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

Supporting Information

Ultrahigh conductivity and antifreezing zwitterionic sulfobetaine hydrogel electrolyte for low-temperature resistance flexible supercapacitors

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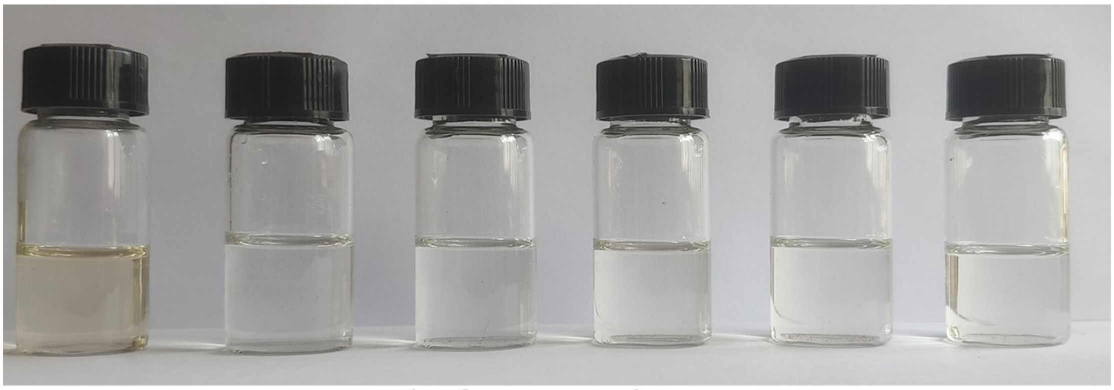

before reaction

after reaction

Fig S1. Images left to right showing the hydrogels before and after the reaction (PHEAA, $PSH_{2\text{-}8}$, $PSH_{4\text{-}6}$, $PSH_{6\text{-}4}$, $PSH_{8\text{-}2}$ and PSBMA)

