Supplementary Information (SI) for Nanoscale Horizons.
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Supporting information

Multi-scale carbon@Sb mesoporous composites activated by in-situ localized electrochemical pulverization as high-rate and long-life anode materials for potassium-ion batteries

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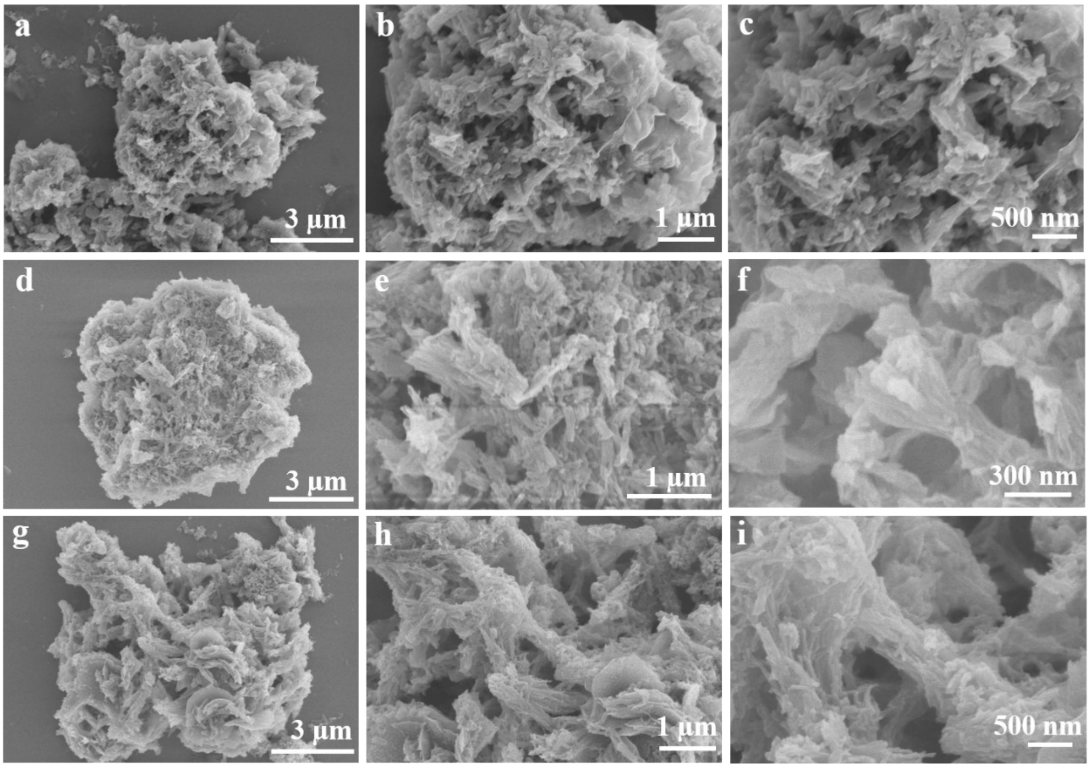

Figure S1. SEM images in different magnifications of samples: (a-c) Sb_2@DCDA/PACP, (d-f) Sb_3@DCDA/PACP, and (g-i) Sb_4@DCDA/PACP.

