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SUPPLEMENTARY INFORMATION

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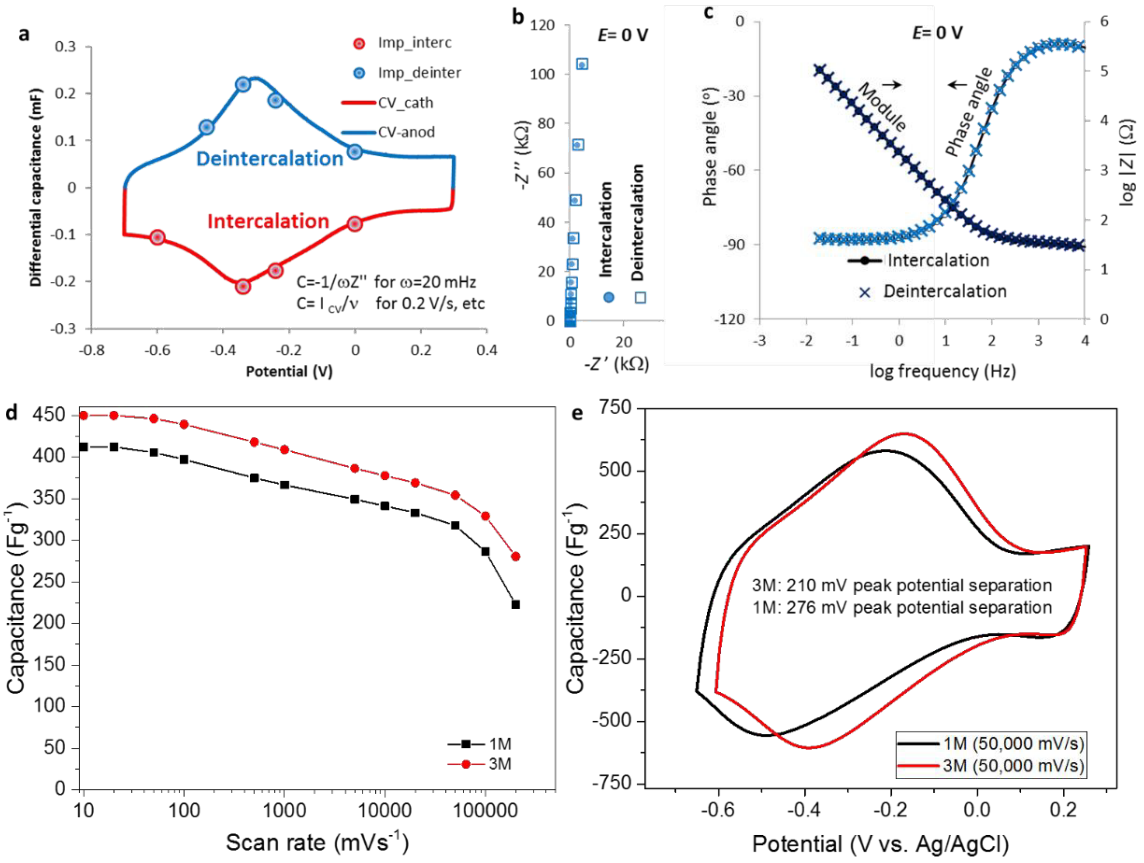
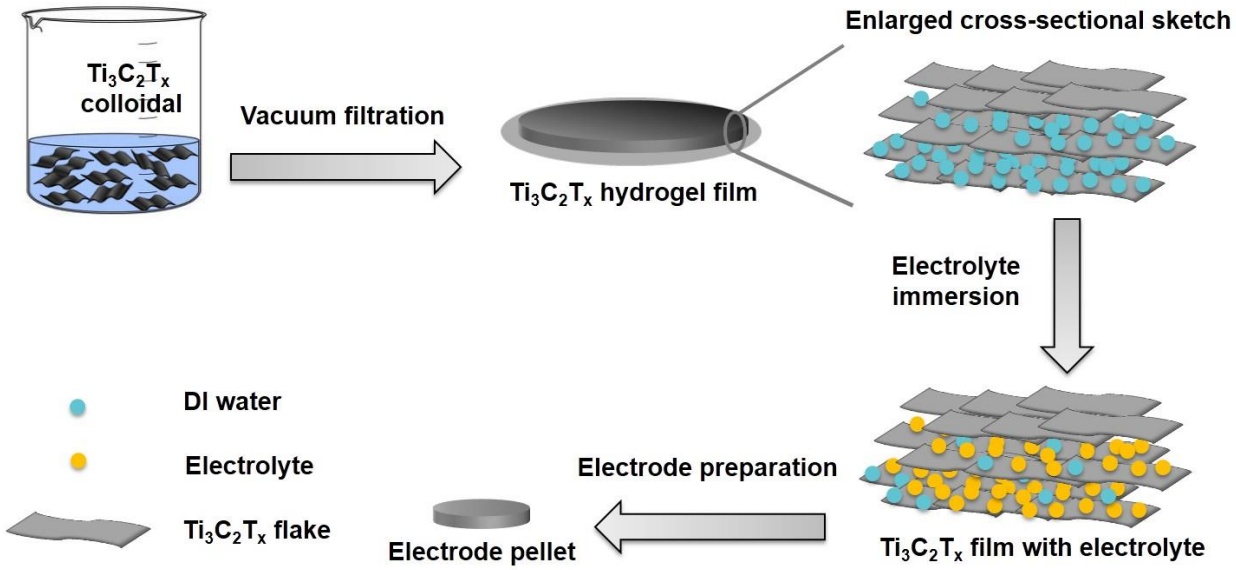
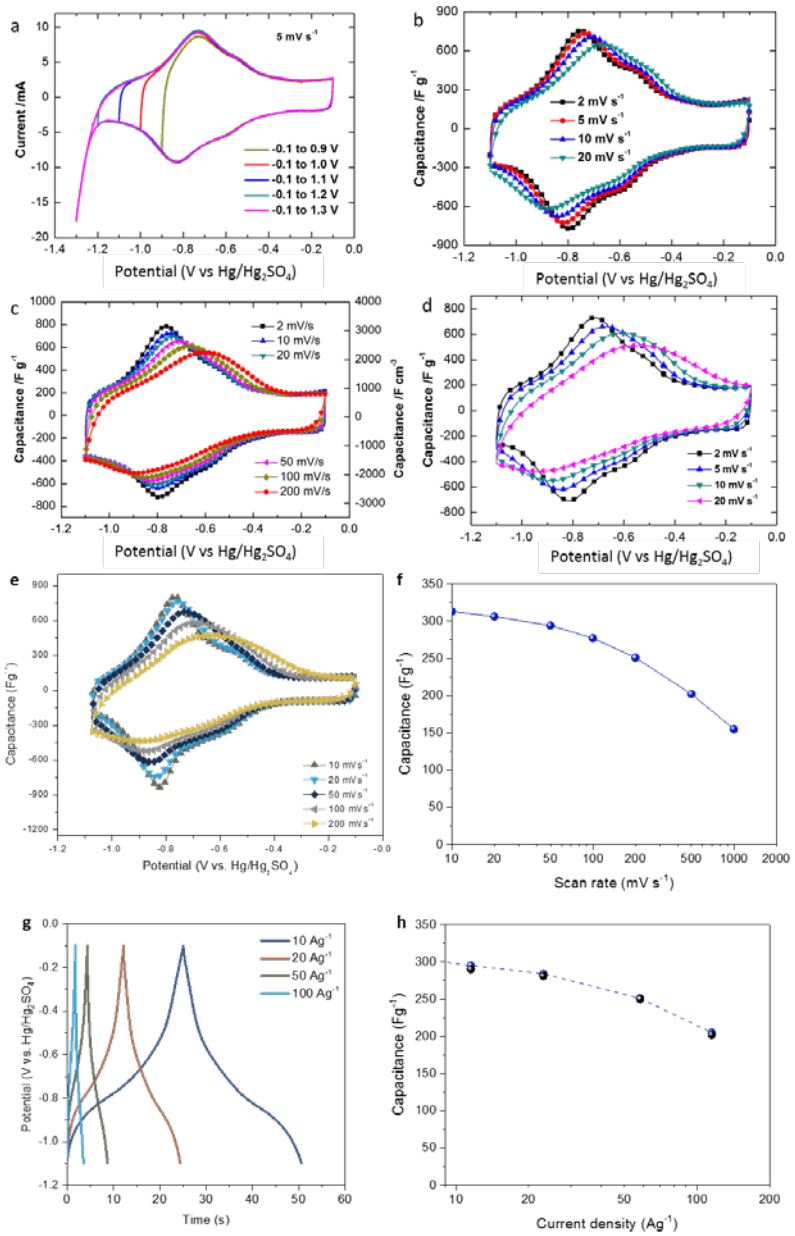
Ultra-high-rate pseudocapacitive energy storage in two-dimensional transition metal carbides



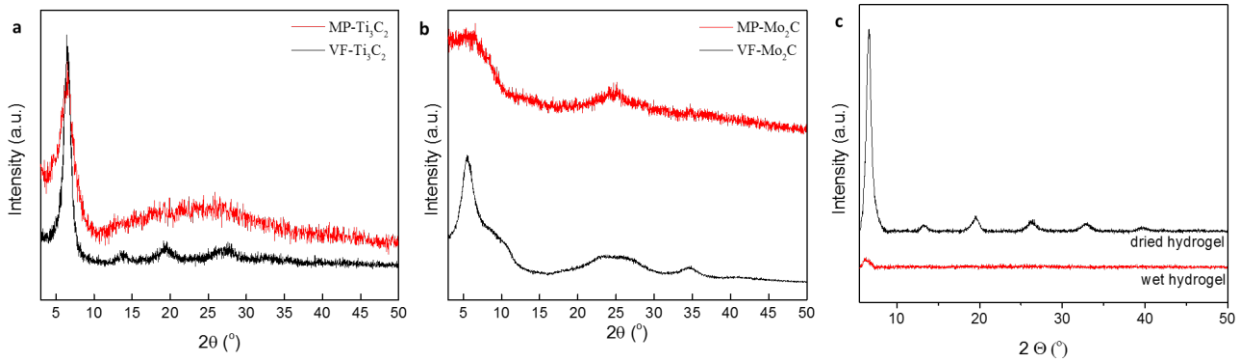
Supplementary Figure 1 | **Electrochemical performance of thin $Ti_3C_2T_x$ films. a**, Cyclic voltammetry profile (line) with over-imposed values of capacitance