 pyrrolidinone solvent. The well-mixed slurry was coated on a CFC substrate using a brush. The electrode was dried at 80 °C for 12 h in a vacuum over. After proper drying, O-CuVSe coated CFC was cut into circular discs. The mass loading of active material over the CFC substrate is around 1–2 mg cm^{-2}. The CR2032 coin-type cells were assembled in an air atmosphere using 2M ZnCF as an electrolyte, Zn metal

was employed as an anode, and GF/D glass fiber membrane (Whatman) was used as a separator. The galvanostatic charge-discharge (GCD) curves at various current densities and cyclic voltammetry (CV) curves at various scan rates were measured using the Wonna Tech battery cycler between the potential window of 0.4-2.0 V (*vs.* Zn/Zn^{2+}).

Table S1. Comparison of the electrochemical performance of the O-CuVSe cathode material along with the previously reported cathode materials.

Cathode material	Electrolyte	Voltage (V)	Reversible capacity (mA h g^{-1})	Current density (A g^{-1})	Cycles	Ref.
$Cu_{2-x}Se$	2M $ZnSO_4$	0.4–1.6	70	5	3000	1
$ZnMn_2O_4/Mn_2O_3$	2M $ZnSO_4$	0.8–1.9	80	1	1000	2
$ZnMn_2O_4$	2M $ZnSO_4$ with 0.05M $MnSO_4$	0.8–1.9	106.5	0.1	300	3
$Ni_xMn_{3-x}O_4$	(2M $ZnSO_4$ with 0.15M $MnSO_4$	1.0-1.8	128.8	0.4	850	4
$ZnNi_{0.5}Mn_{0.5}CoO_4$@C	2M $ZnSO_4$ with 0.1M $MnSO_4$	1.0-1.8	110	0.2	500	5
MoS_2	3M $Zn(CF_3SO_3)_2$	0.2-1.3	125	2	500	6
MoS_2@N	3M $Zn(CF_3SO_3)_2$	0.2-1.3	100	1	600	7
MoO_3	1M $ZnSO_4$	0.2-1.9	35	1	1000	8
VS_2@N-doped carbon	3 M $Zn(CF_3SO_3)_2$	0.2-1.8	144	1	600	9
α-MnO_2@C	1M $ZnSO_4$	1.0-1.8	189	0.066	50	10
MnO@NGS	2M $ZnSO_4$	0.9 -1.8	112.3	0.5	300	11
$Cu_3V_2O_7(OH)_2 \cdot 2H_2O$	2.5M $Zn(CF_3SO_3)_2$	0.2-1.6	100.1	0.2	130	12
CuHCF	1M $ZnSO_4$	1.4-2.0	44	0.1	50	13
CuHCF	1M $ZnSO_4$	0.8-1.9	40	0.02	20	14
CuHCF	20mM $ZnSO_4$	1.4-2.1	53	1	50	15
ZnHCF	1M $ZnSO_4$	0.8-2.0	49.4	0.06	100	16
ZnHCF@MnO_2	0.5M $ZnSO_4$	1.4-1.9	70	0.5	1000	17
$ZnNi_{1/2}Mn_{1/2}CoO_4$	0.3M Zn $(OTf)_2$ in MeCN	0.9-2.15	174	1	200	18
Mo_6S_8	1 M $ZnSO_4$	0.25-1.0	87.4	0.18	150	19
CC@MnO_2@MXene	0.1M $Mn(CH_3COO)_2$ with 0.01M Na_2SO_4	0.8-1.9	80.6	1	800	20
O-CuVSe	**2M $Zn(CF_3SO_3)_2$**	**0.4-2.0**	**166.6 117**	**1 2 5**	**1000 2000 10000**	**This work**