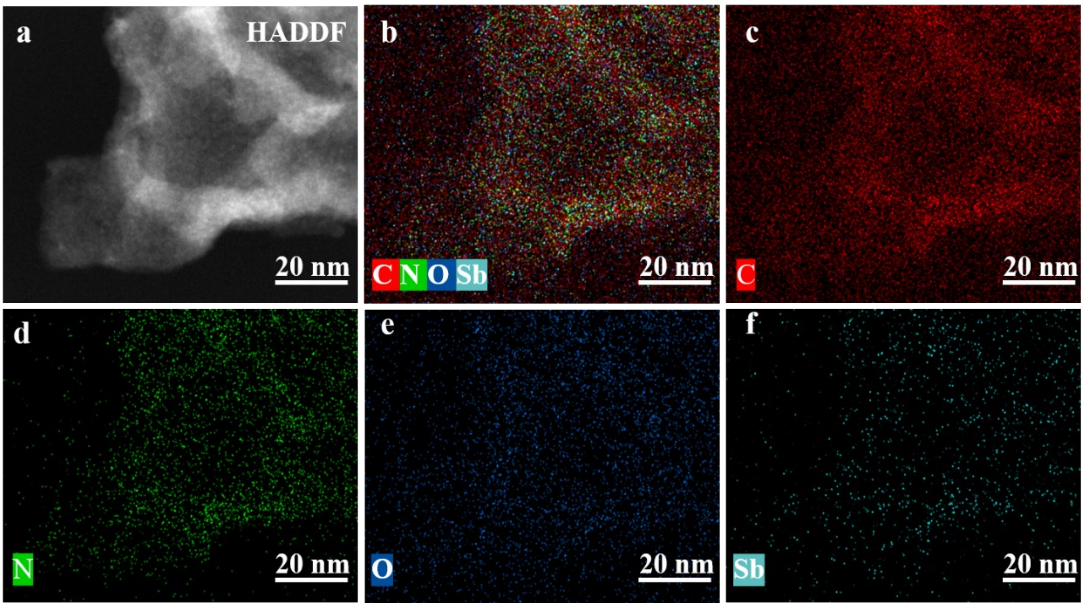

Figure S2. (a) HAADF image of Sb_3@HCNS, and (b-f) combined and individual elemental distribution maps of C, N, O, and Sb.

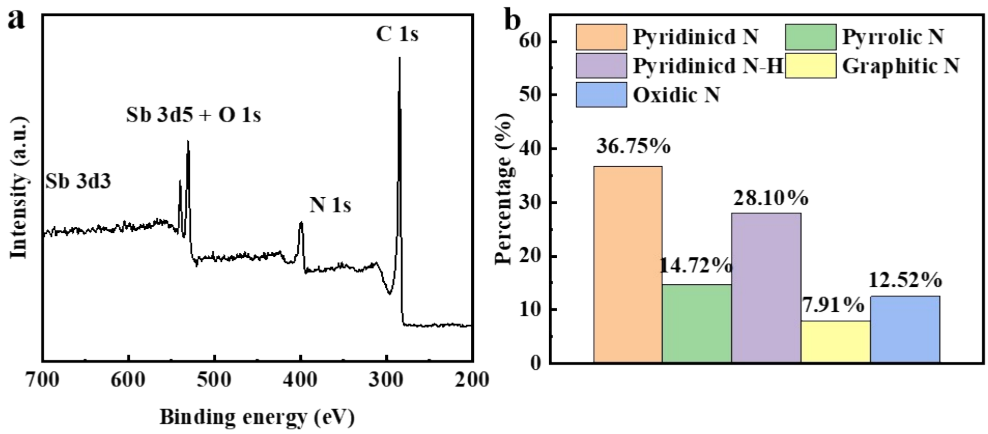

Figure S3. (a) X-ray photoelectron spectroscopy (XPS) full spectrum of Sb_3@HCNS, (b) The fraction of pyridinic N (398.2 eV), pyrrolic N (399.6 eV), pyridinic N-H (400.7 eV), graphitic N (401.5 eV), and oxidized N (403.5 eV) within N 1s spectrum in Figure 3f.

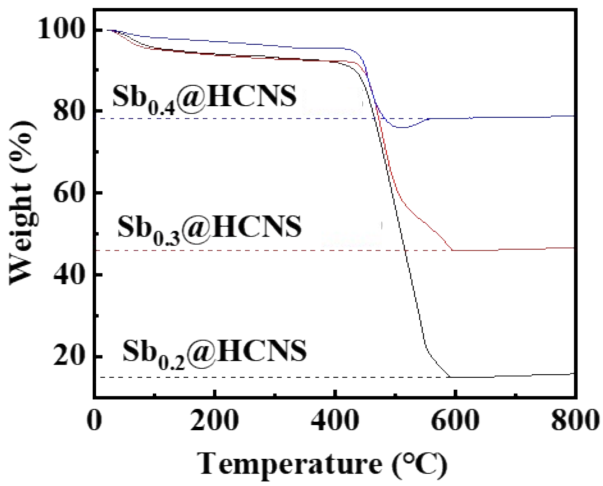

Figure S4. Thermogravimetry (TG) curves of as-prepared Sb_2@HCNS, Sb_3@HCNS, and Sb_4@HCNS.

