Electronic Supplementary Material (ESI) for ChemComm.

Interfacial covalent bonding of MXene-stabilized Sb_2Se_3 nanotube hybrid with fast ion transport for enhanced sodium-ion half/full batteries

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Experimental Section

Synthesis of Sb_2S_3: 4 mmol $SbCl_3$, 8 mmol L-cysteine and 8 mmol $Na_2S\cdot 9H_2O$ were dissolved in 80 mL deionized water and stirred for 3 hours to form a uniform solution. The above solution was transferred to a 100 mL hydrothermal kettle and kept at 180 ℃ for 12 h. Cooling to room temperature, the brown product was centrifuged with deionized water and ethanol for three times and vacuum dried overnight at 60 ℃.

Synthesis of Sb@NC: 100 mg of Sb_2S_3 and 50 mg of dopamine hydrochloride were dissolved in 100 ml buffer solution (10 mM), stirred for 6 h, centrifuged three times with deionized water and ethanol, and dried overnight in vacuum at 60 ℃. The product Sb_2S_3@polydopamine (Sb_2S_3@PDA) was annealed at 500 ℃ (3 ℃/min) Ar/H_2 (95vol %/5vol %) for 1 h to form Sb@NC.

Synthesis of Sb_2Se_3@NC: Sb@NC and selenium powder mass ratio 1:2 mixed evenly, then annealed at 500 ℃ (5 ℃/min) in N_2 atmosphere for 2 h to form Sb_2Se_3@NC.

Synthesis of Sb_2Se_3@NC/MXene: MAX(Ti_3AlC_2) freestanding thin films were purchased from Nanjing/Jiangsu XFNANO Materials Tech Co., Ltd. (No. XFK07).100 mg Sb_2Se_3@NC was ultrasonic dispersed in 100 ml deionized water for

30 min to form a uniform solution, then 10 mg MXene was added to the above solution and stirred for 24 h. Finally, solution was freeze-dried at −55 °C for 48 h until all the water sublimated, and the remaining powder was Sb_2Se_3@NC/MXene.

Material Characterization: The as-prepared samples are in rounded analysis by a large number of characterization equipments, such as conventional scanning electron microscopy (SEM, Hitachi, SU-9010), X-ray diffraction (XRD, D/max-2000, Cu Kα). Also transmission electron microscopy (TEM, Tecani G-20) with high resolution-TEM (HREM), XPS (ESCALAB, 250Xi) and thermogravimetric analysis (TGA; STA 449 F3) are extensively used. A Micromeritics ASAP 2020bsystem was used to quantify the Brunauer–Emmett–Teller (BET) surface area at 77 K.

Electrochemical Measurements: The electrode is prepared by Sb_2Se_3@NC/MXene, Super P, polyvinylidene fluoride and N-methylpyrrolidone. Their weight ratios are 70%, 20% and 10%, respectively. Then the slurry is evenly applied to the copper sheets and dried for 12 h at 100 °C in vacuum oven. The electrode sheets are then pressed under a force of about 10 MPa and cut it into circular sheets. Afterwards, it is assembled into coin-type cells in glove box. Sodium sheet is the counter electrode. The 1.0 M $NaPF_6$ in 1,2-dimethoxyethane is the electrolyte. Cycle performance and rate performance are tested on Neware battery test system (0.01–3.0 V). CV is performed out on the electrochemical workstation. For full cells preparation, the Sb_2Se_3@NC/MXene anode is presodiated in a half-cell for 3 cycles at 0.1 A g^{-1} in voltage range of 0.01–3.0 V to ensure the formation of a stable solid electrolyte interphase film.