extracted from EIS at different intercalation (red spheres) and deintercalation (blue spheres) potentials. **b**, EIS data (Nyquist plot) collected at 0 V vs. Ag/AgCl on the intercalation (filled spheres) and deintercalation (hollow squares) branches. **c**, Bode plot collected at 0 V vs. Ag/AgCl. **c**, Gravimetric rate performance extracted from cyclic voltammetry profiles of a 90 nm film on glassy carbon electrode in 1M (black squares) and 3M (red circles) H_2SO_4. **d**, Cyclic voltammetry profiles collected at 50,000 mV s^{-1} in 1M (black) and 3M H_2SO_4 (red).



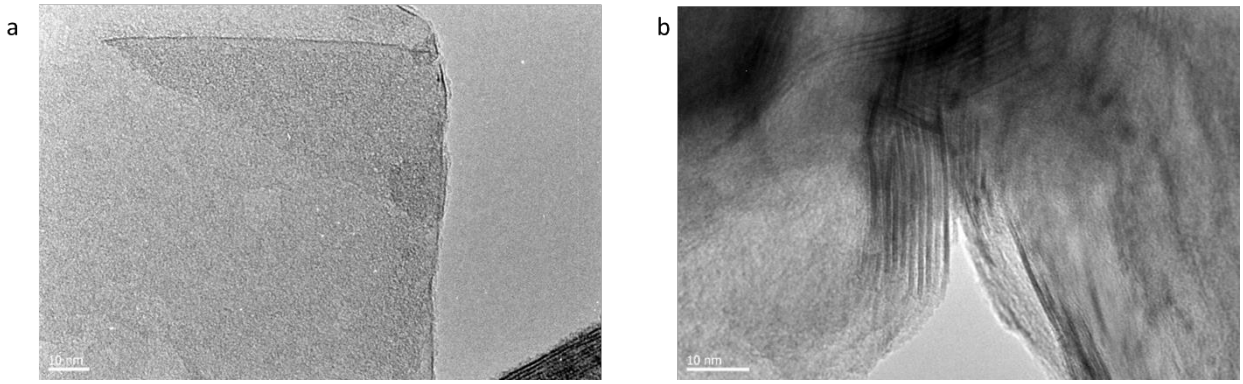
Supplementary Figure 2| Schematic illustration of $Ti_3C_2T_x/H_2SO_4$ hydrogel preparation procedure. $Ti_3C_2T_x$ colloidal solution was taken for vacuum filtration to prepare the $Ti_3C_2T_x$ hydrogel film. The obtained hydrogel film was then immersed in 3 M H_2SO_4 electrolyte to replace the water and increase/ensure accessibility of MXene surface to the electrolytes. Electrode pellet was punched out from the $Ti_3C_2T_x$ film after electrolyte immersion for more than 24 h.