The weight loss of carbon combustion and the weight gain of Sb_2O_4 formation based on the following reactions:

(1) $C+O_2=CO_2$;

(2) $2Sb+2O_2=Sb_2O_4$.

The weight ratio of Sb in the nanocomposite can be calculated based on the following equation:

$$Sb(wt.\%) = \frac{molecular\ weight\ of\ Sb}{molecular\ weight\ of\ Sb2O4} \times \frac{final\ weight\ of\ Sb2O4}{initial\ weight\ of\ Sb@HCNS}$$

Equation S1

Sb_2@HCNS: $S(wt.\%) = \frac{121.76}{307.52} \times \frac{15.1}{100} \times 2 \times 100\% = 11.96\%$

Sb_3@HCNS: $S(wt.\%) = \frac{121.76}{307.52} \times \frac{45.9}{100} \times 2 \times 100\% = 36.35\%$

Sb_4@HCNS: $S(wt.\%) = \frac{121.76}{307.52} \times \frac{78.5}{100} \times 2 \times 100\% = 62.16\%$

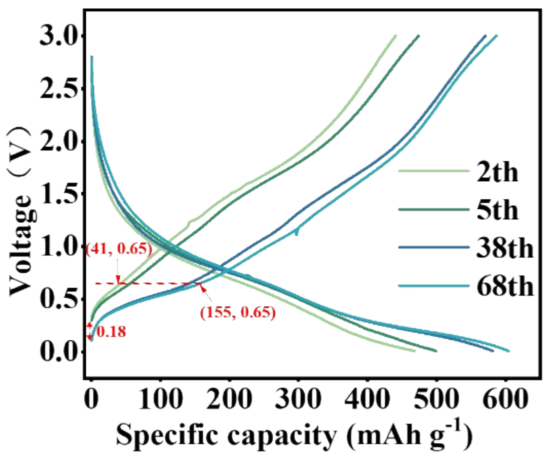

Figure S5. The discharge/charge profiles of Sb_3@HCNS at the 2nd, the 5th, the 38th and the 68th cycle at the current density of 0.1 A g^{-1} during the rate capability testing.

