Supporting Information:

Vanadium Based Carbide-Oxide Heterogeneous V_2O_5@V_2C Nanotube Array for High-Rate and Long-Life Lithium-Sulfur Batteries

Zhenguo Wang[a], Ke Yu[, a,b], Shijing Gong[a], Erwei Du[a] and Ziqiang Zhu[a]*

[a] Key Laboratory of Polar Materials and Devices (MOE), Department of Electronics, East China Normal University, Shanghai 200241, China

[b] Collaborative Innovation Center of Extreme Optics, Shanxi University, Taiyuan, Shanxi 030006, China

Corresponding Author

* Tel.: +86 21 54345198; Fax: +86 21 54345119. E-mail address: yk5188@263.net

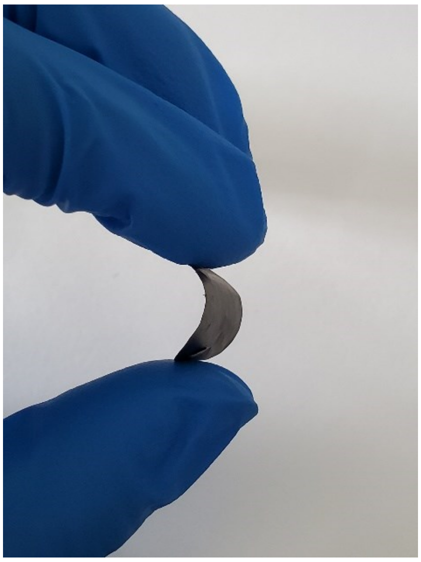

Figure S1 The V_2O_5@V_2C/S cathode.

The amount of pole piece prepared for 8.4 mg·cm^{-2}: 1.68 g sublimed sulfur, 0.42 g V_2O_5@V_2C, and the coating thickness is about 70 microns; the amount of pole piece prepared for 4.2 mg·cm^{-2}: 0.84 g sublimed sulfur, 0.21 g V_2O_5@V_2C, the coating thickness is about 45 microns; the amount of pole piece prepared for 2.0 mg·cm^{-2}: 0.40g sulfur, 0.10 g V_2O_5@V_2C, the coating thickness is about 25 microns; during the battery preparation and assembly process, the size of the aluminum foil is 200 mm×100 mm, use a microtome to cut the positive pole piece with a diameter of 15 mm, the electrolyte dosage is 80-120 microliters, the diameter of the cut diaphragm disc is 16 mm, the thickness of the metal lithium sheet used is 0.6 mm, and the diameter is also 15 mm.

Figure S2 Digital photo of removable three-electrode battery.

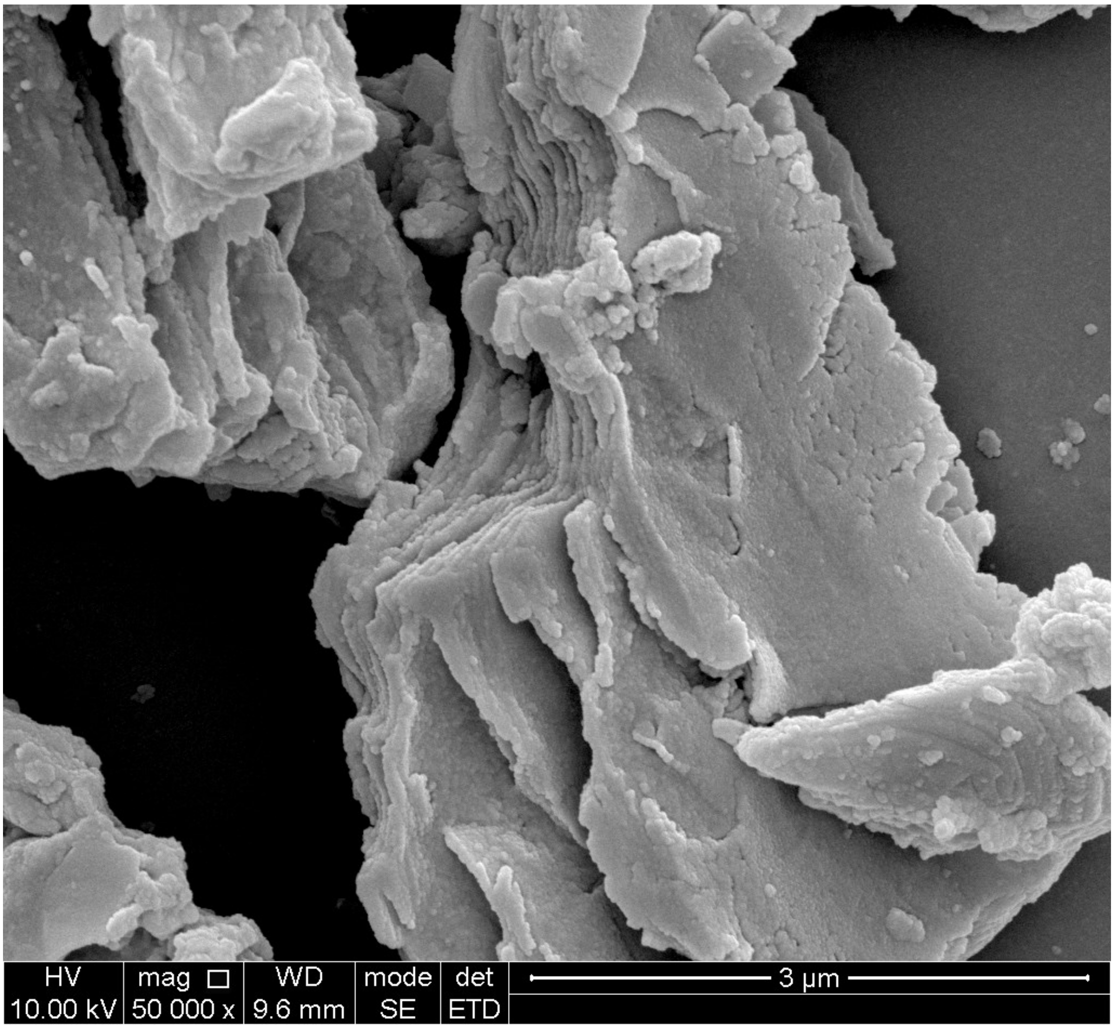

Figure S3 SEM graph of V_2C-MXene after hydro-thermal treatment.