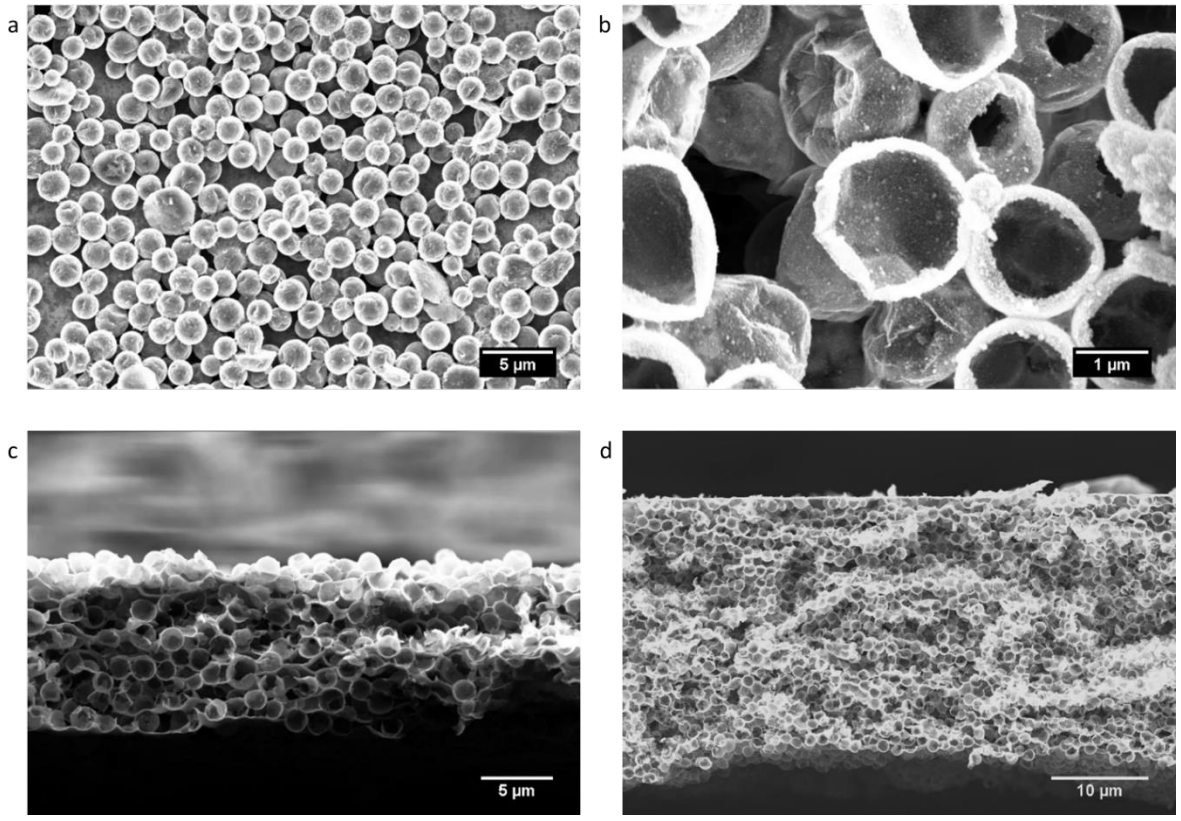
Supplementary Figure 3 | **Electrochemical performance of $Ti_3C_2T_x$ hydrogel films**. **a**, Cyclic voltammetry profiles collected at 5 mVs^{-1} in different potential ranges (active material mass loading of 5.3 mg/cm^2, 13 µm thick). **b**, Cyclic voltammetry profiles collected at scan rates from 2 to 20 mV s^{-1} (active material mass loading of 5.3 mg/cm^2, 13 µm thick)**. c**, Cyclic voltammetry profiles collected at scan rates from 2 to 200 mV s^{-1} (active material mass loading of 1.2 mg/cm^2, 3 µm thick)**. d,** Cyclic voltammetry profiles collected at scan rates from 2 to 20 mV s^{-1} (active material mass loading of 11.3 mg/cm^2, 40 µm thick)**. e-h:** Rate performance of a hydrogel sample with mass loading of 2.65 mg/cm^2: **e,** Cyclic voltammetry profiles collected at scan rates from 10 to 200 mV s^{-1}. **f,** Gravimetric rate performance (from CV): capacitance vs. scan rate. **g,** Galvanostatic cycling profiles collected at 10, 20, 50 and 100 Ag^{-1}. **e,** Gravimetric rate performance (from GCPL): capacitance vs. charge/discharge current density.