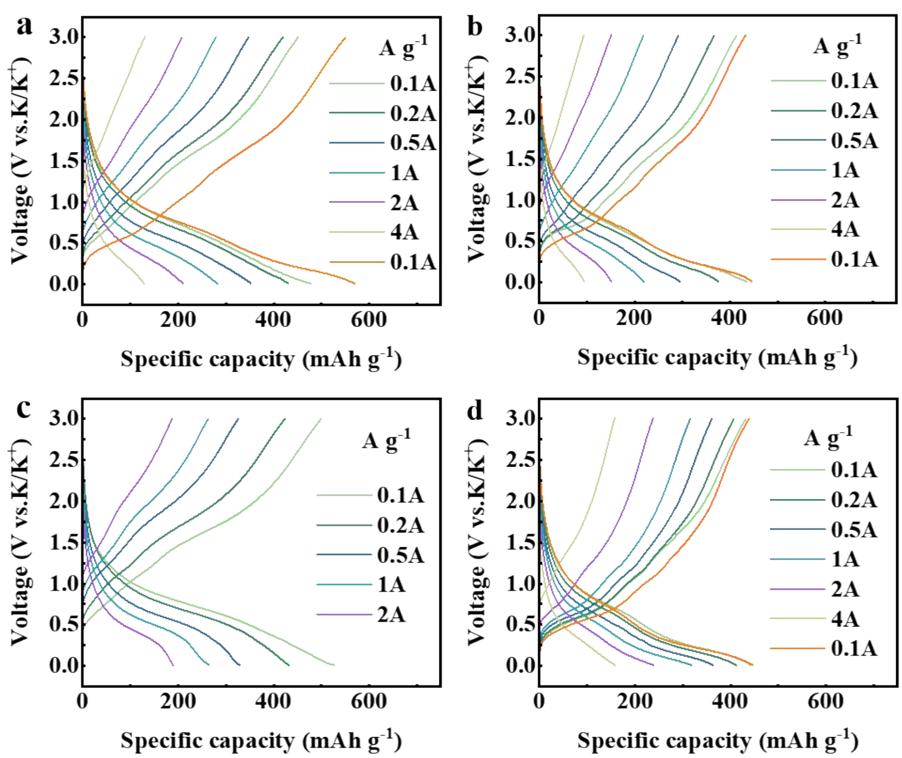

Figure S6. The typical charge/discharge profiles of (a) Sb_2@HCNS, (b) Sb_3@HCNS, (b) Sb_4@HCNS at various current densities at 2nd, 7th, 12th, 17th, 22nd, 27th and 32nd, respectively. (d) The corresponding discharge/charge profiles of Sb_2@HCNS at 38th, 43rd, 48th, 53rd, 58th, and 63rd.

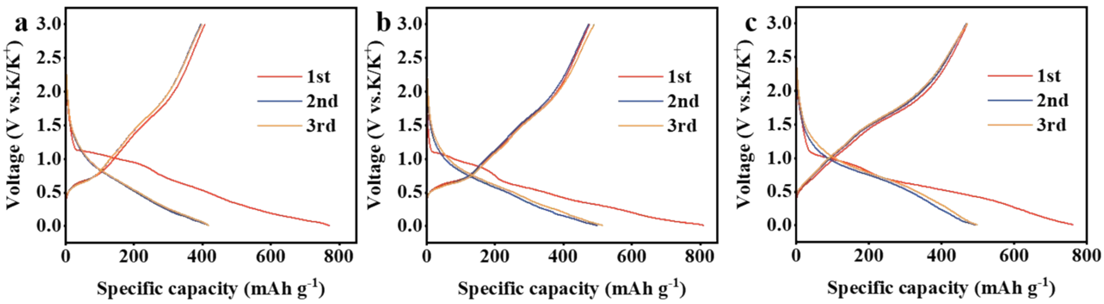

Figure S7. The discharge/charge profiles of Sb_2@HCNS (a), Sb_3@HCNS (b), and Sb_4@HCNS (c) at the current density of 0.1 A g^{-1} during the initial three activation cycles before long-term cyclic testing at 2 A g^{-1}.

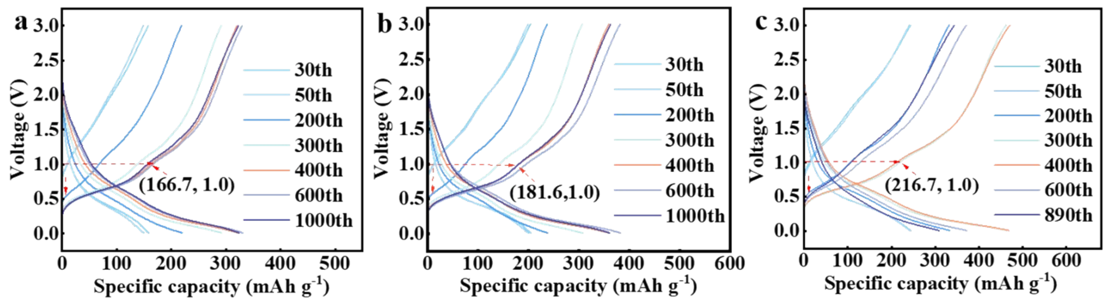

Figure S8. The different cycle discharge/charge profiles of Sb_2@HCNS (a), Sb_3@HCNS (b), and Sb_4@HCNS (c) at the current density of 2 A g^{-1} during the long-term cyclic testing.