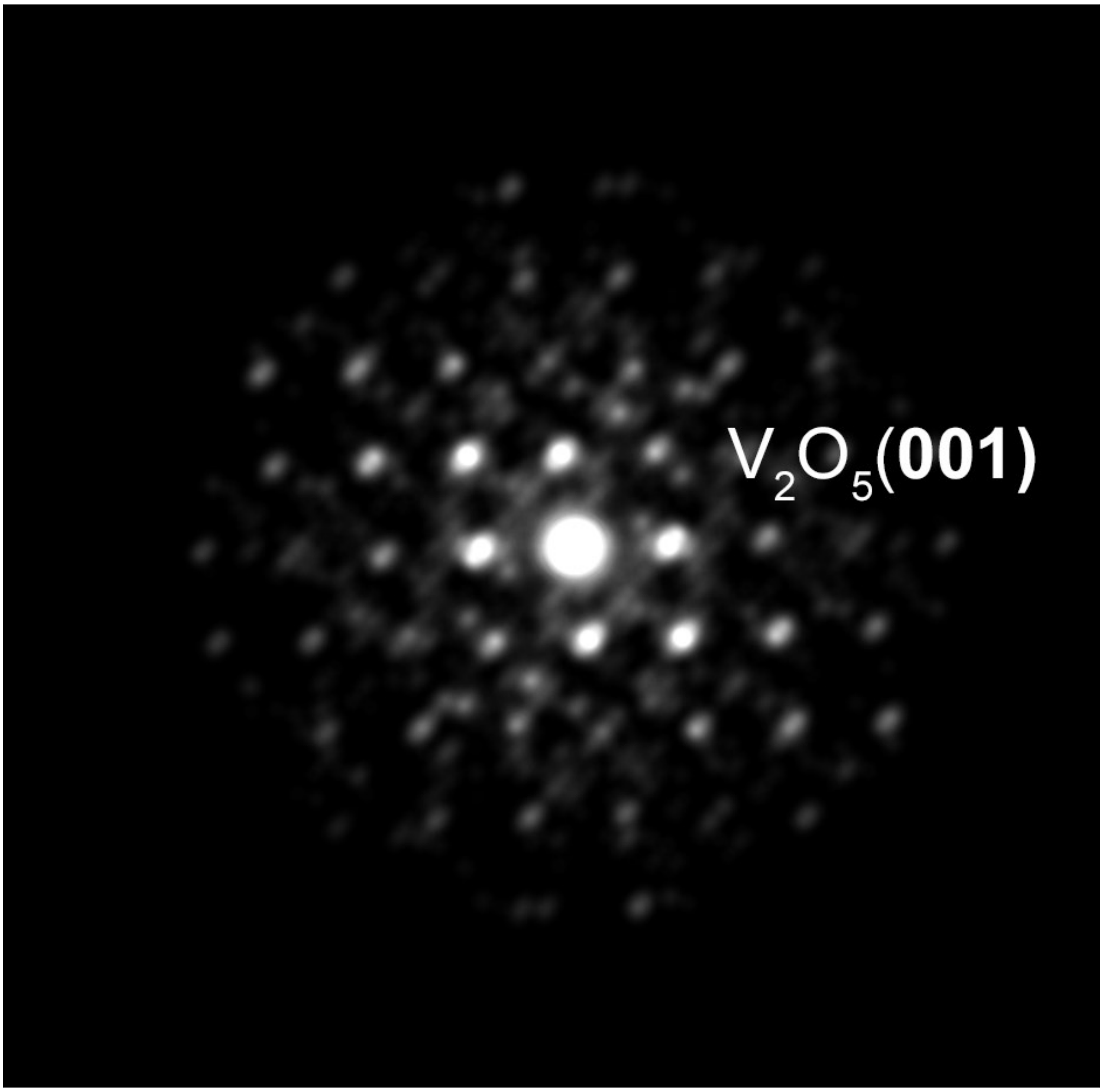

Figure S4 The selected electron diffraction FFT diagram.

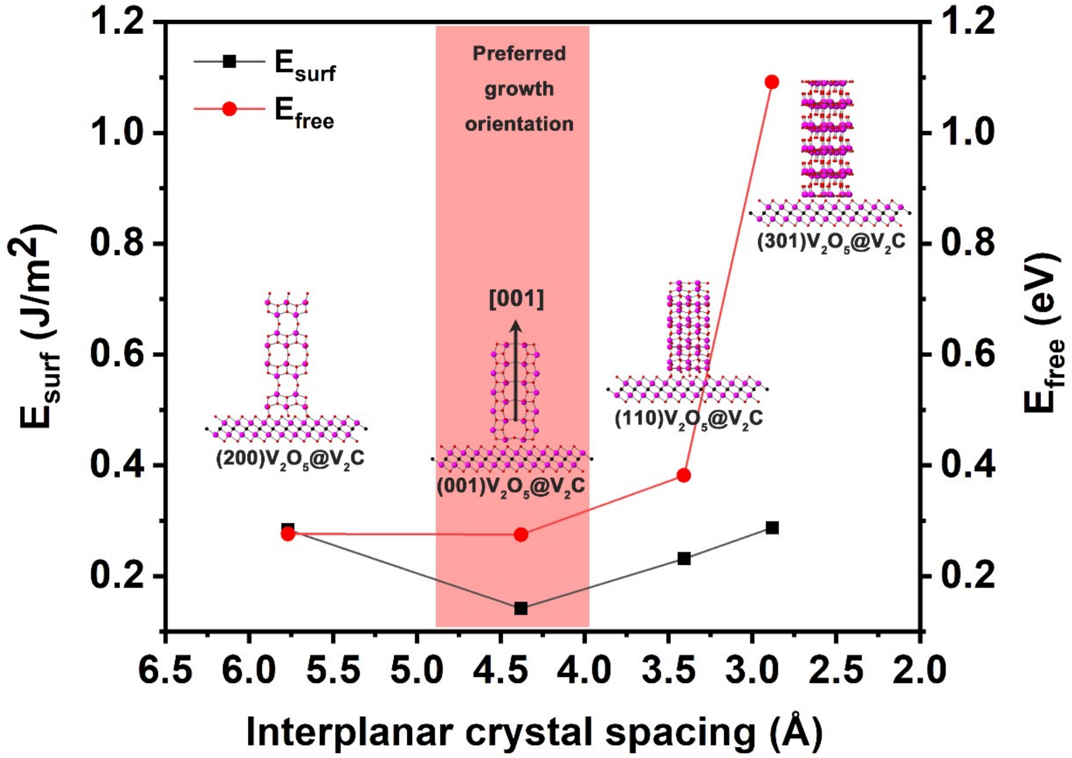

Figure S5 Surface energy and interface free energy calculation for V_2O_5@V_2C.

