## Supporting Information for

## Tellurium -Impregnated P-doped porous carbon nanosheets as both cathode and anode for ultra-stable hybrid aqueous energy storage

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**Figure S1.** Characterization of the prepared carbon quantum dots (CQDs). (a) TEM, (b) XPS, and (c) C1s spectrum of the CQDs. In the XPS spectrum, peaks at binding energy of 295.92, 521.33 and 981.21 eV corresponding to the C 1s, O1s and O KLL, respectively. In C 1s XPS spectrum, C-C bond located at the binding energy of 283.92 eV. The C-O and C=O functional groups marked at 285.14 and 288.29 eV are related to the surface functionalization of CQDs.



**Figure S2.** (a) SEM image, (b) EDS mapping and (c) TEM image of the bubble-like structures on the prepared P-doped porous carbon nanosheets confined Te nanocrystals (PCCT). From the SEM image in Figure S2a, bubble-like structures with some breakage could be found. The EDS mapping result in Figure S2b showed the uniform distribution of C, Te, and P elements in the prepared sample. In the TEM image in Figure S2c, the yellow arrow pointed places corresponded to the bubble-like structures.



Figure S3. (a)  $N_2$  adsorption and desorption isotherms and (b) BJH pore size distributions of the prepared P-doped porous carbon nanosheets confined Te nanocrystals (PCCT).



**Figure S4**. P 2p XPS spectral of the prepared PCCT. The peaks located at binding energy of 131.8 and 132.6 corresponding to P-C. Peaks at 134.5 and 135.7 eV represent P-O-C and P-O, respectively. This result demonstrates the P doping of the prepared PCCT product.



**Figure S5.** Raman spectrum of the prepared PCCT sample. Raman shifts at 1375 and 1879 cm<sup>-1</sup> match with the D-band and G-band of carbon, respectively.



Figure S6. CV curves of PCCT cathode and Ni foam current collector at 10 mV s<sup>-1</sup> in 2 M KOH.

The comparison shows the negligible capacity contribution of the current collector.



Figure S7. The Te 3d XPS spectral of the charged PCCT cathode material. After charging, the Te

 $3d_{5/2}$  and Te  $3d_{3/2}$  signals shift to the binding energy of 576.01 and 586.48 eV, which matched well

with the Te (IV).



**Figure S8**. The energy and coulombic efficiency of the PCCT cathode at different current densities. Energy efficiencies at 1, 2, 3, 5 and 10 A  $g^{-1}$  are 0.76, 0.72, 0.66, 0.59 and 0.50, respectively. Coulombic efficiency at all current densities are all higher than 98%.



**Figure S9.** The (a) SEM image, (b) HRTEM image, (c) XPS spectrum, and (d) Te 3d XPS spectrum of the electrode materials after 10000 cycles. From the SEM image in S9a, nanosheet structures could still be found after cycling, suggesting the high robustness of the prepared electrode material. From the HRTEM image in S9b, clear lattice structure of Te nanocrystals (red cycles) and the amorphous structure of the carbon matrix (yellow arrow) could be found. In the XPS spectrum of the electrode material (Figure S9c), peaks from PTFE binder (F 2s, C 1s, F 1s, F KLL), conducting carbon black (C 1S, O 1s), and the prepared PCCT (P 2p, C 1s, O 1s, Te 3d) could be found. The Te 3d XPS spectrum in Figure S9d further revealed the zero valence of Te. These results demonstrated the high structure stability of the PCCT electrode material, as well as the highly stable Te/Te (IV) electrode process.



**Figure S10**. Electrochemical properties of the prepared PCCT as anode materials. (a) CV curves at various scan rates. (b) GCD curves at 1, 2, 3, 5 and 10 A  $g^{-1}$ . (c) Specific capacities at different current desities. (d) Cycling performance of the PCCT anode at a current density of 2 A  $g^{-1}$  for 10000 cycles, no obvious capacity decay can be found, and the coulombic efficiency stayed above 98% during the whole cycling.



**Figure S11.** The Coulombic efficiencies of the assembled BSH system at different current densities. The efficiencies are all above 98%, revealing the high reversibility of the system.