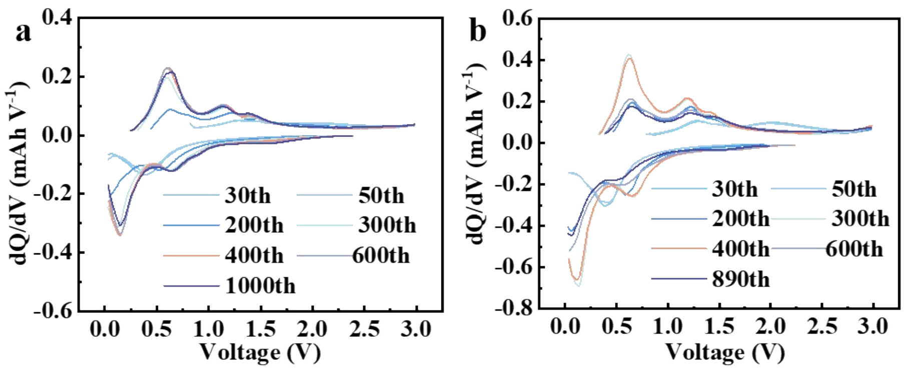

Figure S9. The dQ/dV profiles of Sb_2@HCNS (a) and Sb_4@HCNS (b) corresponding to the different cycle discharge/charge profiles at the current density of 2 A g^{-1} during the long-term cyclic testing shown in Figures S7a and S7c.

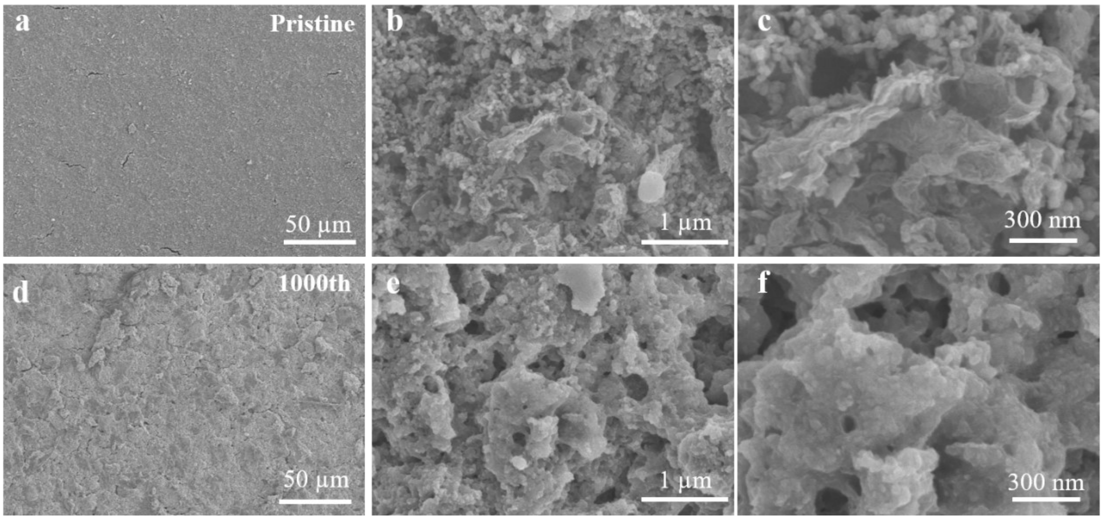

Figure S10. SEM images of (a-c) pristine Sb_3@HCNS electrode, and (d-f) the Sb_3@HCNS electrode being cycled for 1000 cycles at 2 A g^{-1}.

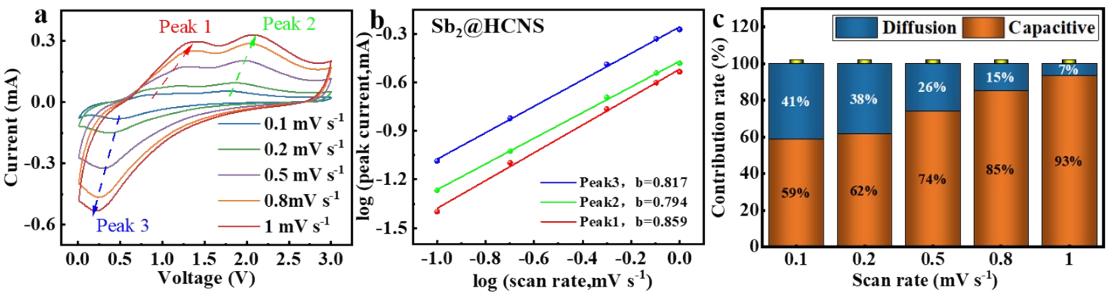

Figure S11. (a) CV curves of Sb_2@HCNS at various scan rates from 0.1 to 1.0 mV s^{-1}. (b) The plot of log (peak current) versus log (scan rate) of redox peaks from CV curves and b-value determination lines. (c) Contribution ratios of the surface capacitance and inside diffusion-based capacity to the total capacity of Sb_2@HCNS at different scan rates.