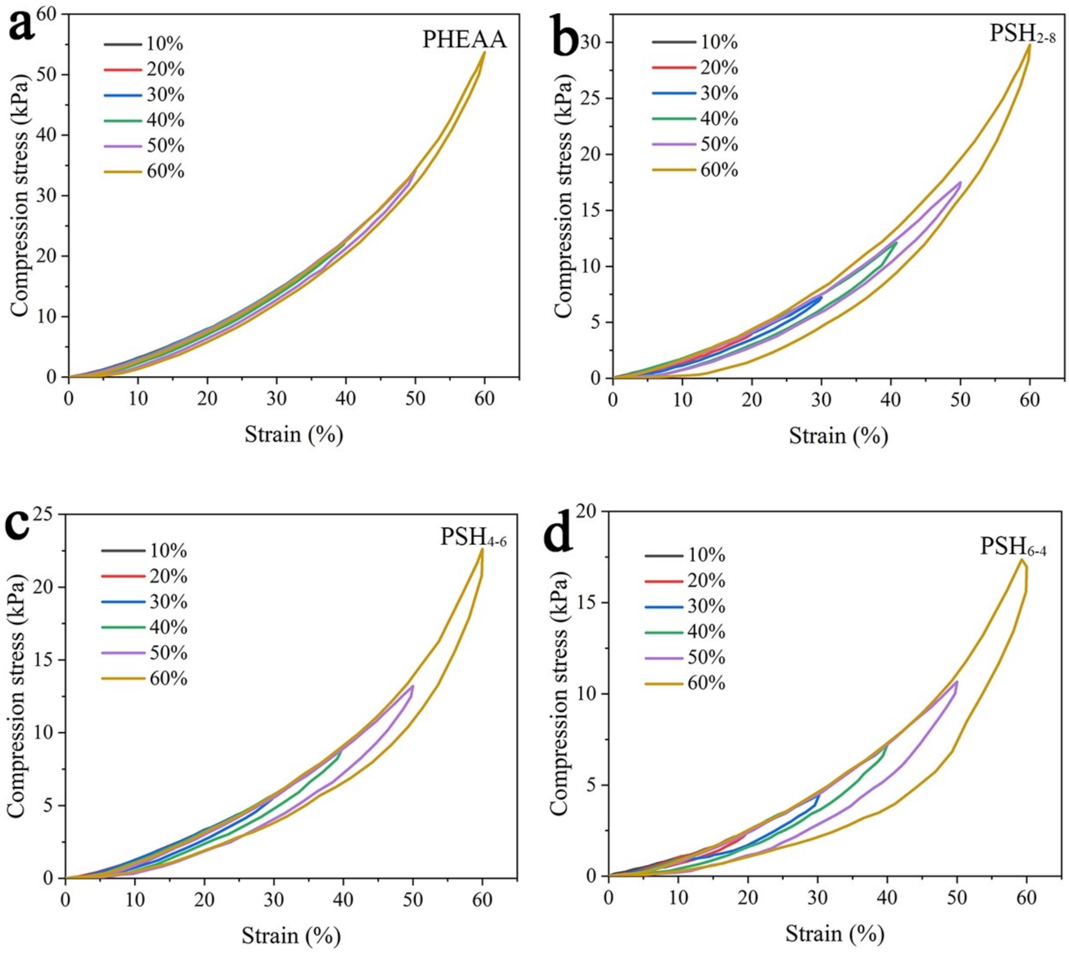

Fig S2. Compressive stress-strain curves of (a) PHEAA, (b) PSH_{2-8}, (c) PSH_{4-6}, (d) PSH_{6-4}.

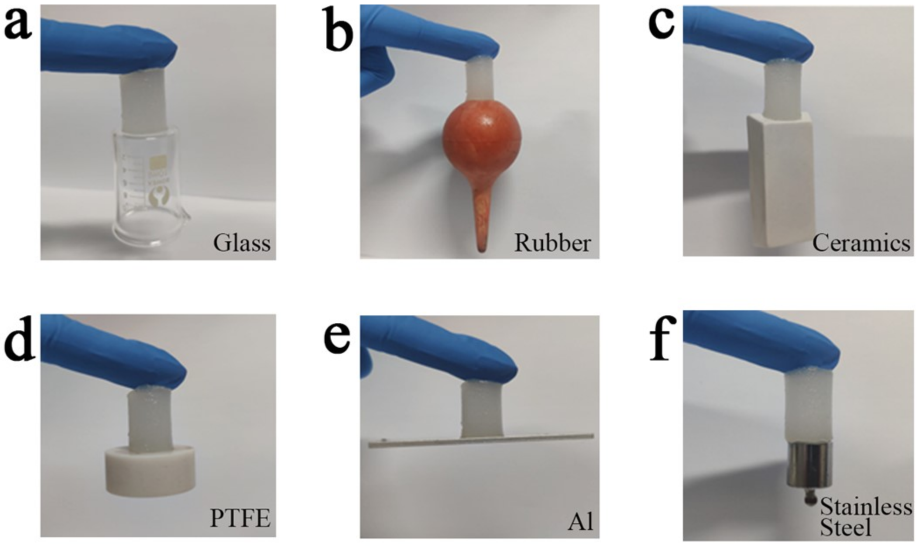

Fig S3. Hydrogels adhered to various materials (a) glass, (b) rubber, (c) ceraics, (d) PTFE, (e) Al, (f) stainless steel.