Figure S12. The leakage current curve of the assembled BSH aqueous system charged at 5 mA to a floating voltage of 1.6 V and kept at 1.6 V for 1 h. The leakage current is  $19.3 \mu$  A.



**Figure S13**. Contribution of capacitive-controlled capacity at different scan rates for the BSH device. As the increase of scan rates, the capacitive capacity with fast electrode kinetics becomes dominant, which explains the high rate capability and the capacity decrease at high scan rates of the device.

**Table S1.** Detail comparison of the hybrid device based on the prepared P-doped porous carbon nanosheets confined Te nanocrystals (PCCT) as both cathode and anode with the reported symmetric and asymmetric supercapacitors.

Cathode	Anode	Electrolyte	Voltage	Mass loading cathode / anode (mg cm <sup>-2</sup> )	E(Wh kg <sup>-1</sup> ) / P(W kg <sup>-1</sup> )	Retention% / cycles	Ref.
РССТ	РССТ	1 M KOH	1.6 V	2.5/5	36.31 / 870 16.67 / 12010	94.8 % / 10,000 2 A g <sup>-1</sup>	This work
doped carbon nanoflakes	doped carbon nanoflakes	1 M Na <sub>2</sub> SO <sub>4</sub>	1.8 V	8 / 8	24.4 / 223 7.3 / 9,360	93% / 10,000	56
N, S co-doped porous carbon	N, S co-doped porous carbon	1M Na <sub>2</sub> SO <sub>4</sub>	1.8 V	4.4 / 4.4	21 / 180 10 / 8700	99.7 / 10,000 2 A g <sup>-1</sup>	57
spinel CoMn <sub>2</sub> O <sub>4</sub> hollow nanospheres	activated carbon	1M KOH	1.45 V	1.82 / 2.74	26.8 / 384.8 13.3 / 9816	~96% / 10,000	58
Co-Mn MOF on Ni-foam	activated carbon	2 M KOH	1.7 V	Not mentioned	30.85 / 685 22.8 / 2285.7	<85% / 3000	59
NiCo <sub>2</sub> O <sub>4</sub> nanosheets	graphene oxide	3 M Koh	1.6 V	1 / 1	38.53 / 299.3 21.05 / 340	91% / 2000 5 A g <sup>-1</sup>	60
flower-like Co <sub>3</sub> O <sub>4</sub> - G>N-PEGm	3D rGO-CNT>N- PEGm aerogels	6 M KOH	1.6 V	1.4/2.8	34.4 / 400 15 / 10800	$\frac{84.7\ \%\ /\ 10,\ 000}{10\ A\ g^{-1}}$	61
conjugated aromatic polymers	activated carbon	2 M KCl	1.6 V	1.0/3.0	23 / 200 12 / 8700	~80% / 10, 000 2 A g <sup>-1</sup>	62
MnCO <sub>3</sub> microcrystals	home-made carbon	2 M KOH	1.6 V	5.3 / 2.8	14.7 / 90.2 11.0 / 3300	97.3 % / 10,000	63
porous MnO <sub>2</sub>	activated carbon	1 M Na <sub>2</sub> SO <sub>4</sub>	2 V	2 / 2	27.6 / 200 19.4 / 5000	94% / 5000 1 A g <sup>-1</sup>	64
Mn <sub>3</sub> O <sub>4</sub> /Ni(OH) <sub>2</sub> composite	activated carbon	1 M KOH	1.6 V	Not clear	15.3 / 168.8 3.6 / 3200	Not mentioned	65
NiCo <sub>2</sub> S <sub>4</sub> @Ni(OH) <sub>2</sub> @Polypyrole on nickel foam	activated carbon	2 M KOH	1.6 V	3.21/30.2	34.67 / 120.127 12.5 / 1450	98.87% / 30,000	66
NiCoP/NiCo-OH on carbon cloth	MOF-derived porous carbon	6 M KOH	1.6 V	Not clear	34 / 775 20 / 11600	92% / 1000 2 A g <sup>-1</sup>	67

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