The contributions of the surface-controlled and diffusion-controlled reactions were quantitatively estimated based on the redox peak currents of CV curves according to the equation: $i = av^b$. Normally, the peak current, i, is proportional to the sweep rate, v. The b value was determined from the plot slope of the log (i) versus log (v). When the b value is 1, the electrochemical reaction is purely surface-controlled. when the b value is 0.5, the electrochemical reaction is entirely diffusion-controlled. The surface-controlled ($k1v$) and diffusion-controlled ($k_2v^{1/2}$) contribution to final capacity can be divided into components according to the equation: $i = k_1v + k_2v^{1/2}$ [1].

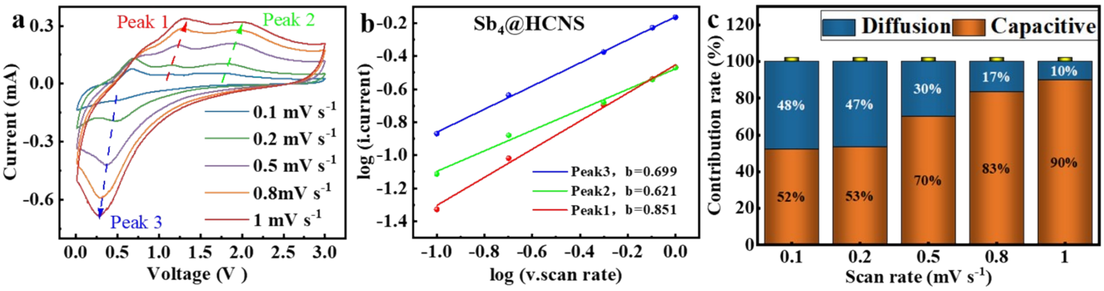

Figure S12. (a) CV curves of Sb_4@HCNS at various scan rates from 0.1 to 1.0 mV s^{-1}. (b) The plot of log (peak current) versus log (scan rate) of redox peaks from CV curves and b-value determination lines. (c) Contribution ratios of the surface capacitance and inside diffusion-based capacity to the total capacity of Sb_4@HCNS at different scan rates.

Table S1. HRTEM EDX analysis of C, N, O, Sb atomic and mass fraction in Sb_3@HCNS.

Element	Atomic fraction (%)	Mass fraction (%)
C	83.83	73.39
N	10.15	10.36
O	4.82	5.62
Sb	1.20	10.63

Table S2. XPS analysis of C, N, O, Sb atomic and mass fraction in Sb_3@HCNS.

Element	Atomic fraction (%)	Mass fraction (%)
C	71.15	56.26
N	13.73	12.67
O	12.95	13.65
Sb	2.17	17.42%

Table S3. The performance comparison of Sb_3@HCNS with the reported counterparts.

Materials	Cyclability (mAh g^{-1})	Rate performance (mAh g^{-1})	Ref.
Sb SQ@MA	~314 at 1 A g^{-1} after 1000 cycles	~447 at 0.2 A g^{-1} ~419 at 0.4 A g^{-1} ~366.4 at 0.8 A g^{-1} ~299 at 1.6 A g^{-1} ~246 at 3.2 A g^{-1}	[37]
Sb-N-C	~254 at 1 A g^{-1} after 2000 cycles	~379 at 0.1 A g^{-1} ~343 at 0.2 A g^{-1} ~302 at 0.5 A g^{-1} ~274 at 1 A g^{-1} ~245 at 2 A g^{-1}	[39]
O-Sb-N SA@NC2	~195 at 2A g-1 after 2000 cycles	~576 at 0.1 A g^{-1} ~536 at 0.2 A g^{-1} ~312 at 0.5 A g^{-1} ~238 at 1 A g^{-1} ~225 at 2 A g^{-1} ~166 at 4 A g^{-1}	[41]
Sb SA/C	~331.3 at 1A g^{-1} after 1100 cycles	~441 at 0.1 A g^{-1} ~418 at 0.2 A g^{-1} ~356 at 0.5 A g^{-1} ~312 at 1 A g^{-1} ~252 at 2 A g^{-1}	[48]
NPS-FCM	~162.1 at 1 A g^{-1} after 1000cycles	~231.2 at 0.1 A g^{-1} ~205.7 at 0.3 A g^{-1} ~190.4 at 0.5 A g^{-1} ~179.4 at 1 A g^{-1} ~162.7 at 2 A g^{-1}	[49]
HTSb@Sb_2O_3@C	~241.67 at 2 A g^{-1} after 2000 cycles	~442.9 at 0.1 A g^{-1} ~420.2 at 0.2 A g^{-1} ~361.4 at 0.5 A g^{-1} ~311.3 at 1 A g^{-1} ~273 at 2 A g^{-1}	[50]

