Electronic Supplementary Material (ESI) for Journal of Materials Chemistry A.

Supporting Information

In-Situ Fabrication of MXene/CuS Hybrids with Interfacial Covalent Bonding via Lewis Acidic Etching Route for Efficient Sodium Storage

Pengfei Huang[#], Hangjun Ying[#], Shunlong Zhang, Zhao Zhang and Wei-Qiang Han[*]

School of Materials Science and Engineering, Zhejiang University, Hangzhou 310027, China

*Corresponding Author Email: hanwq@zju.edu.cn

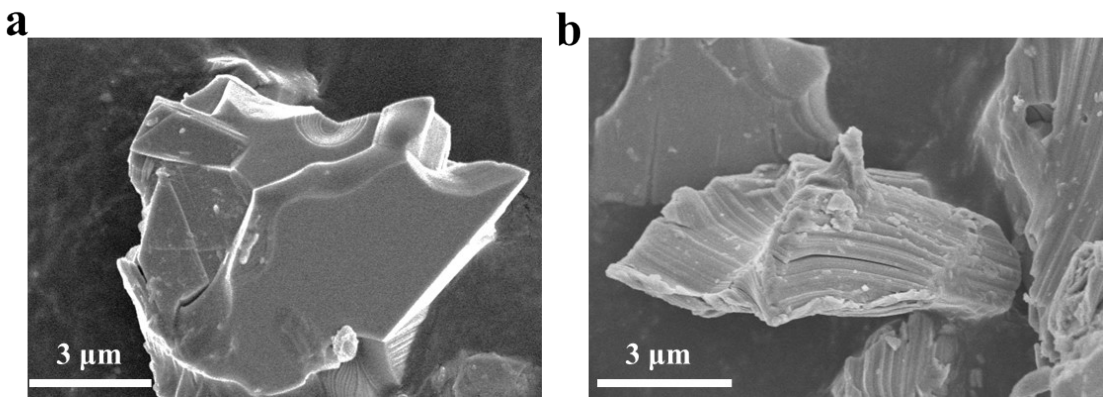

Fig. S1 (a-b) SEM images of Ti_3AlC_2 MAX.

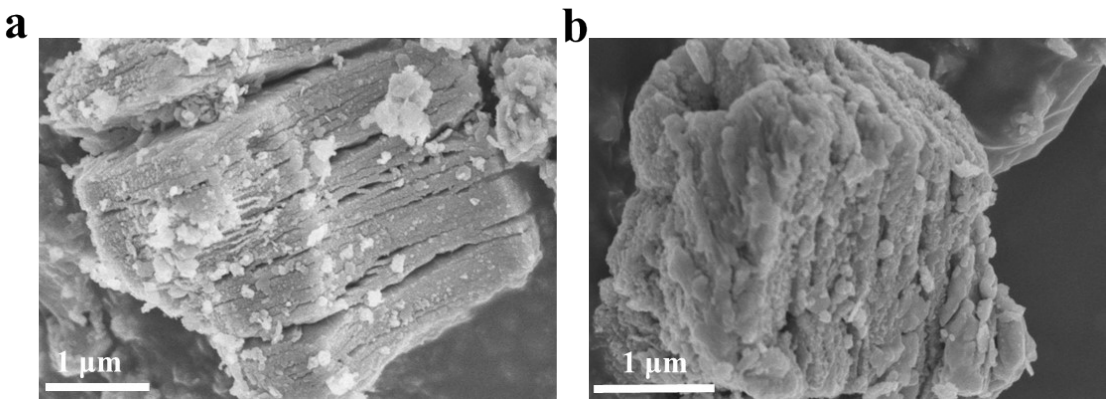

Fig. S2 (a-b) SEM images of $Ti_3C_2T_x$/Cu hybrids.