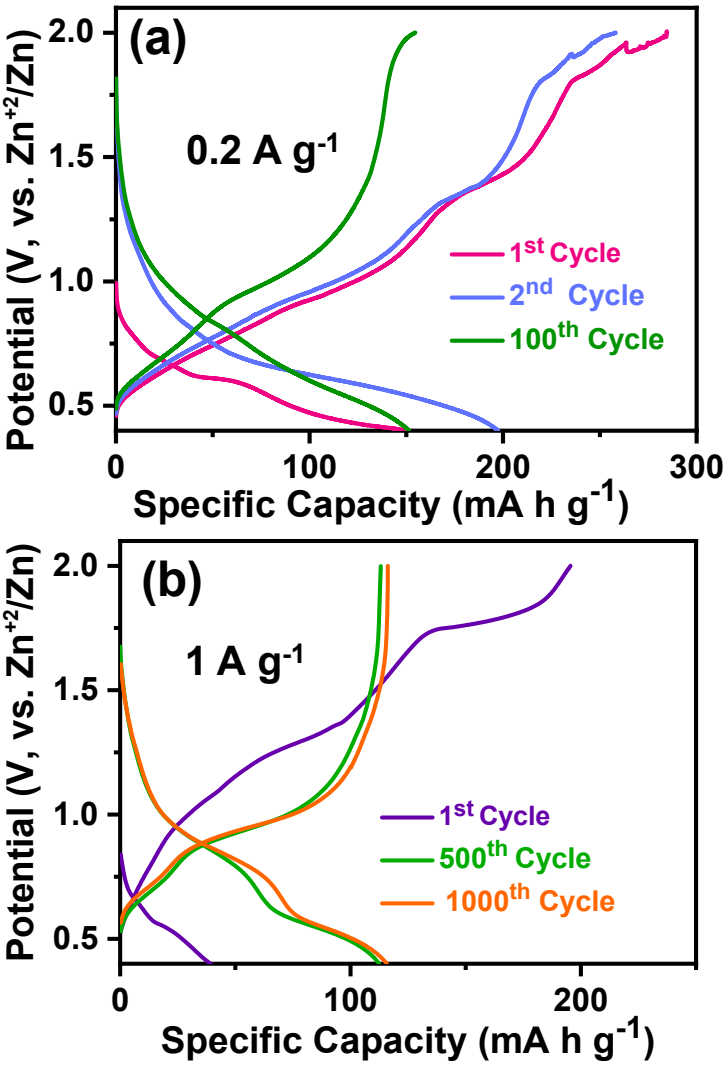

Fig. S1 Cycling performance of the O-CuVSe cathode at (a) 0.2 A g^{-1} and (b) 1 A g^{-1}.

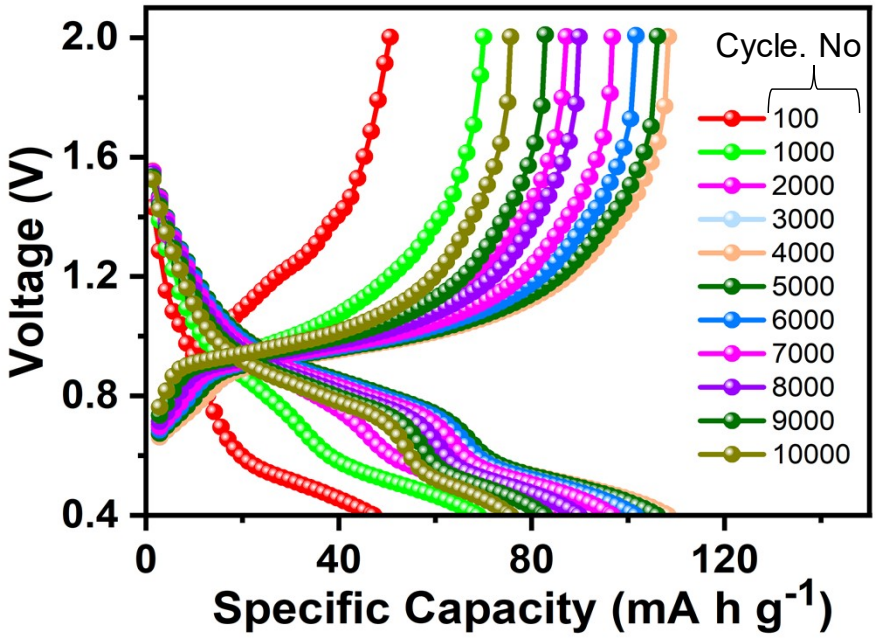

Fig. S2 Voltage profile curves of the O-CuVSe cathode at 5 A g^{-1}.