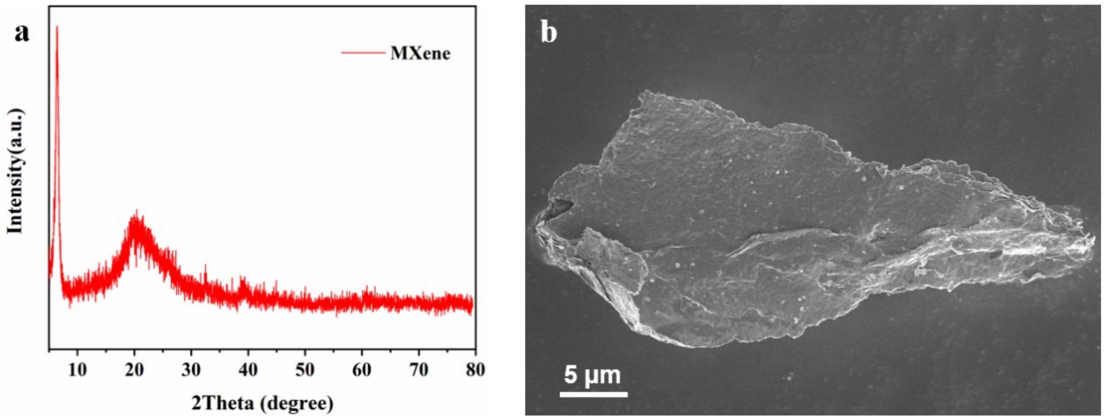

Figure S1. (a) XRD pattern. (b) SEM image of MXene.

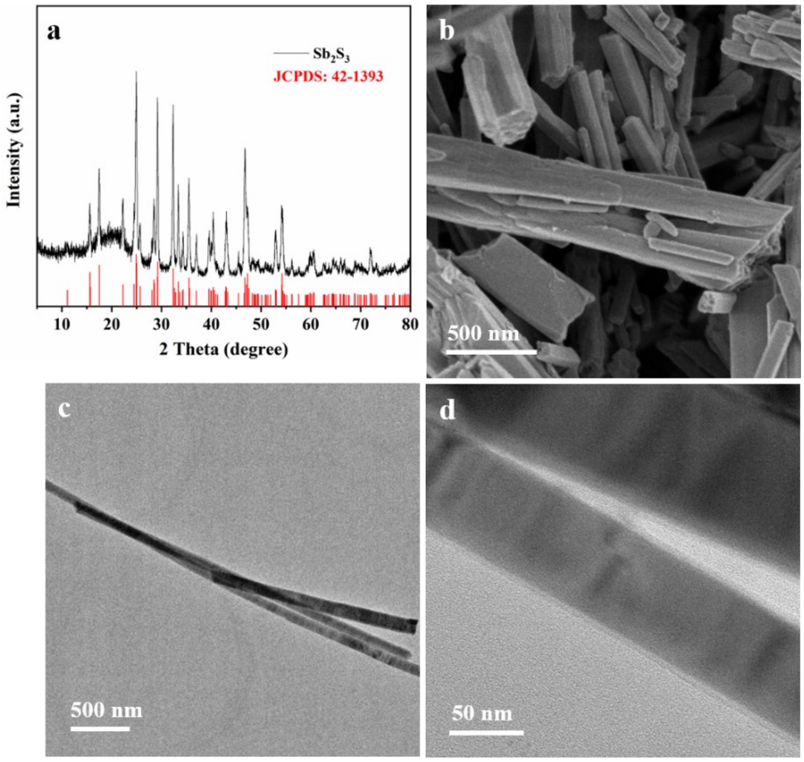

Figure S2. (a) XRD pattern. (b) SEM image. (c, d) TEM images of Sb_2S_3.