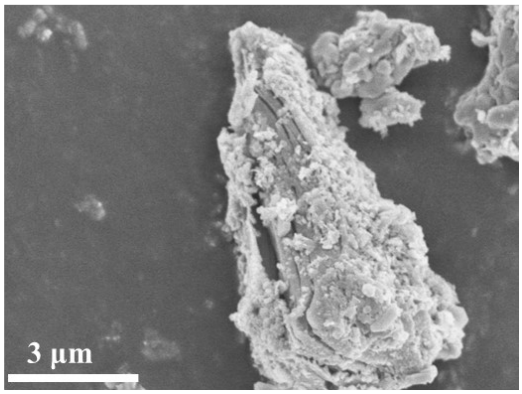

Fig. S3 SEM image of $Ti_3C_2T_x$/CuS hybrids.

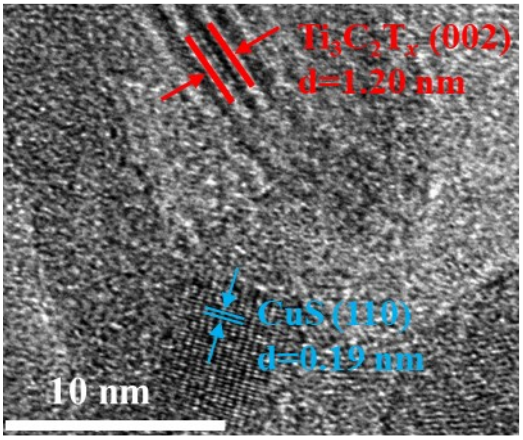

Fig. S4 HRTEM image of $Ti_3C_2T_x$/CuS hybrids.

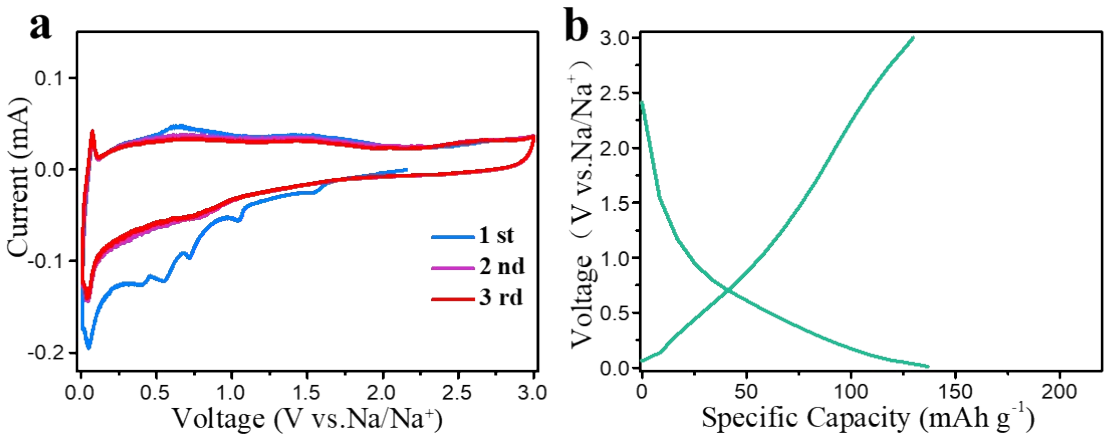

Fig. S5 (a) CV curves of $Ti_3C_2T_x$ anode at a scan rate of 0.1 mV s^{-1}. (b) GCD curves of $Ti_3C_2T_x$ electrode at 500 mA g^{-1}.