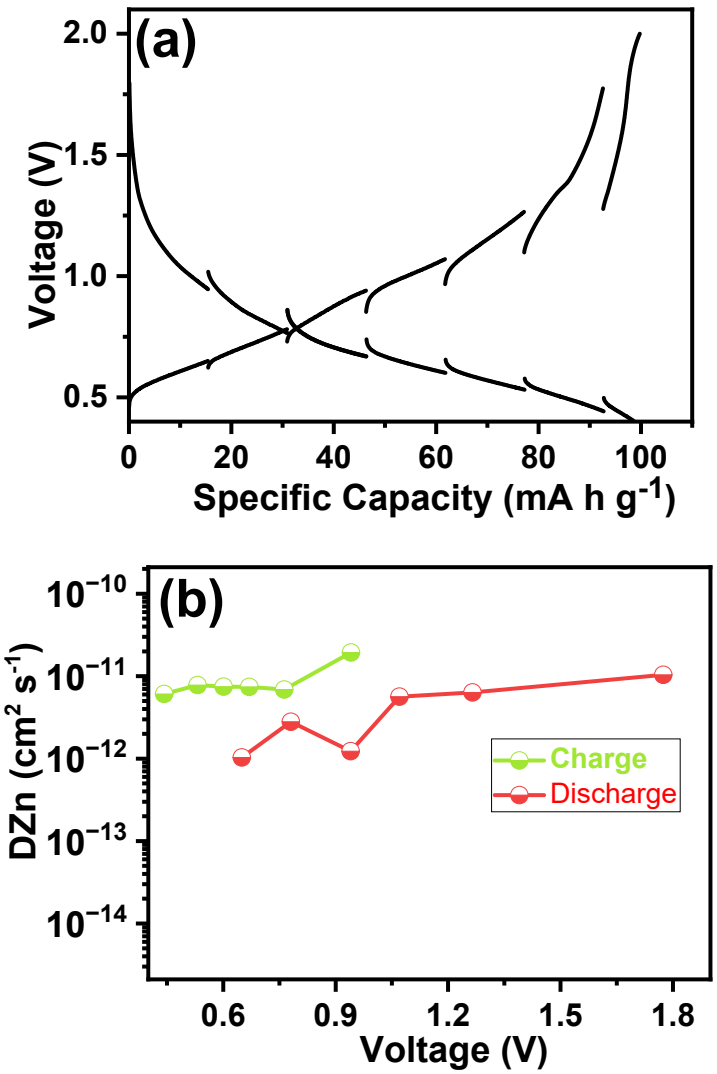

Fig. S3 (a) GITT curves and (b) corresponding diffusivity coefficient for Zn^{2+} in Zn/O-CuVSe battery *vs*. voltage.