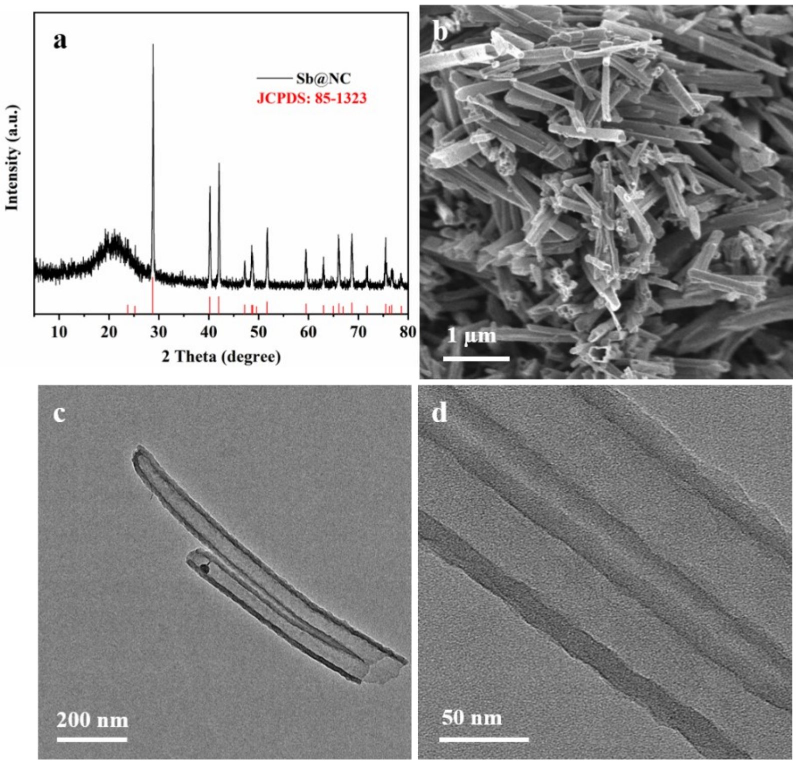

Figure S3. (a) XRD pattern. (b) SEM image. (c, d) TEM images of Sb@NC.

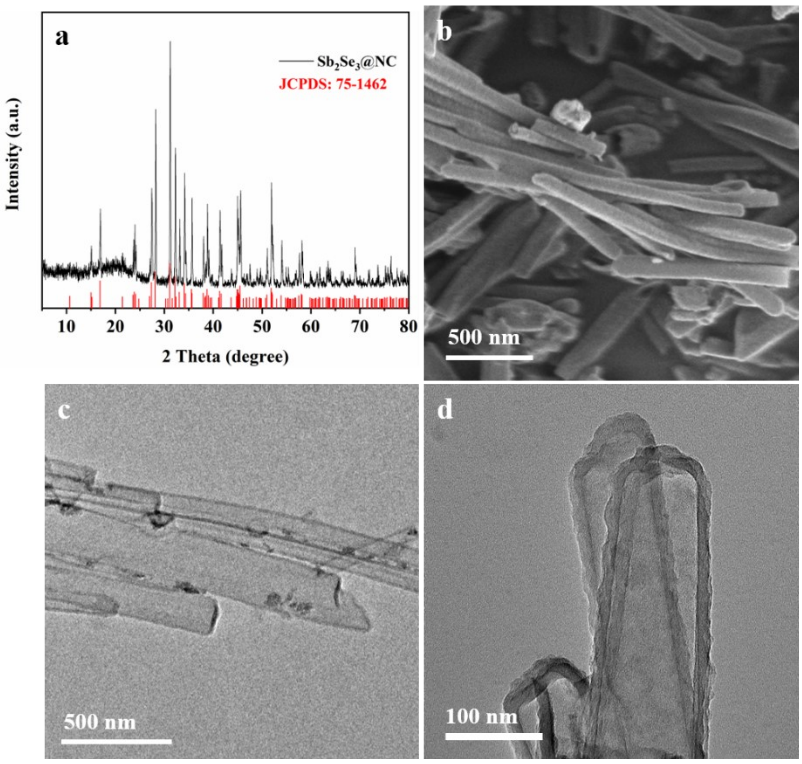

Figure S4. (a) XRD pattern. (b) SEM image. (c, d) TEM images of Sb_2Se_3@NC.