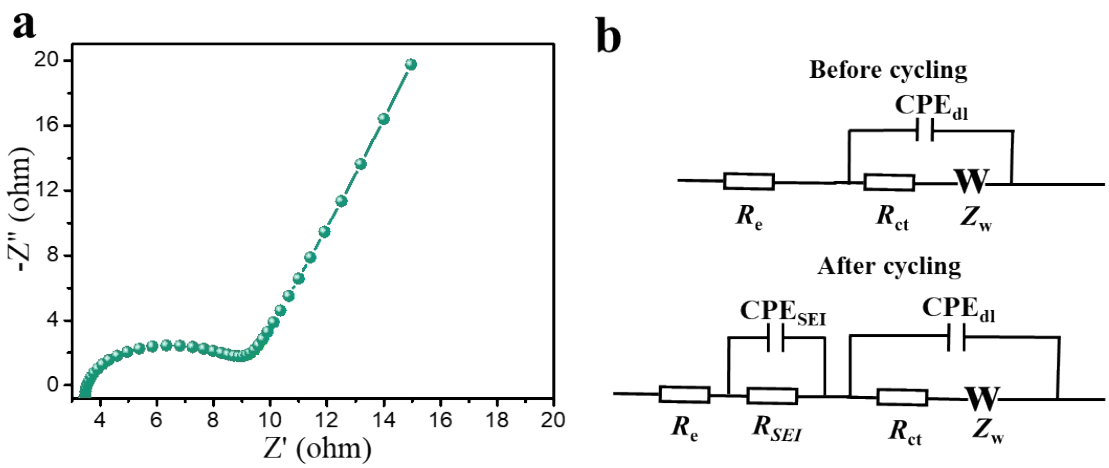

Fig. S6 (a) Nyquist plot of $Ti_3C_2T_x$ electrode at open circuit. (b) The equivalent circuit model for Nyquist plots.

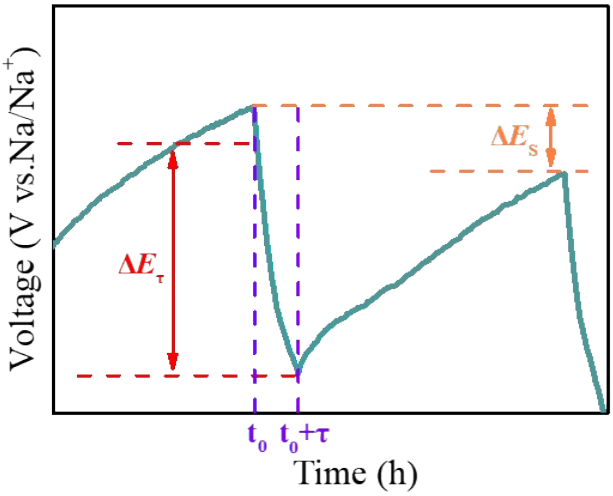

Fig. S7 Schematic diagram of GITT profile.

The diffusion coefficient of Na^+ ion is calculated according to following equation:

$$D_{Na} = \frac{4}{\pi\tau}\left(\frac{mV_m}{MA}\right)^2\left(\frac{\Delta E_s}{\Delta E_\tau}\right)^2$$

τ is the time for applied galvanostatic current, m is the weight of active material, A is the electrode surface area, V_m is the molar volume of active material, M is the relative molecular mass of active material, ΔE_s refers to the voltage change of steady-state before and after the current pulse, ΔE_τ is the potential vibration during the current pulse.