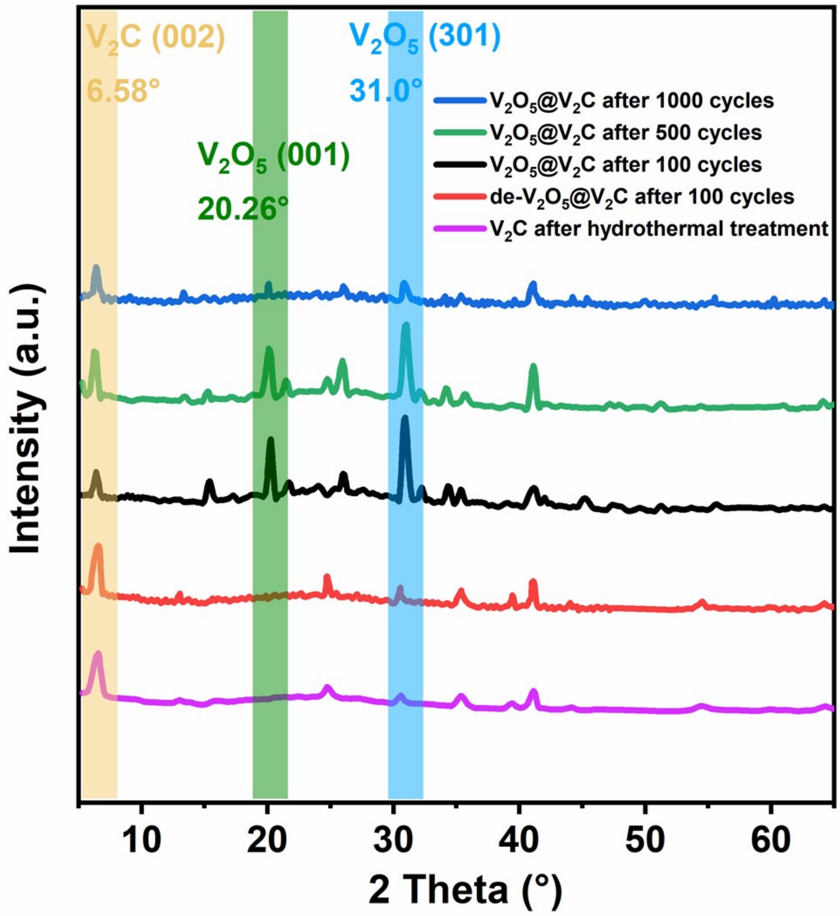

Figure S6 The XRD spectrum of V_2C, V_2O_5@V_2C after different cycles and de-V_2O_5@V_2C.

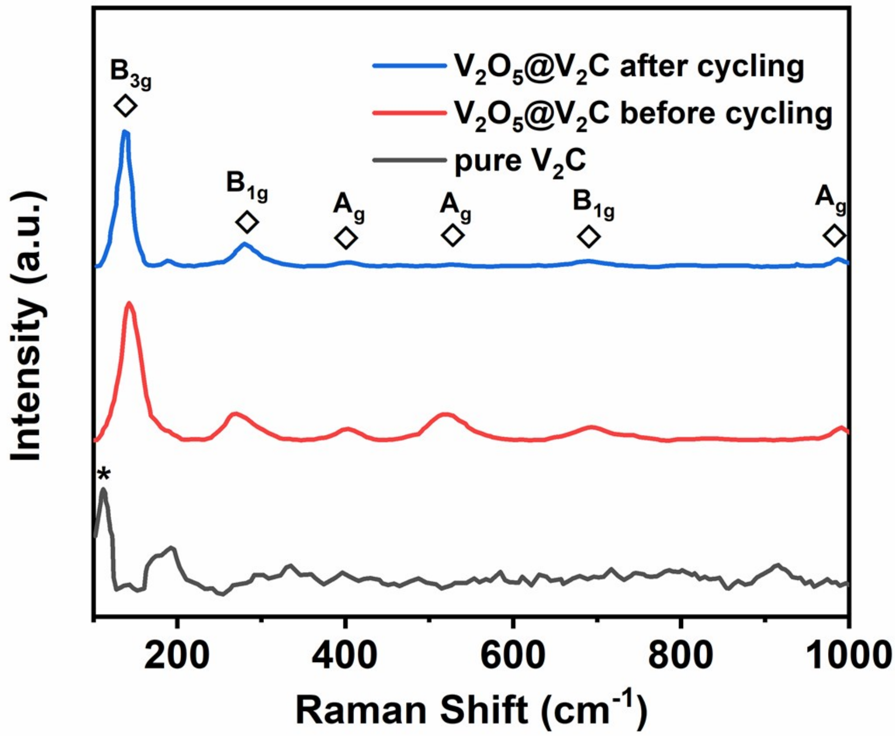

Figure S7 The Ranman spectrum of V_2O_5@V_2C after & before cycling and pure V_2C.

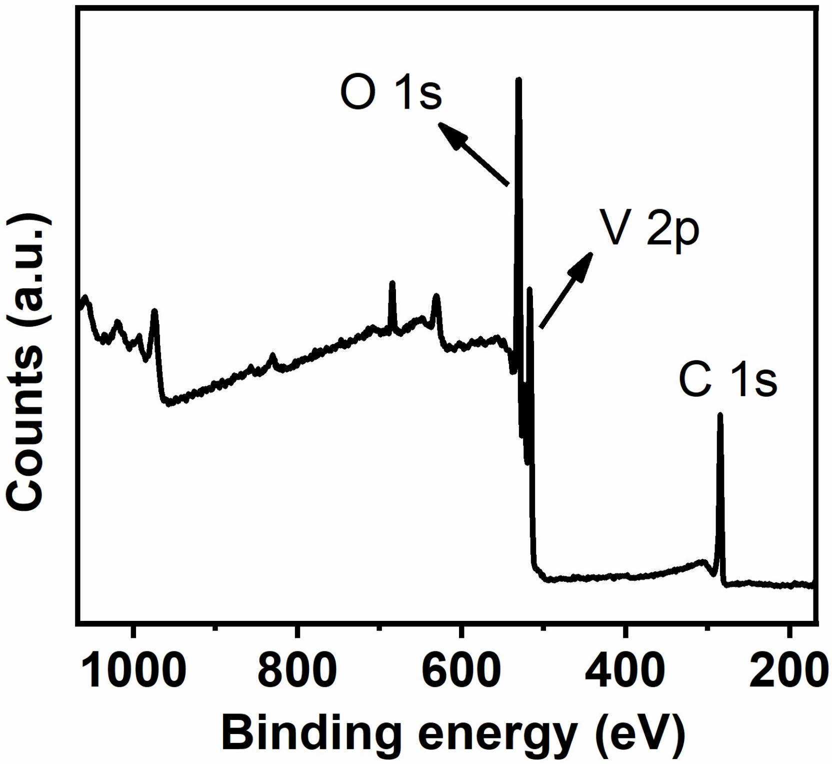

Figure S8 XPS full spectrum of V_2O_5@V_2C.