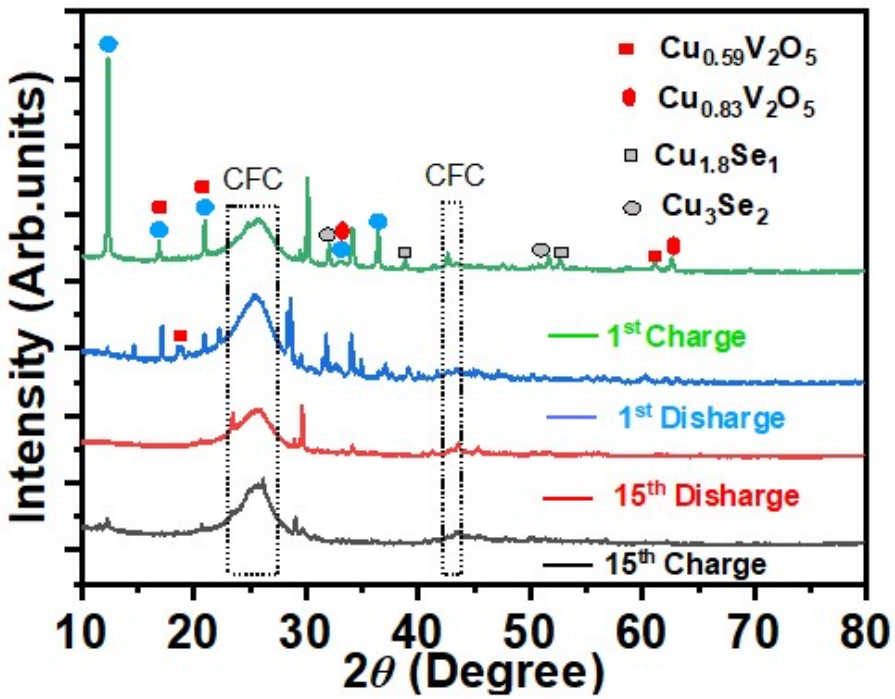

Fig. S4 Ex-situ XRD patterns of the O-CuVSe composite cathode measured after the 1st charge/discharge and 15th charge/discharge cycles.

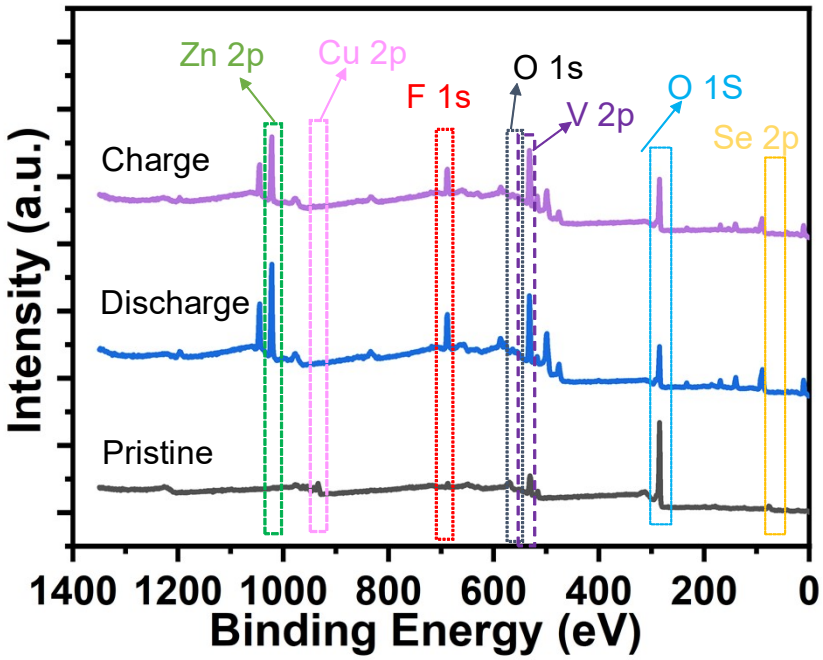

Fig. S5 XPS survey scan spectra of the O-CuVSe cathode in pristine, charge, and discharge states.