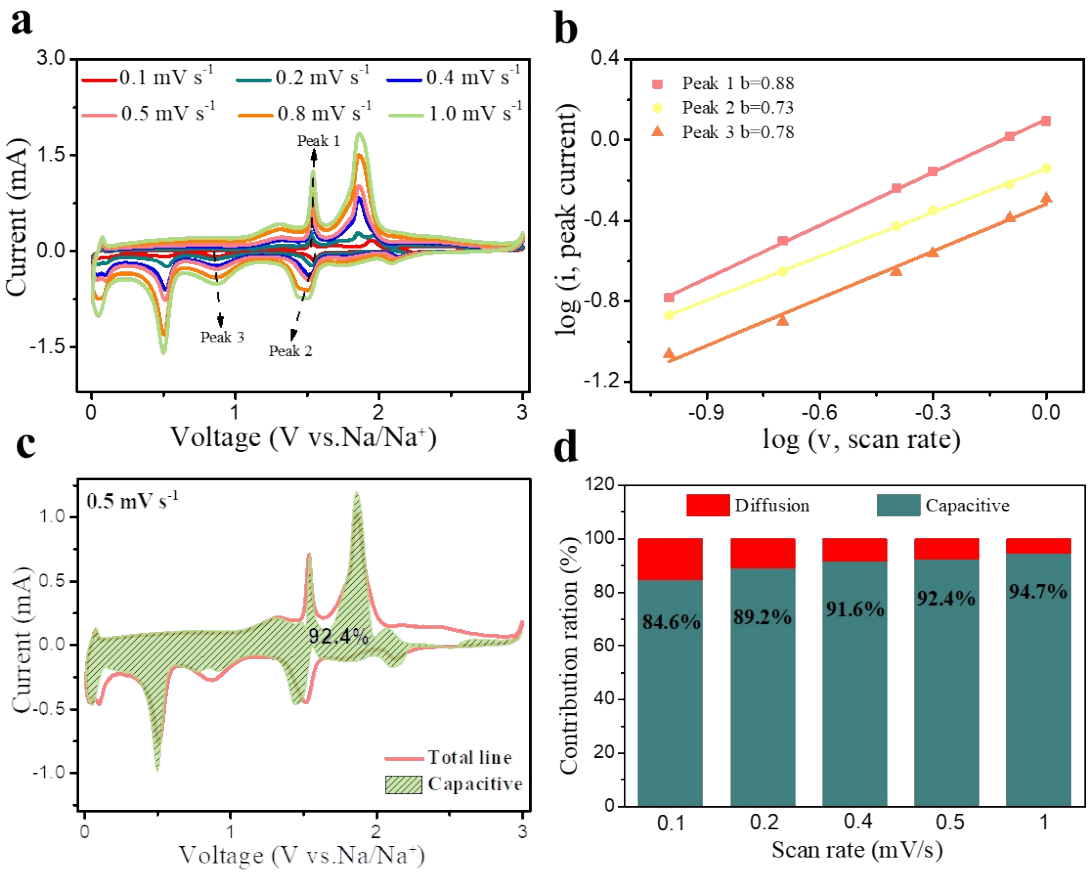

Fig. S8 (a) CV curves of $Ti_3C_2T_x$/CuS anode at various sweep rates. (b) The plots of log (*i*) vs log (*v*) calculated from CV curves. (c) CV curve with corresponding capacitive contribution at 0.5 mV s^{-1}. (d) Capacitive contribution at different sweep rates.

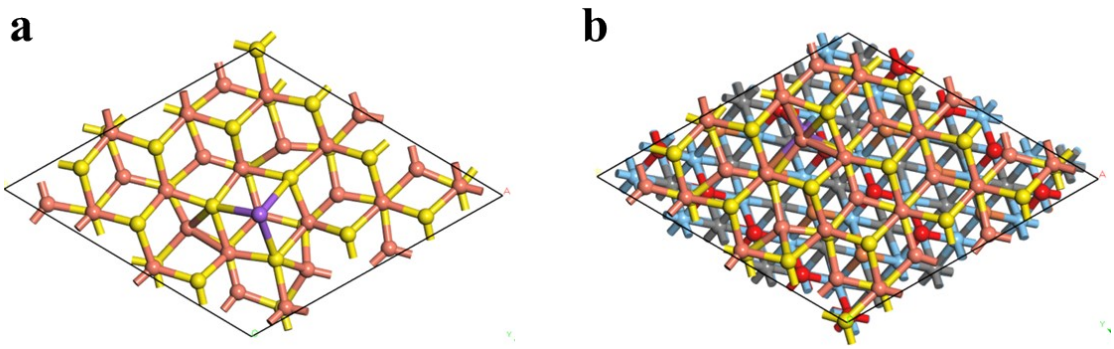

Fig. S9 Top view structure of Na adsorption on (a) CuS and (b) $Ti_3C_2T_x$/CuS.