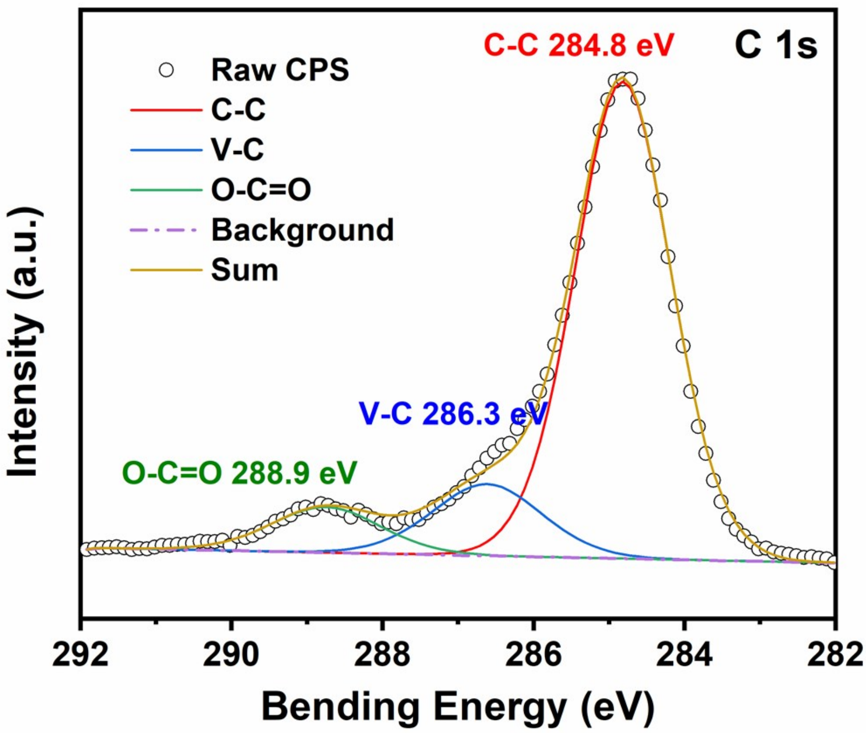

Figure S9 The XPS spectrum of C1s.

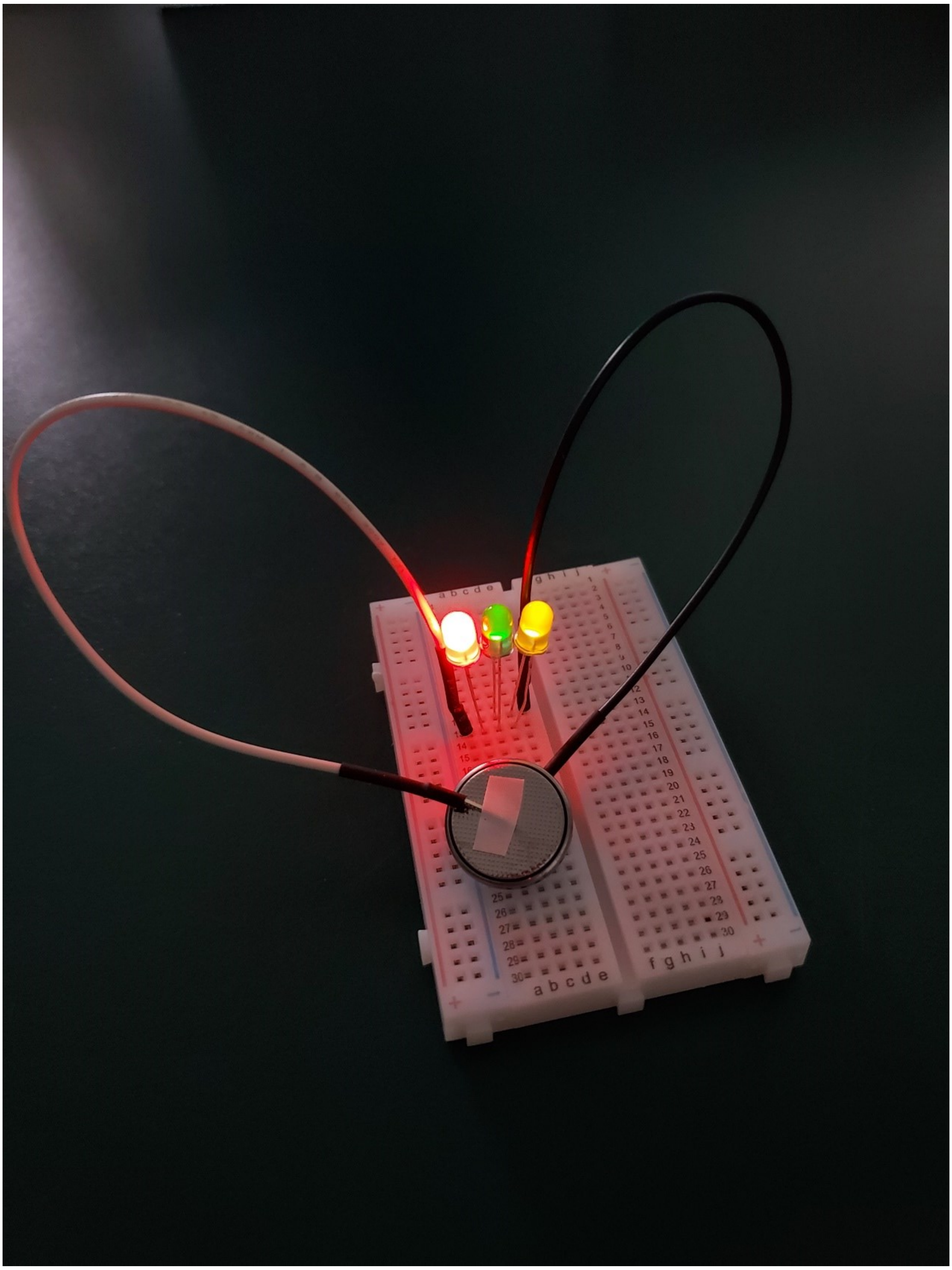

Figure S10 The actual working diagram of as-assembled lithium sulfur battery.