Mn-NC	~146 at 1 A g^{-1} after 3000cycles	~284 at 0.1 A g^{-1} ~258 at 0.2 A g^{-1} ~240 at 0.4 A g^{-1} ~207 at 0.8 A g^{-1} ~191 at 1 A g^{-1} ~162 at 2 A g^{-1}	[51]
Ni @BNHC	~279 at 1A g-1 after 1500cycles	~417 at 0.1 A g^{-1} ~329 at 0.2 A g^{-1} ~268 at 0.5 A g^{-1} ~215 at 1 A g^{-1} ~154 at 2 A g^{-1}	[52]
SCNs	~80 at 5 A g^{-1} after 5000cycles	~230 at 0.1 A g^{-1} ~201 at 0.2 A g^{-1} ~183 at 0.5 A g^{-1} ~167 at 1 A g^{-1} ~126 at 2 A g^{-1}	[53]
Sb@$Cu_{15}Si_4$ NW	~250.2 at 0.2 A g^{-1} after 1250cycles	~604 at 0.1 A g^{-1} ~550 at 0.2 A g^{-1} ~495 at 0.5 A g^{-1} ~321 at 1 A g^{-1} ~228.4 at 2 A g^{-1} ~104.9 at 4 A g^{-1}	[54]
NS-SGNR	~224 at 0.5A g-1 after 500cycles	~274.6 at 0.05A g-1 ~264.2 at 0.1A g-1 ~257.5 at 0.2A g-1 ~248.3 at 0.5A g-1 ~237.4 at 1A g-1 ~211.7 at 2A g-1	[55]
QLGC	~200at 0.1 A g^{-1} after 100cycles	~239 at 0.1 A g^{-1} ~200 at 0.2 A g^{-1} ~108at 0.5 A g^{-1} ~63 at 1 A g^{-1} ~28.4 at 2 A g^{-1}	[56]
		~500 at 0.1 A g^{-1}	

NP-Sb	~318 at 0.1 A g^{-1} after 50cycles	~430 at 02 A g^{-1} ~373 at 0.3 A g^{-1} ~312 at 0.4 A g^{-1} ~265 at 0.5 A g^{-1}	[57]
Defect-rich C	~321 at 0.05 A g^{-1} after 400cycles	~362 at 0.1 A g^{-1} ~314 at 02 A g^{-1} ~267 at 0.5 A g^{-1} ~240 at 1 A g^{-1} ~215 at 1 A g^{-1}	[58]
Sb_2O_3@PCN	~3437 at 0.1 A g^{-1} after 50cycles	~437 at 0.1 A g^{-1} ~400 at 02 A g^{-1} ~337 at 0.5 A g^{-1} ~210 at 1 A g^{-1}	[59]
Sb@CTF-NC	~440 at 0.05 A g^{-1} after 2000cycles	~501 at 0.1 A g^{-1} ~480 at 02 A g^{-1} ~402 at 0.5 A g^{-1} ~351 at 1 A g^{-1} ~232 at 2 A g^{-1}	[60]
Sb_3@HCNS	~382 at 2 A g^{-1} after 1000 cycles	~580.8 at 0.1 A g^{-1} ~540.6 at 0.2 A g^{-1} ~477.5 at 0.5 A g^{-1} ~413.0 at 1 A g^{-1} ~325 at 2 A g^{-1} ~215.5 at 4 A g^{-1}	The work