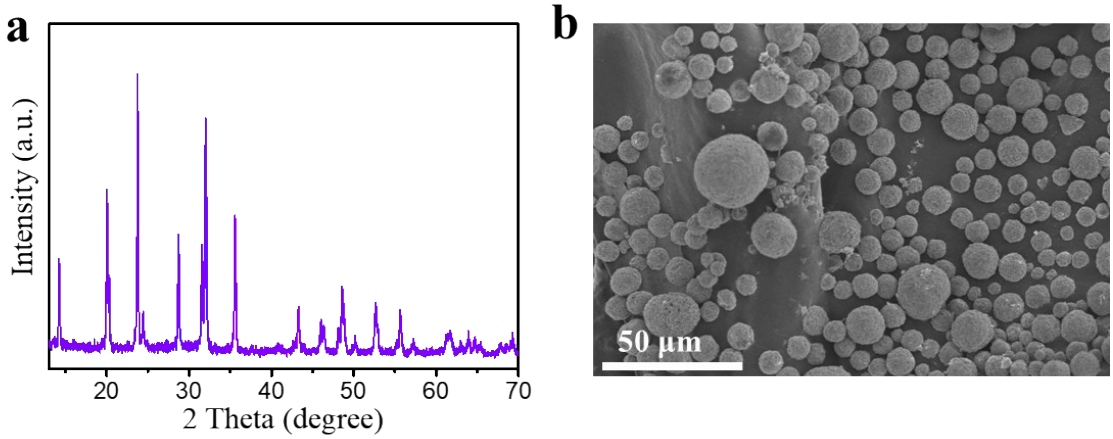

Fig. S10 (a) XRD pattern and (b) SEM image of NVP powders.

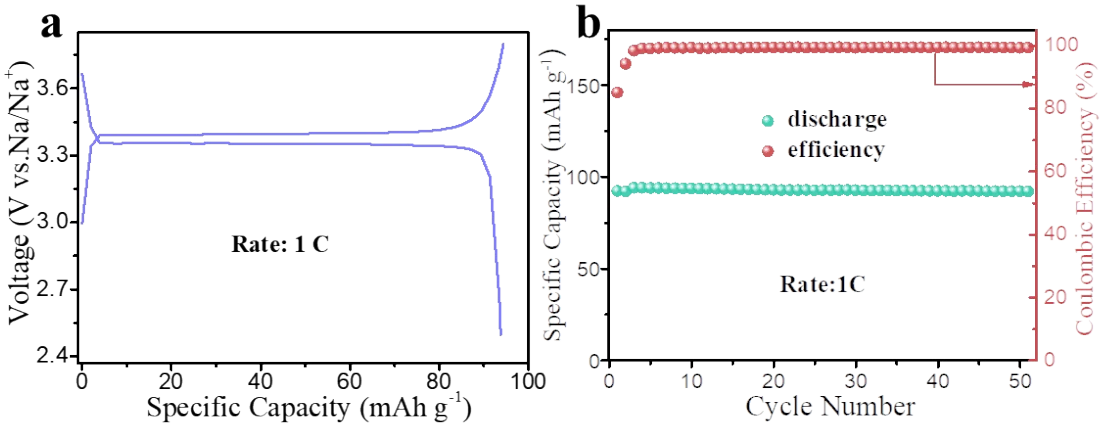

Fig. S11 (a) GCD profiles and (b) Cyclic performance of NVP cathode.