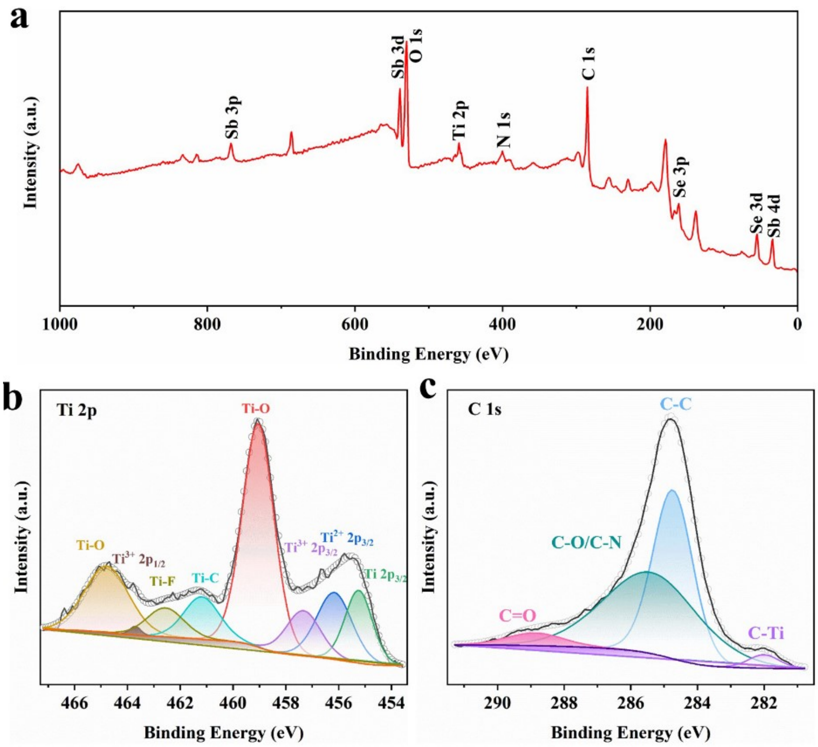

Figure S5. (a) XPS survey spectrum of Sb_2Se_3@NC/MXene. High-resolutions XPS spectra of (b) Ti 2p and (c) C 1s.

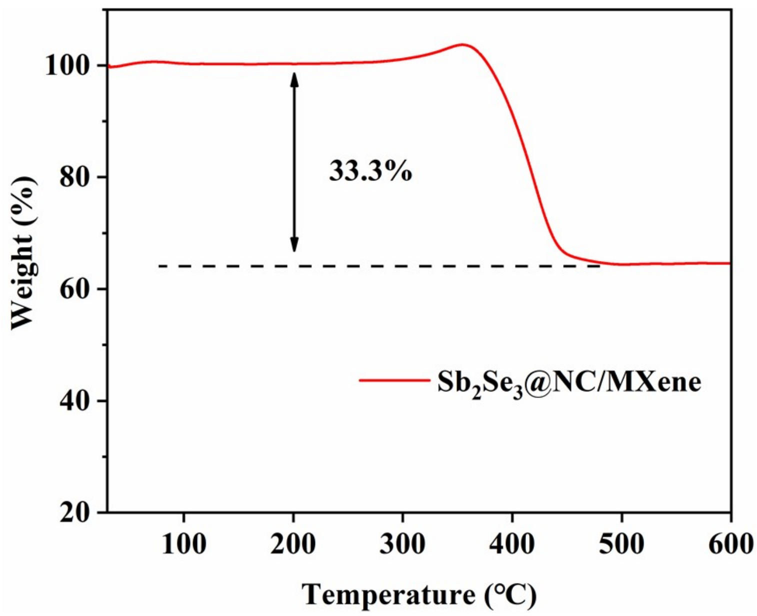

Figure S6. TGA curves of Sb_2Se_3@NC/MXene.

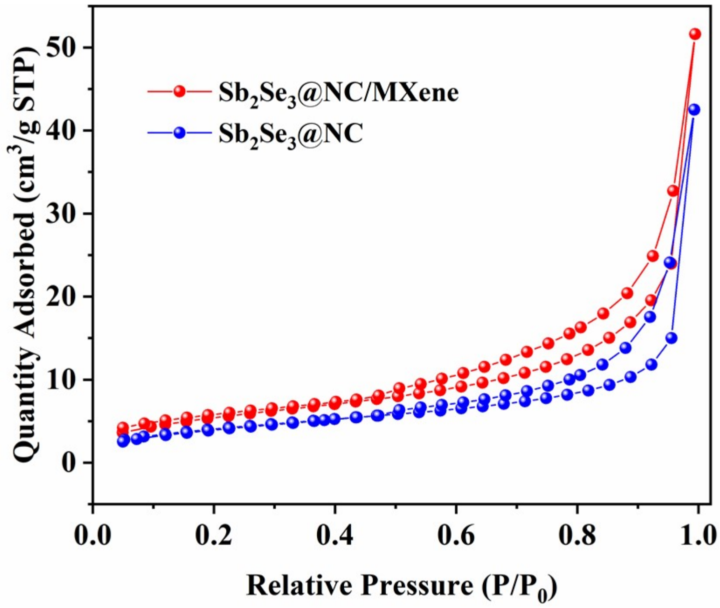

Figure S7. N_2 adsorption–desorption isotherms of Sb_2Se_3@NC/MXene and Sb_2Se_3@NC.