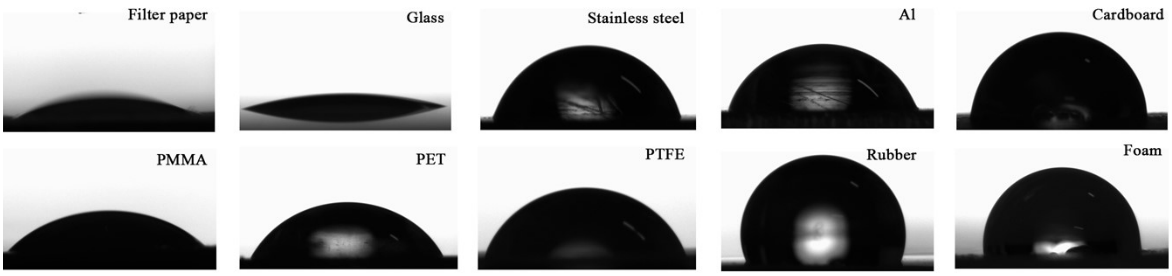

Fig S4. Contact angel of water droplet on different substrates

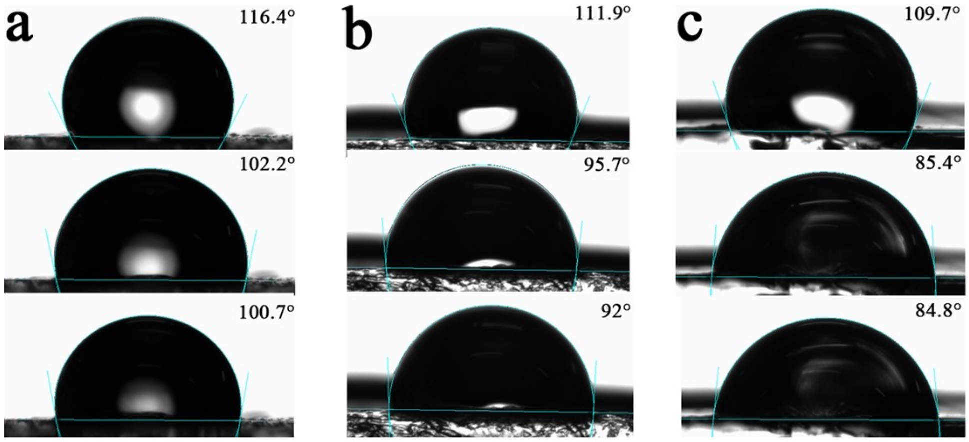

Fig S5. Change of contact angles of water at 0 second, 10 seconds and 15 seconds for different hydrogel, (a) $PSH_{2\text{-}8}$, (b) $PSH_{4\text{-}6}$, (c) $PSH_{6\text{-}4}$.

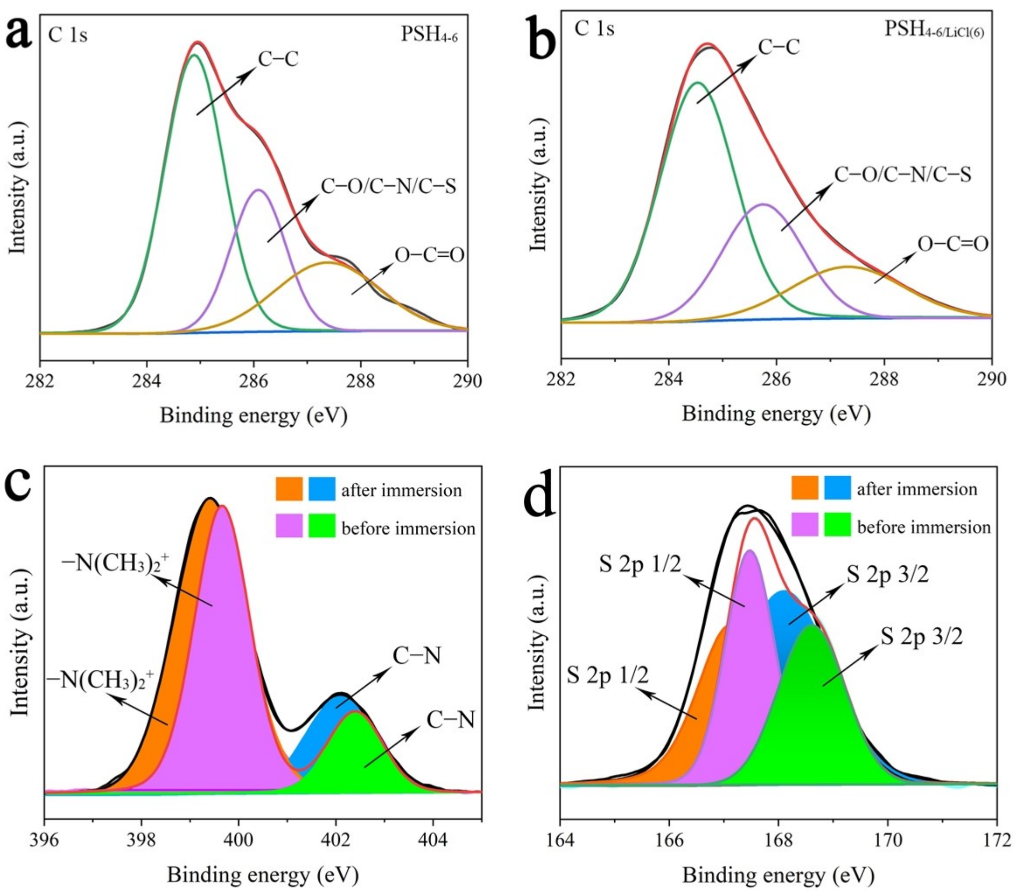

Fig S6. C 1s spectra of (a) $PSH_{4\text{-}6}$ and (b) $PSH_{4\text{-}6/LiCl(6)}$. (c) N 1s and (d) S 2p spectra of $PSH_{4\text{-}6}$ and $PSH_{4\text{-}6/LiCl(6)}$ for comparison.