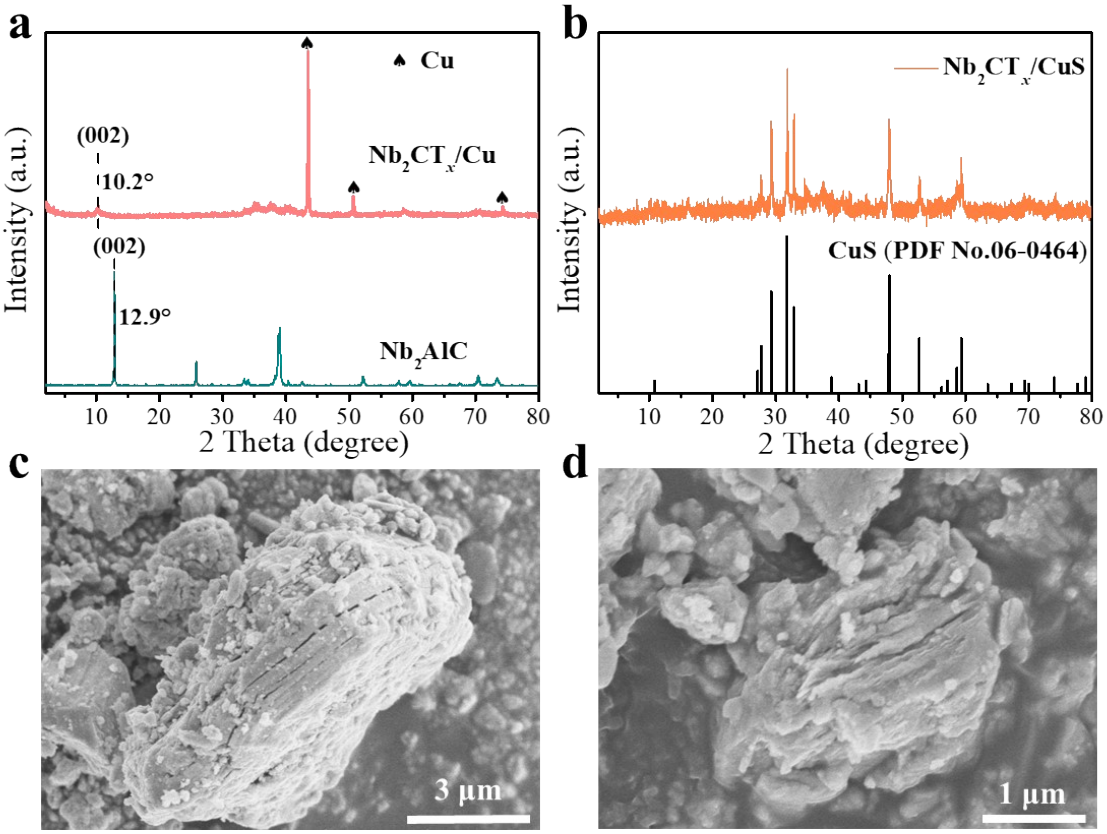

Fig. S12 (a) XRD patterns of Nb_2AlC MAX and Nb_2CT_x/Cu hybrids. (b) XRD pattern of Nb_2CT_x/CuS composites. SEM images of (c) Nb_2CT_x/Cu and (d) Nb_2CT_x/CuS.