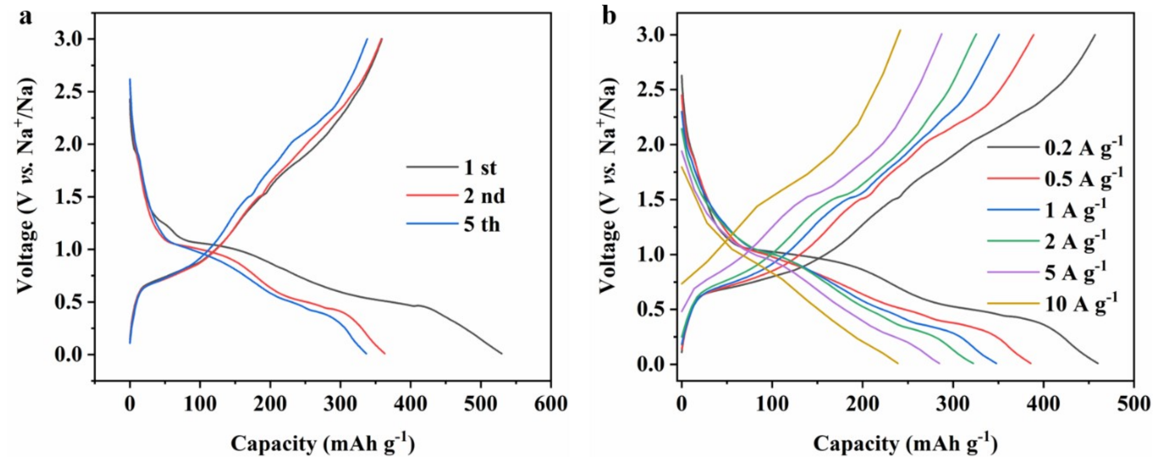

Figure S8. (a) Charge/discharge curves of Sb_2Se_3@NC profiles at 0.2 A g^{-1}. (b) Charge/discharge curves from 0.2 to 10 A g^{-1} of Sb_2Se_3@NC/MXene.

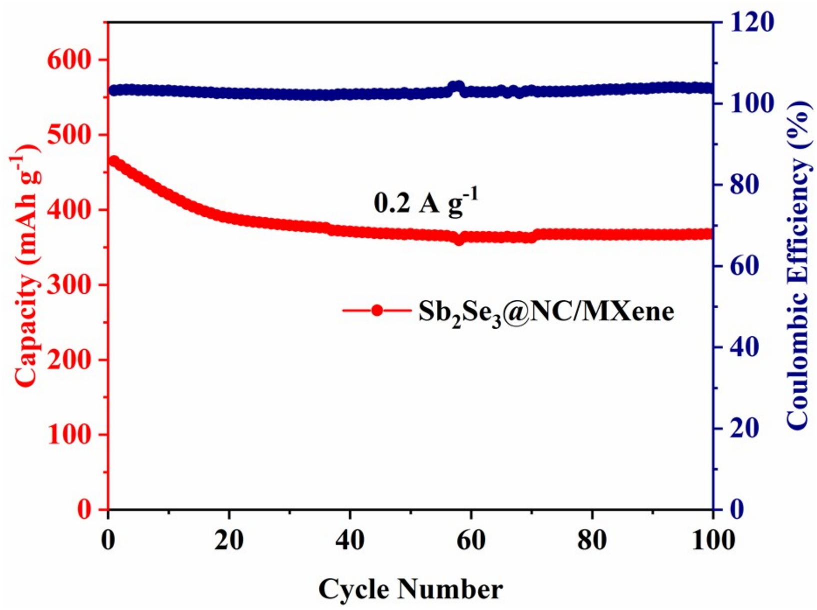

Figure S9. Cycle performance of Sb_2Se_3@NC/MXene at 0.2 A g^{-1}.