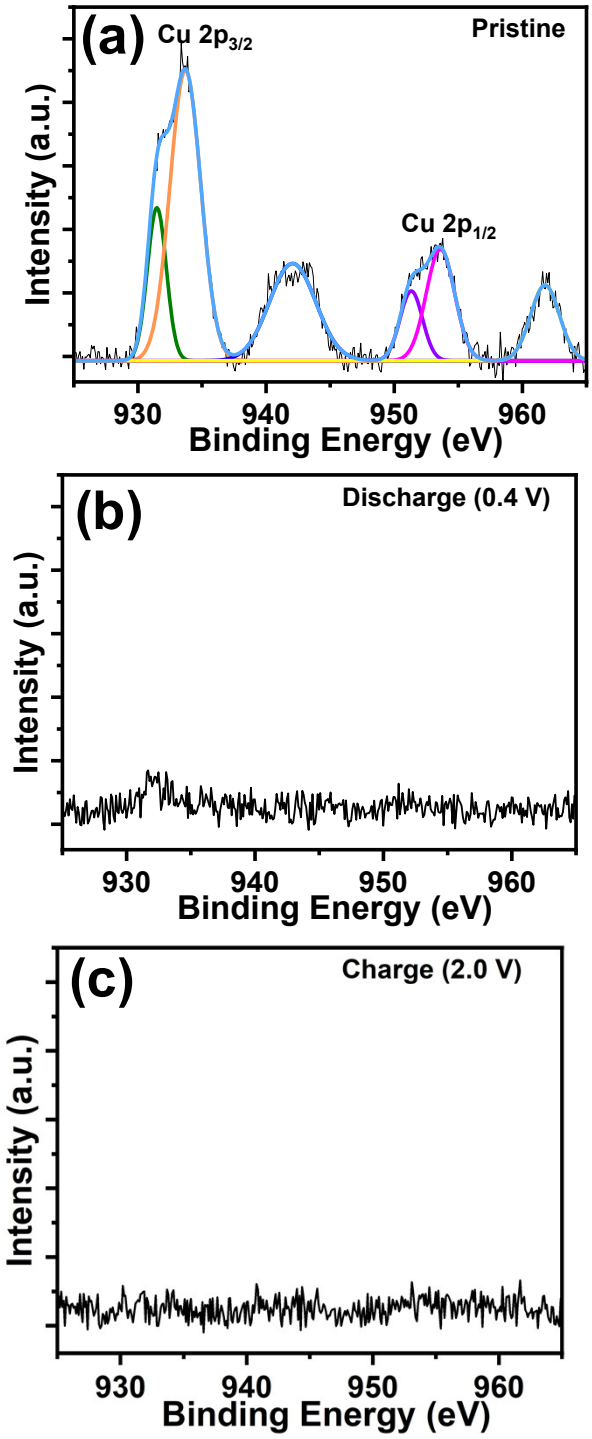

Fig. S6 High-resolution Cu 2p XPS spectra: (a) pristine state, (b) discharge state, and (c) charge state.