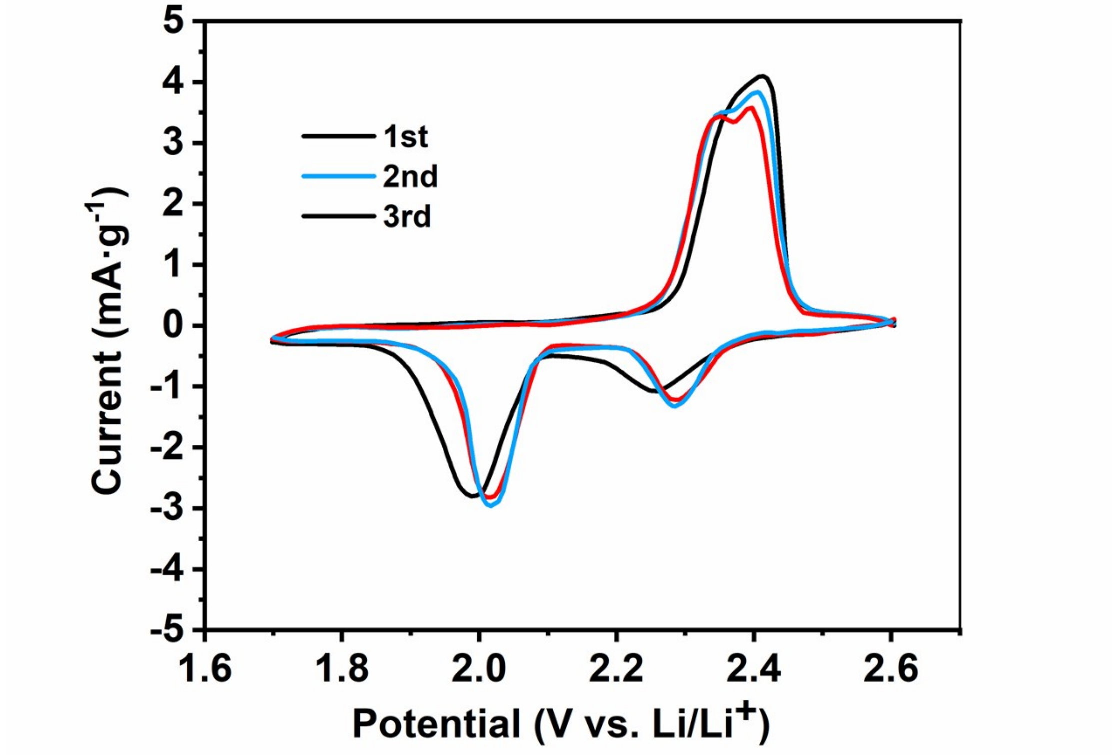

Figure S11 The C-V curve of V_2O_5@V_2C of the initial 3 cycles.

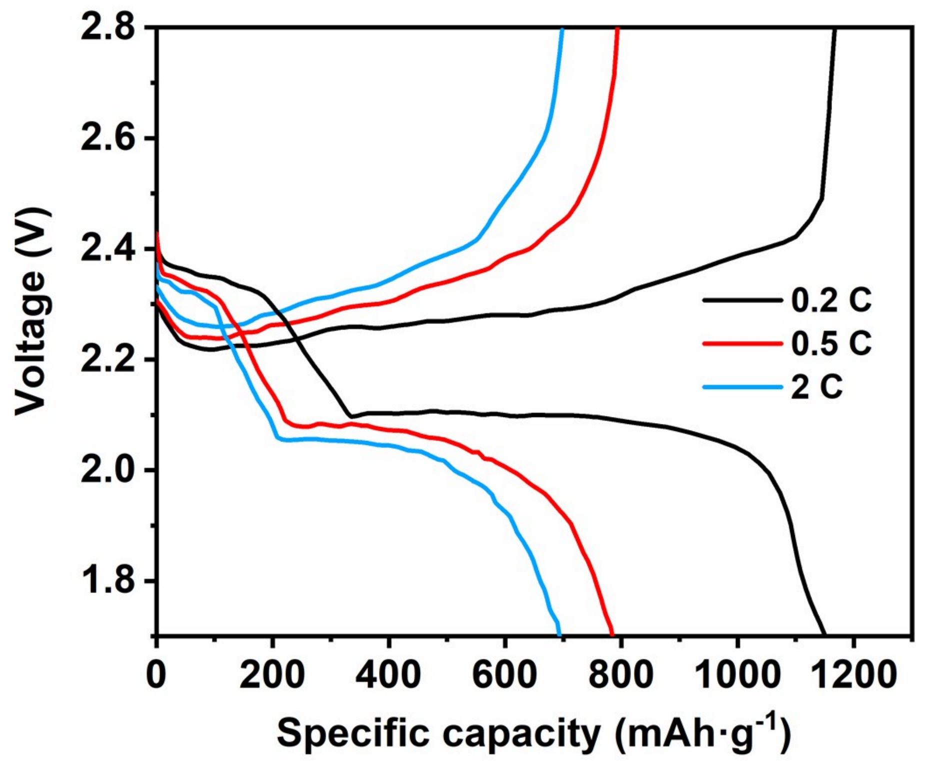

Figure S12 The charge and discharge curve of V_2O_5@V_2C.

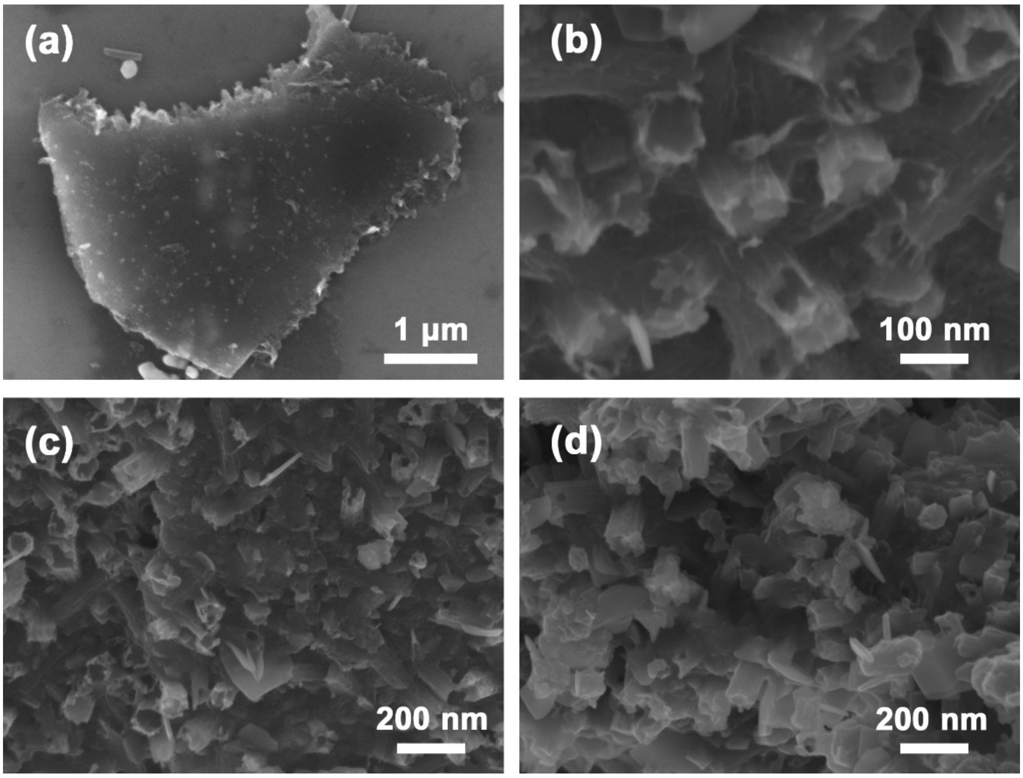

Figure S13 The SEM graph of (a) de-V_2O_5@V_2C (b) V_2O_5@V_2C after 100 cycles (c) V_2O_5@V_2C after 500 cycles (d) V_2O_5@V_2C after 1000 cycles.