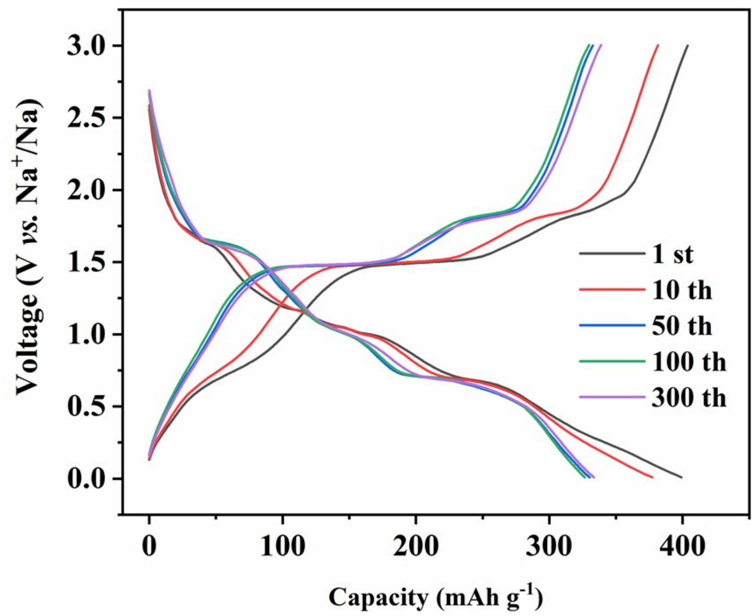

Figure S10. Charge/discharge curves at 1 A g^{-1} of Sb_2Se_3@NC/Mxene for different cycles.

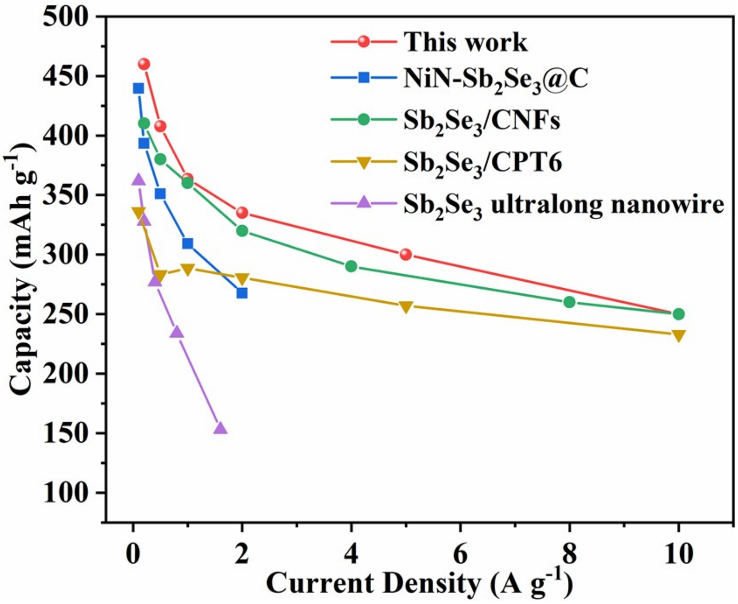

Figure S11. Rate capability comparisons of Sb_2Se_3@NC/MXene electrode and other Sb_2Se_3 based electrodes as previously reported.[1-4]