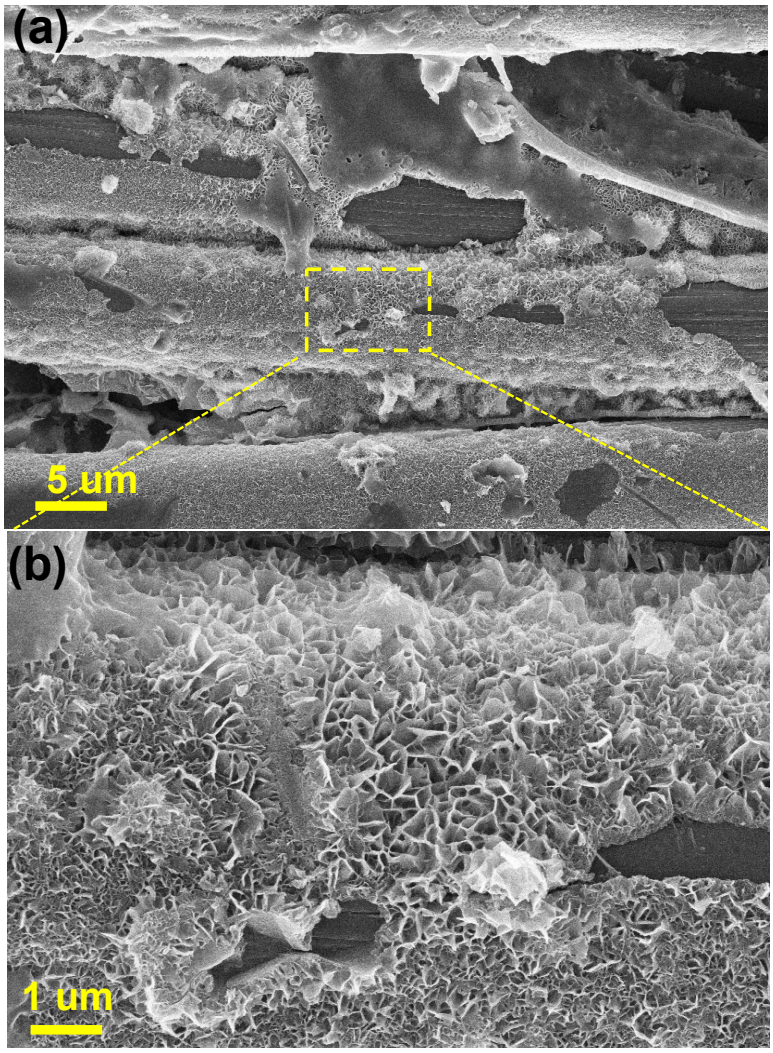

Fig. S7 (a) Low- and (b) high-magnification FE-SEM images for the O-CuVSe cathode after 2000 cycles at 2 A g^{-1}.

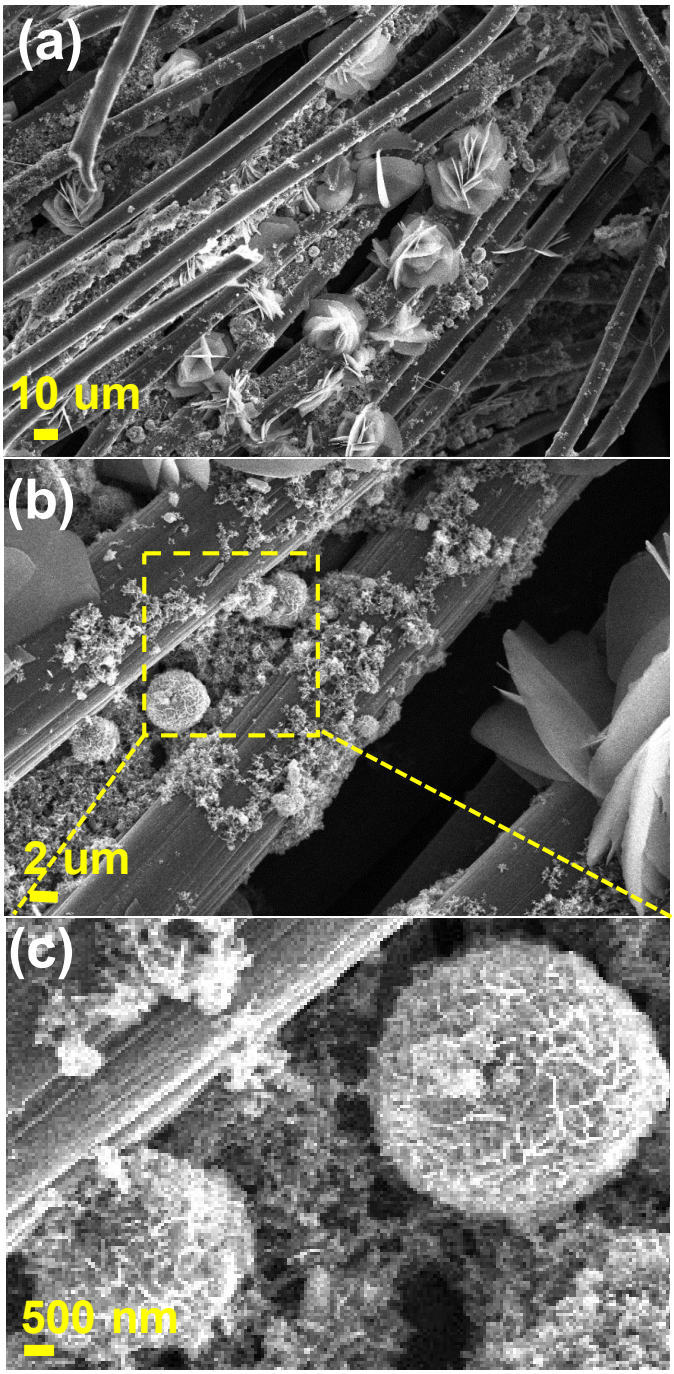

Fig. S8 (a-c) FE-SEM images under different magnifications for the O-CuVSe cathode after 10000 cycles at 5 A g^{-1}.

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