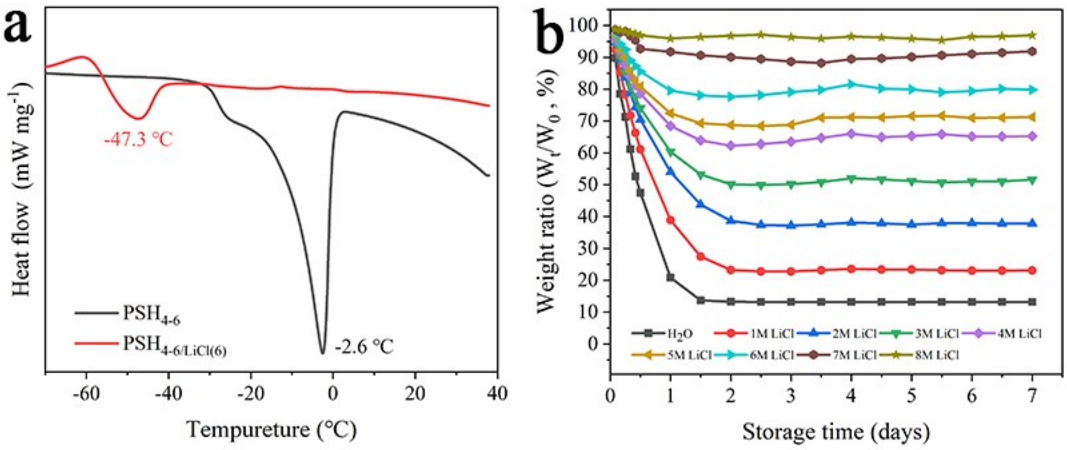

Fig S7. (a) DSC results of PSH_{4-6} hydrogel without and with 6 M LiCl. (b) Water loss rate of PSH_{4-6} hydrogels after immersing in different concentrations of LiCl solution at room temperature.

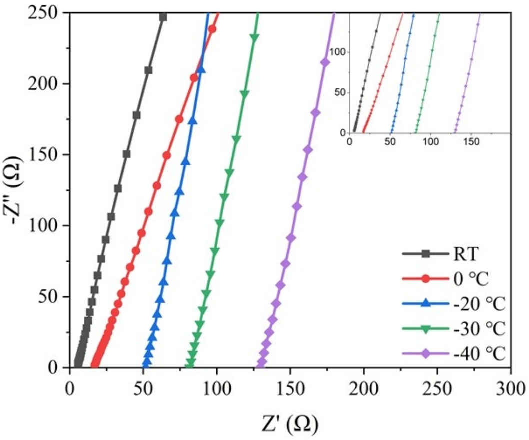

Fig S8. The EIS curves of $PHEAA_{/LiCl(6)}$ hydrogels at different temperatures.