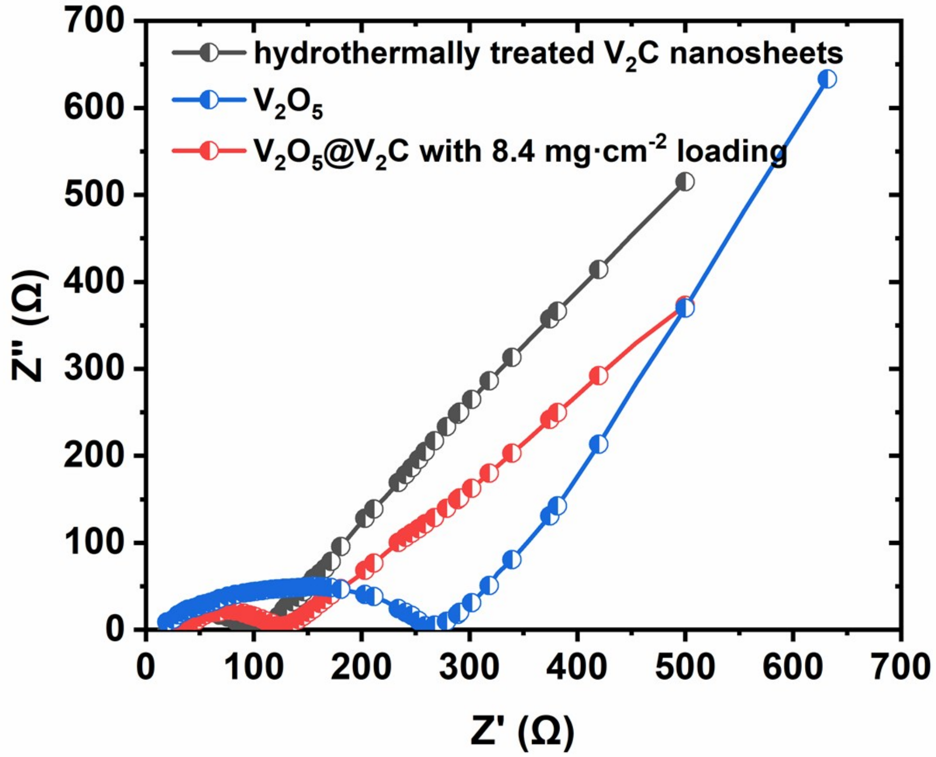

Figure S14 The EIS spectrum of V_2C, V_2O_5 and V_2O_5@V_2C with high S loading.

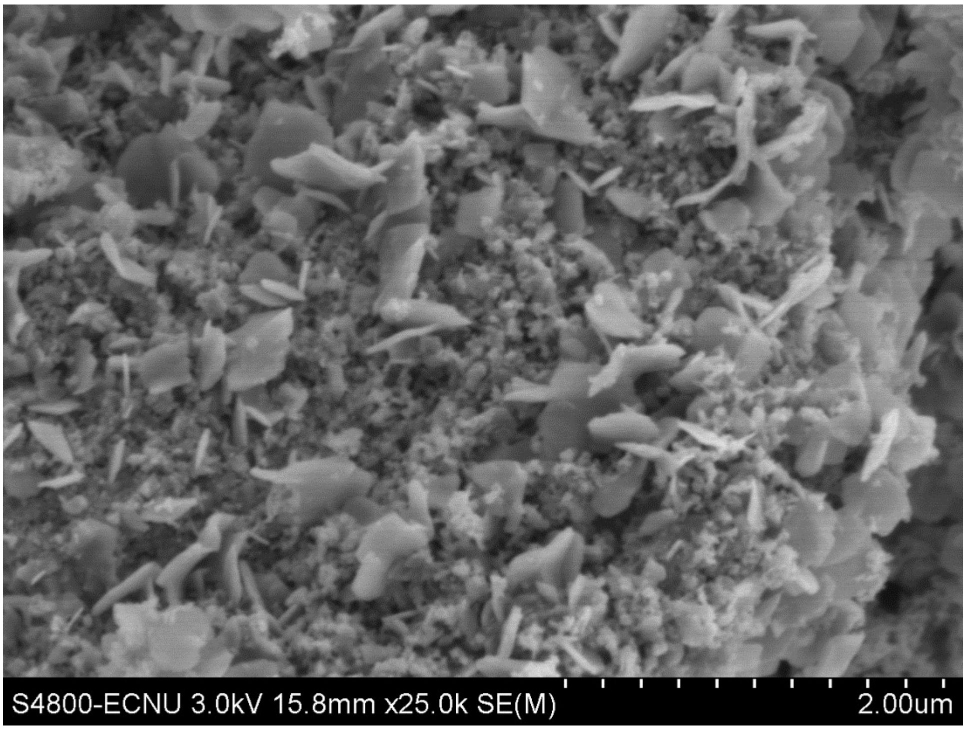

Figure S15 The V_2O_5/S on Al foil.

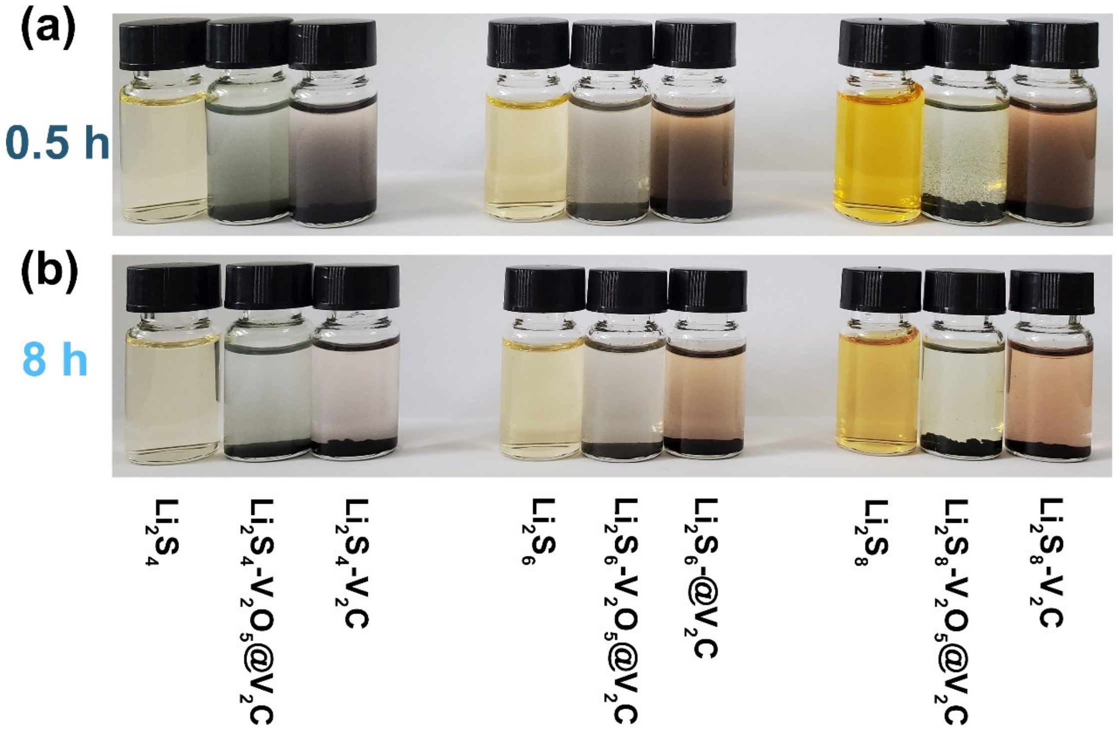

Figure S16 Adsorption performance test diagram of V_2C and V_2O_5@V_2C.