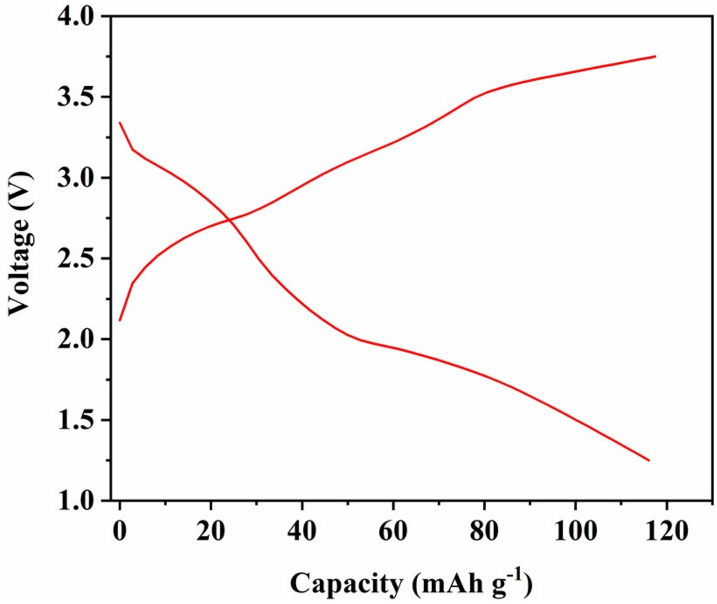

Figure S12. Charge/discharge curves at 1 A g^{-1} of the Sb_2Se_3@NC/MXene // NVPOF full cell.

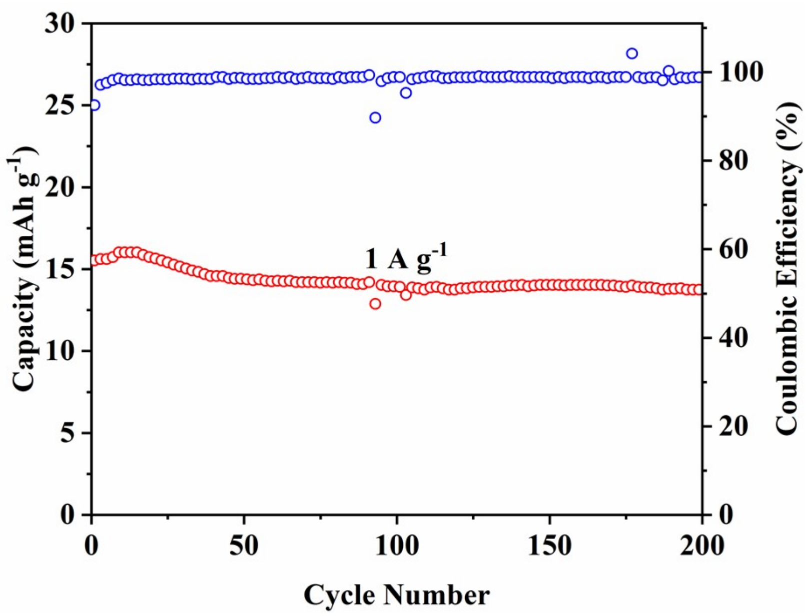

Figure S13. Cycling performance at 1 A g^{-1} of the Sb_2Se_3@NC/MXene // NVPOF full cell based on the mass loading of NVPOF.

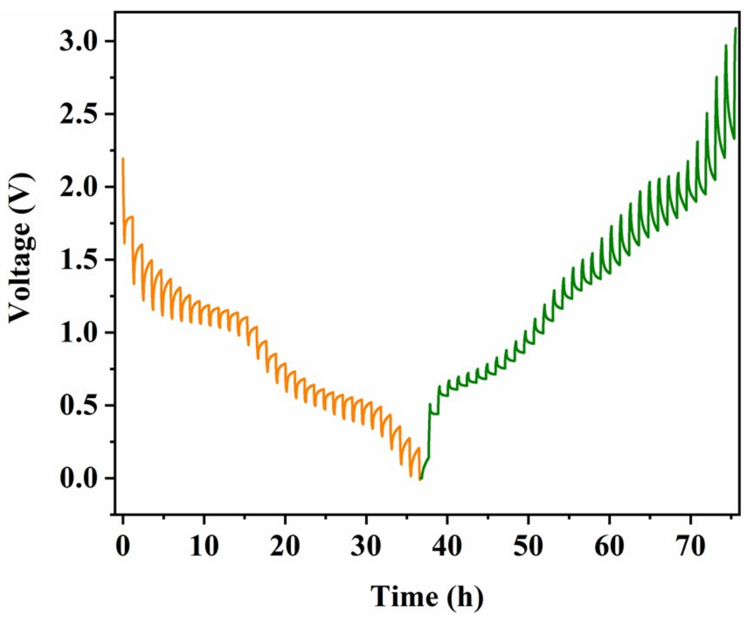

Figure S14. GITT curves of Sb_2Se_3@NC.