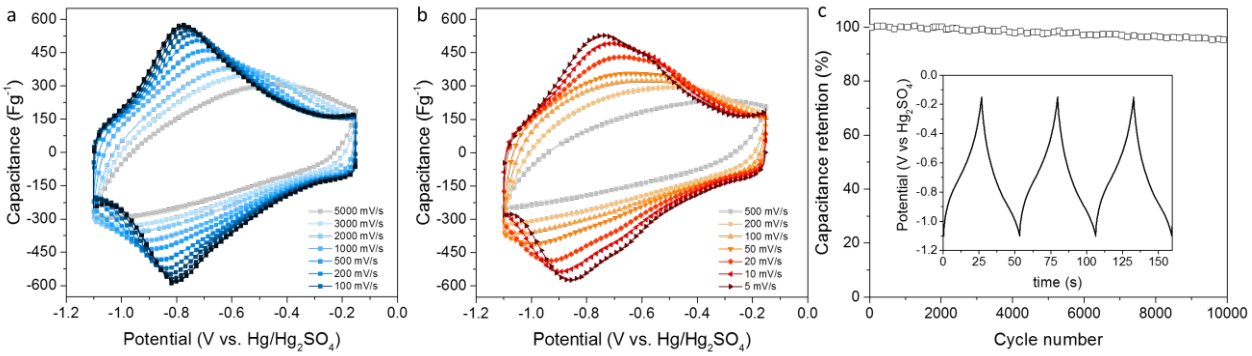
Supplementary Figure 4 | X-ray diffractograms of a, $Ti_3C_2T_x$ MXene macroporous and vacuum-filtered freestanding films. **b,** Mo_2CT_x MXenes macroporous and vacuum-filtered freestanding films. **c**, dry and wet hydrogel.



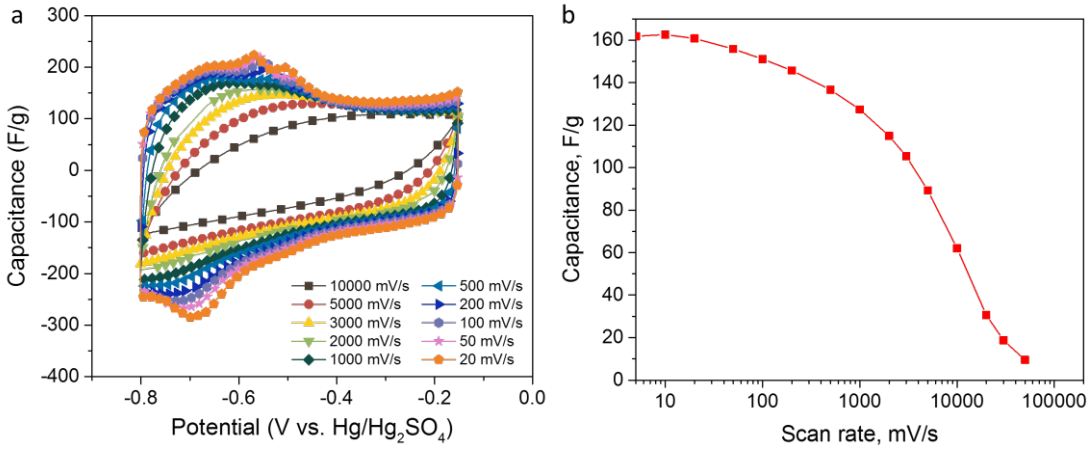
Supplementary Figure 5| TEM micrographs of hollow Ti_3C_2 spheres. **a,** edge of an individual $Ti_3C_2T_x$ flake, confirming presence of single-layer flakes and **b,** the connection point of two $Ti_3C_2T_x$ hollow spheres. They are with few layers and share some of them, indicating a good connection. This is important for the charge transfer throughout the entire macroporous framework.