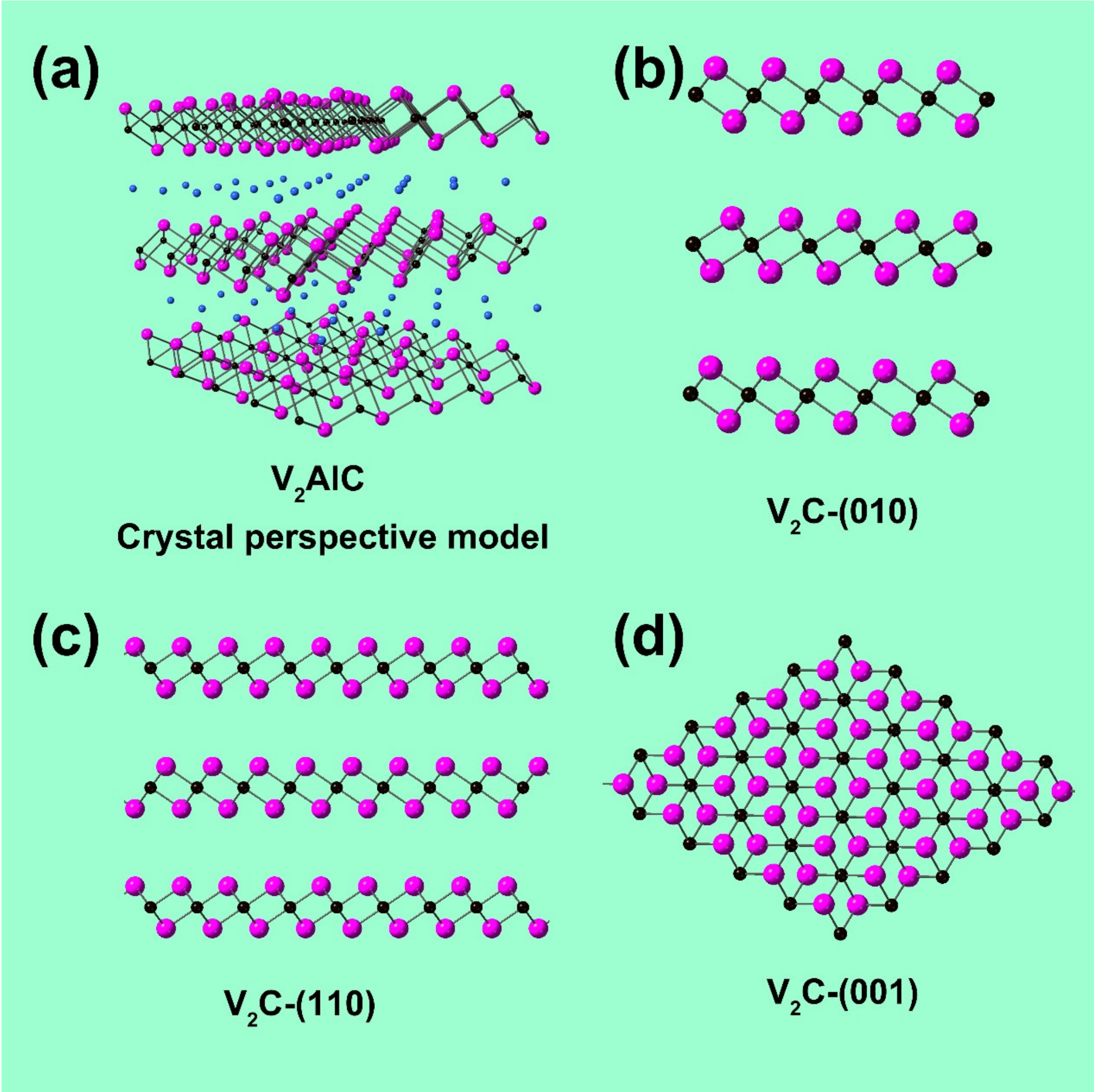

Figure S17 The crystal model of V_2AlC and V_2C.