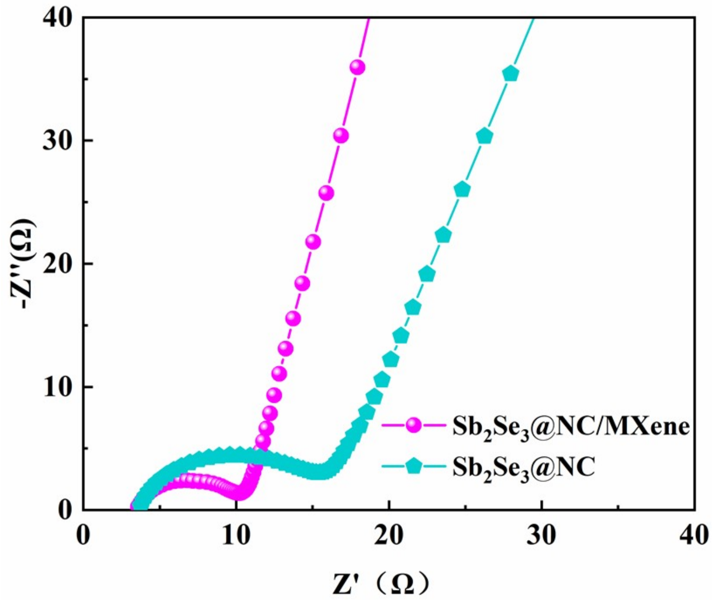

Figure S15. Nyquist plots of the Sb_2Se_3@NC/MXene and Sb_2Se_3@NC

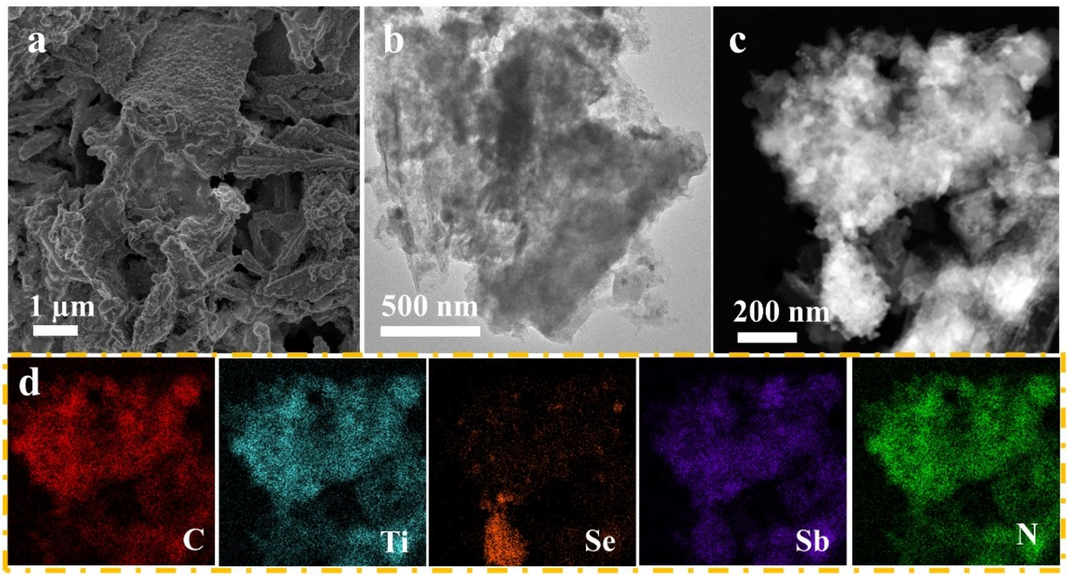

Figure S16. SEM, TEM and EDX mapping images of Sb_2Se_3@NC/MXene after 20th cycle at 0.5 A g^{-1}.

References

1. X.-Z. Li, S.-H. Tian, Z.-C. Lv, P.-F. Wang and T.-F. Yi, *Ceram. Int.*, 2023, **49**, 7414-7423.
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