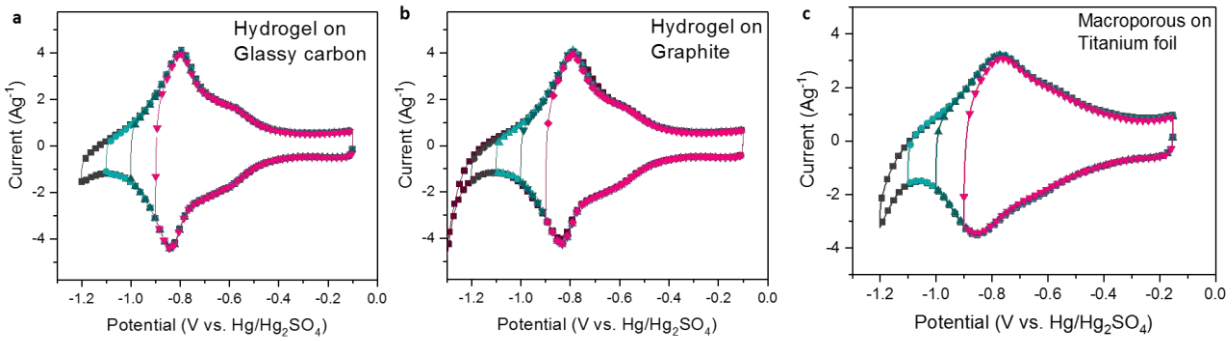
Supplementary Figure 6| Scanning electron micrographs of macroporous MXene films. **a,** few-layer $Ti_3C_2T_x$ wrapping PMMA spheres, **b,** $Ti_3C_2T_x$ wrapped PMMA after annealing in Ar at 400 ^oC, and **c,d,** cross-sections of $Ti_3C_2T_x$ and Mo_2CT_x films, respectively.



Supplementary Figure 7| a,b, Cyclic voltammetry profiles collected at different scan rates for macroporous $Ti_3C_2T_x$ films: **a,** 25 µm thick, loading of 0.9 mg/cm^2. **b**, 180 µm thick electrode, loading 4.3 mg/cm^2. **c**, Capacitance retention test of a 180 µm thick macroporous electrode performed by galvanostatic cycling at 10 Ag^{-1}. Inset depicts galvanostatic cycling profiles collected at 10 Ag^{-1}.



Supplementary Figure 8| Electrochemical performance of macroporous Mo_2CT_x. a, Cyclic voltammetry profiles of a 30 µm thick macroporous Mo_2CT_x film with 0.6 mg/cm^2 loading collected in 3 M H_2SO_4 at scan rates from 20 mV/s to 10000 mV/s, **b,** Rate performance of macroporous Mo_2CT_x MXene film represented as mass-normalized capacitance.



Supplementary Figure 9| Electrochemical stability window for $Ti_3C_2T_x$ electrodes collected at 5 mVs^{-1} in 3 M H_2SO_4 with different current collectors. Cyclic voltammetry profiles for hydrogel $Ti_3C_2T_x$ electrodes (2.65 mg/cm^2) on **a,** glassy carbon and **b**, graphite current collector. **c**, Cyclic voltammetry profiles for macroporous $Ti_3C_2T_x$ electrode (4.3 mg/cm^2) on Ti foil.