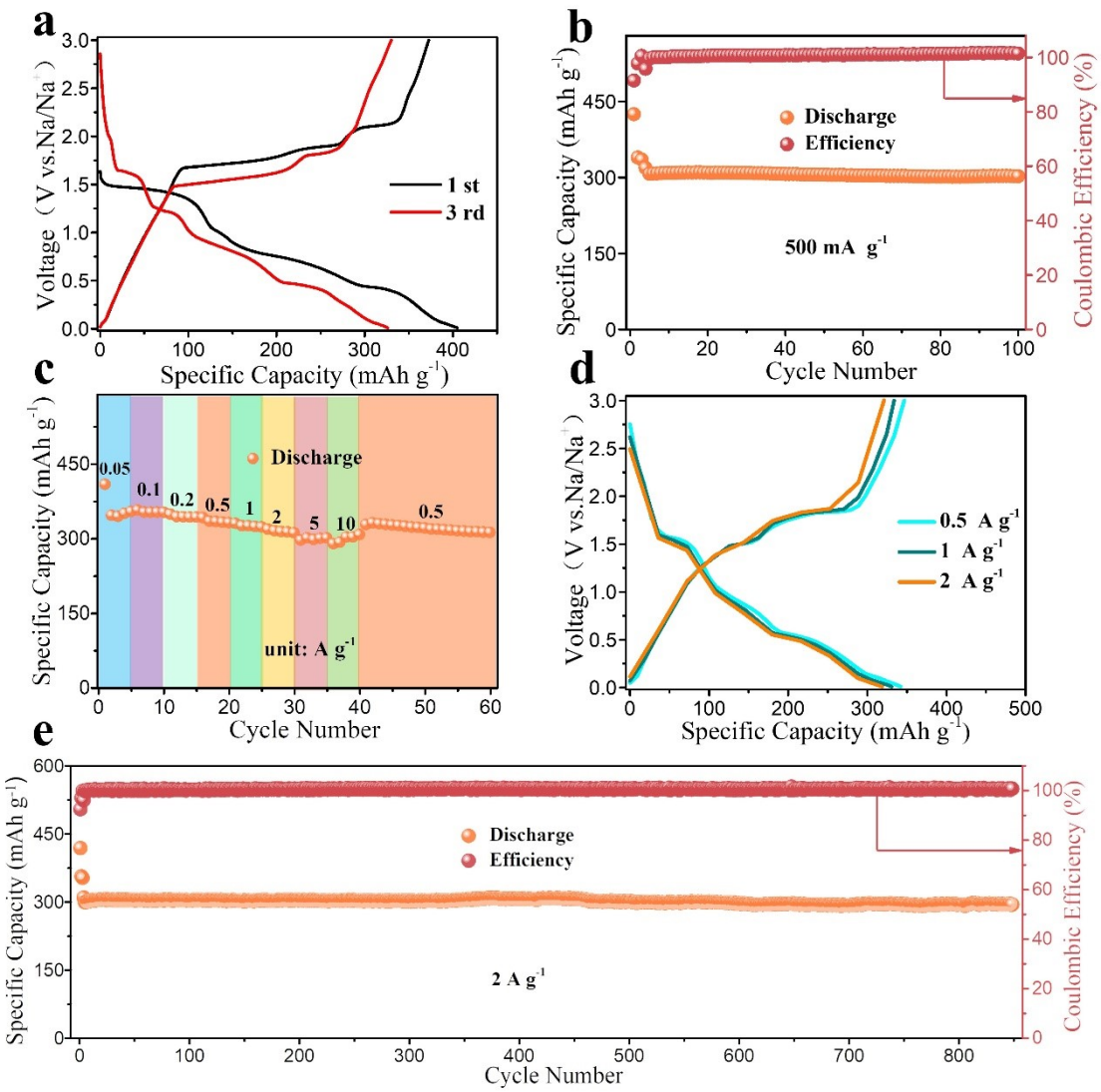

Fig. S13 (a) GCD curves of Nb_2CT_x/CuS electrode at 50 mA g^{-1}. (b) Cycling performance of Nb_2CT_x/CuS anode at 500 mA g^{-1}. (c) Rate performance of Nb_2CT_x/CuS anode. (d) GCD profiles of Nb_2CT_x/CuS electrode at various current densities. (e) Long-term cyclic performance of Nb_2CT_x/CuS anode at 2 A g^{-1}.

Table S1 The mass change of $Ti_3C_2T_x$/Cu hybrids before and after washing with ammonium persulfate ($(NH_4)_2S_2O_8$) solution.

	weight (mg)
before washing	350
after washing	123

Table S2 The mass change of $Ti_3C_2T_x$/Cu hybrids before and after vulcanization treatment.

	weight (mg)
before vulcanization	75
after vulcanization	89

As exhibited in Table S1, for $Ti_3C_2T_x$/Cu hybrids, Cu clusters can be removed by washing with $(NH_4)_2S_2O_8$ solution and the $Ti_3C_2T_x$ MXene remains. Therefore, the content of $Ti_3C_2T_x$ MXene in the $Ti_3C_2T_x$/Cu hybrids can be calculated to be (123/350)×100=35.1%. After sulfidation treatment for $Ti_3C_2T_x$/Cu, the mass of $Ti_3C_2T_x$ MXene remains unchanged and the Cu metal can be transformed into CuS. According to above analysis and the weight change before and after vulcanization reaction process, the mass of $Ti_3C_2T_x$ MXene in the $Ti_3C_2T_x$/CuS is around 75×35.1%=26.3, so the mass of CuS in the $Ti_3C_2T_x$/CuS is around 89-26.3=62.7. Finally, the content of CuS in the $Ti_3C_2T_x$/CuS hybrids can be roughly calculated to be (62.7/89)×100%=70.4%.

Table S3 The EIS fitting results of $Ti_3C_2T_x$/CuS electrode after cycling.

Cycle number	R_e /Ω	R_{ct} /Ω
10^{th} cycle	3.46	1.23
20^{th} cycle	2.63	0.70
60^{th} cycle	2.27	0.67