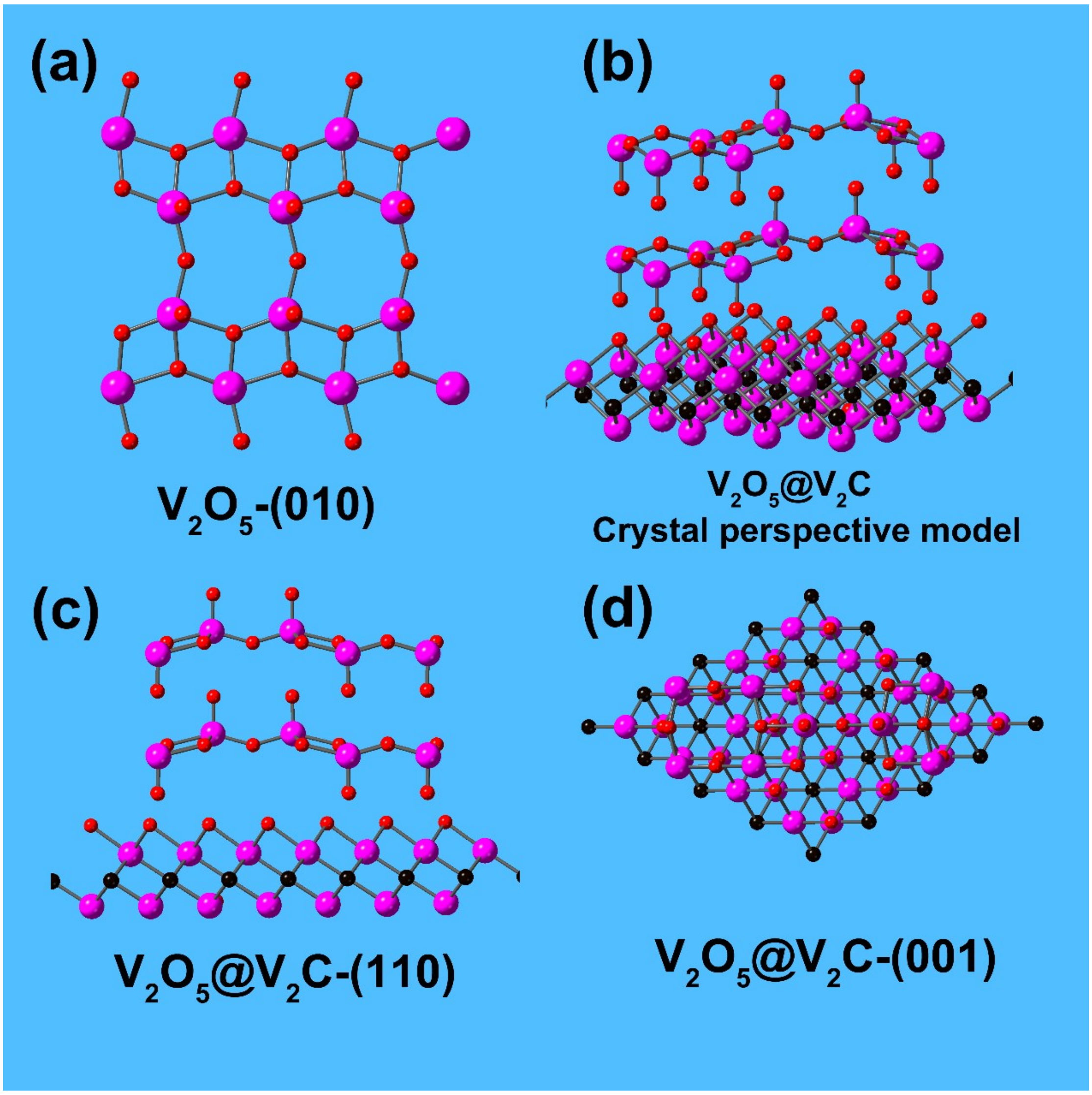

Figure S18 The crystal model of V_2O_5 and V_2O_5@V_2C.

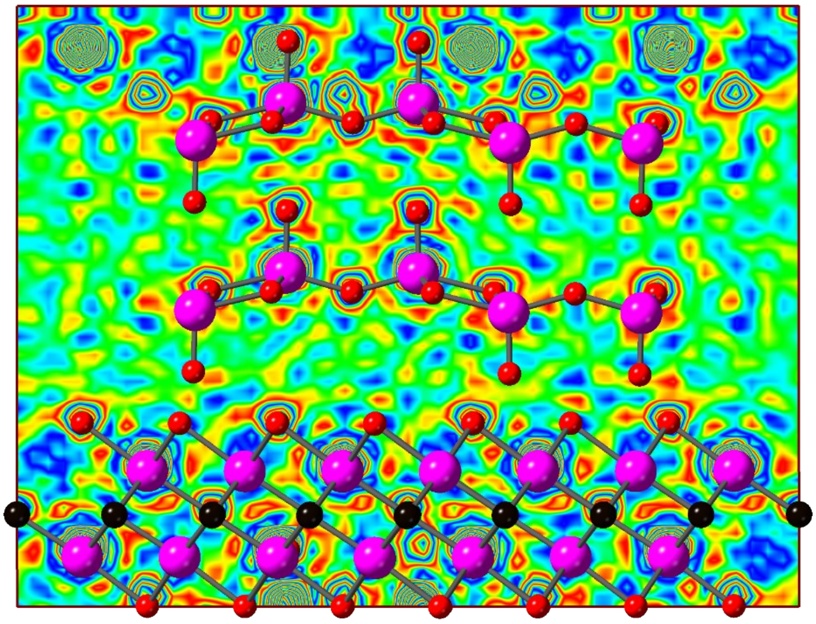

Figure S19 Regional charge density differential diagram of V_2O_5@V_2C.

Table S1. EDX distribution of V, O and C elements of pure V_2C, hydrothermally treated V_2C, V_2O_5@V_2C before and after cycling.

Element	Pure V_2C (at. %)	185°C hydrothermally treated V_2C (at. %)	de-V_2O_5@V_2C before cycling (at. %)	de-V_2O_5@V_2C after cycling (at. %)
V	62.74	53.07	57.83	56.42
C	35.11	22.89	25.36	25.03
O	2.15	24.04	16.81	18.55

Table S2 The surface energy of V_2O_5 with different crystal planes and the free

energy of the interface of V_2O_5@V_2C.

Lattice plane	XRD diffraction peak (°)	A (Å^2)	E_{slab} (10^4eV)	E_{bulk} (10^4eV)	E_{surf} (J/m^2)	V_2O_5@V_2C E_{free} (eV)	Interplanar crystal spacing (Å)
V_2O_5-(200)	15.35	15.54	-2.45674	-1.22840	0.2835	0.2761	5.768
V_2O_5-(001)	20.26	31.66	-2.45675		0.1419	0.2750	4.379
V_2O_5-(110)	26.13	26.30	-2.45528		0.2315	0.3816	3.408
V_2O_5-(301)	31.0	60.79	-2.45462		0.2876	1.0913	2.882
V_2C-(002)	8.50	68.20	-0.83330	-0.42217	1.2960	-	-

Table S3 Performance comparison table of vanadium base positive electrode matrix materials in recent years.

Host	**S loading ($mg\ cm^{-2}$)**	**Current density (C)**	**Cycles**	**Initial capacity ($mAh\ g^{-1}$)**	**Areal capacity ($mAh\ cm^{-2}$)**	**Capacity decay (% per cycle)**	**Year**	**Ref**
V_2O_5@V_2C	2.0	0.2	100	1173	2.35	0.043	-	**This work**
		0.5	1000	1138	2.28	0.047		
		2	500	1106	2.21	0.053		
	4.2	0.2	200	1093	4.50	0.078		
	8.4	0.2	200	1058	8.59	0.11		
VO_2(p)@V_2C	2.0	2	500	1210	2.42	0.062	2019	1
V_2O_5- rGO	1.2-1.5	0.2	300	~1000	1.2-1.5	0.048	2018	2
rGO-VS_2	2.6	0.1	100	721	1.87	0.094	2018	3
VS_2-C	1-2	2	100	1185	1.18-2.37	0.16	2018	4
V_2O_5-C	5.5	2	500	790	1.6	0.041	2017	5
VO_x-SWCNT	1.0	1	300	1069	1.7	0.095	2018	6
VN-C	2.8	1	200	1200	2.8	0.24	2017	7
VN nanobubbles	6.8	0.5	200	800	5.4	0.15	2016	8
VO_2–VN	4.2	2	800	1105	2.21	0.06	2018	9

Table S4 Equivalent circuit fitting parameter result table.

Equivalent parameter	**Initial**		**after cycling**	
	V_2O_5@V_2C	**V_2C**	**V_2O_5@V_2C**	**V_2C**
R_s / Ohm	3.12	5.01	3.93	8.22
R_{surf} / Ohm	11.67	17.10	33.71	61.32
R_{ct} / Ohm	51.23	82.63	88.27	184.6

Table S5 Equivalent circuit fitting parameter result table.

Equivalent parameter	Hydrothermally treated V_2C	Pure V_2O_5	V_2O_5@V_2C with 8.4 mg·cm^{-2} loading
R_s / Ohm	9.73	8.72	7.38
R_{surf} / Ohm	19.84	22.14	14.51
R_{ct} / Ohm	45.31	128.37	63.03

Reference

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