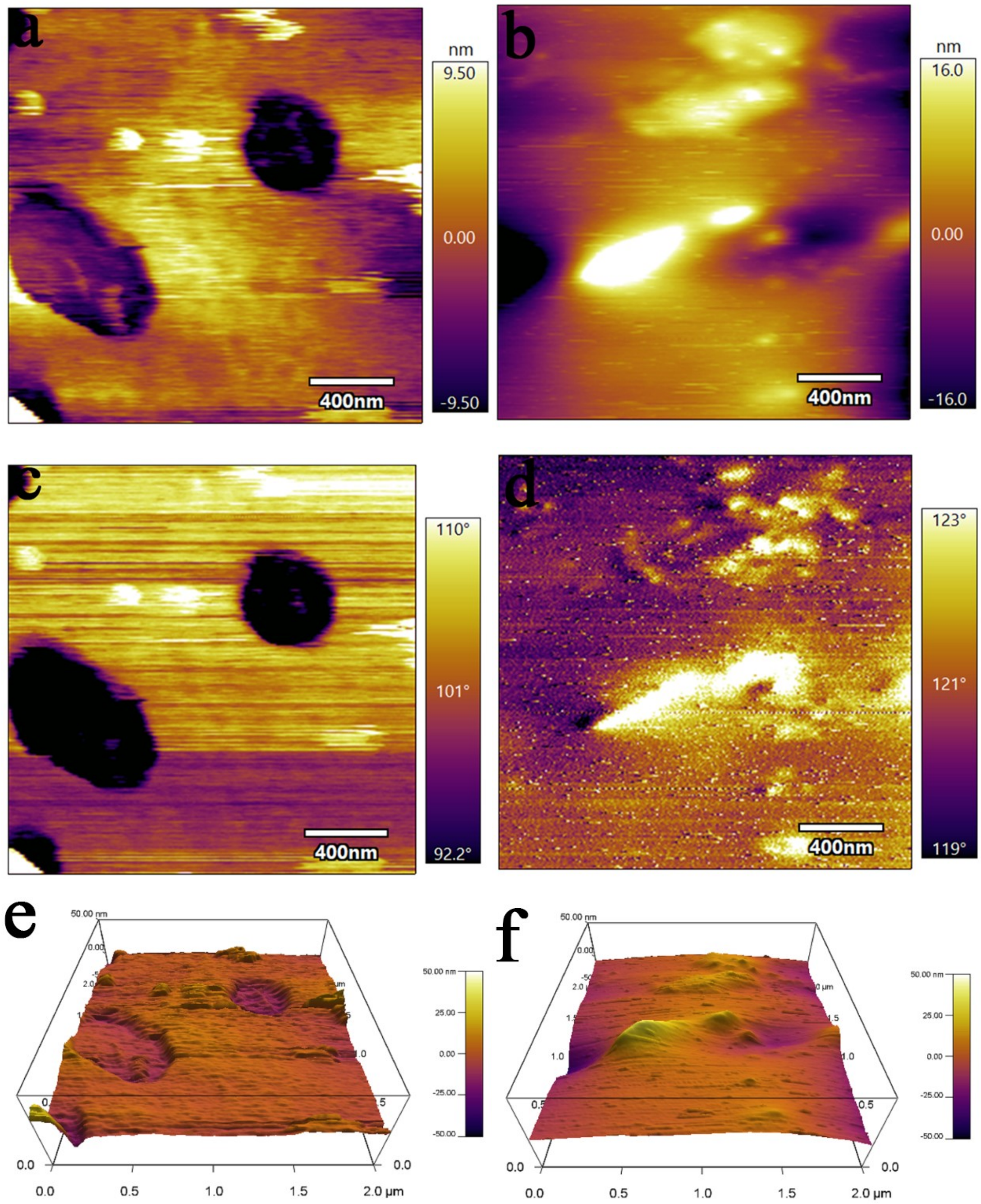

Fig S9. In-situ AFM graph of PSH$_{4-6}$ hydrogel without/with 6 M LiCl at the same location. The height retrace (a), phase retrace (c) and 3D images (e) of PSH$_{4-6}$ hydrogel. The corresponding graph of PSH$_{4-6/LiCl(6)}$ ((b) (d) (f)).

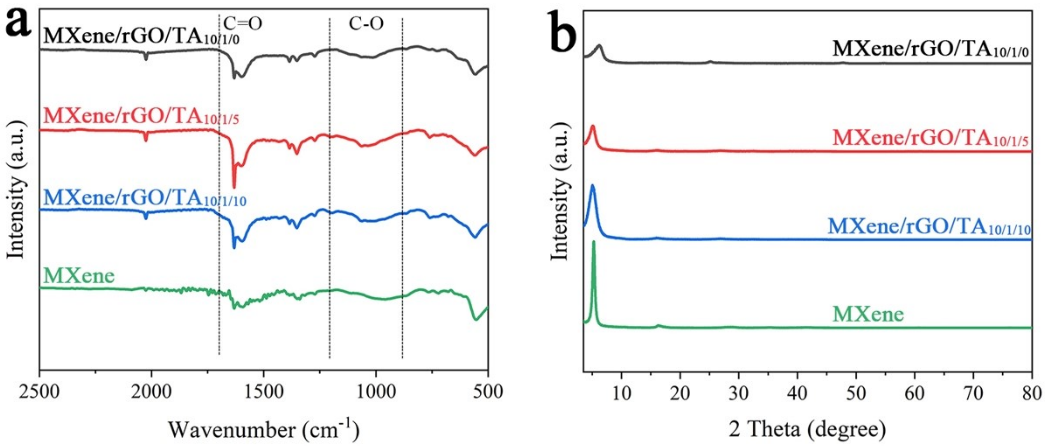

Fig S10. (a) FITR spectra and (b) XRD spectra of $Ti_3C_2T_X$/rGO/TA composite films.

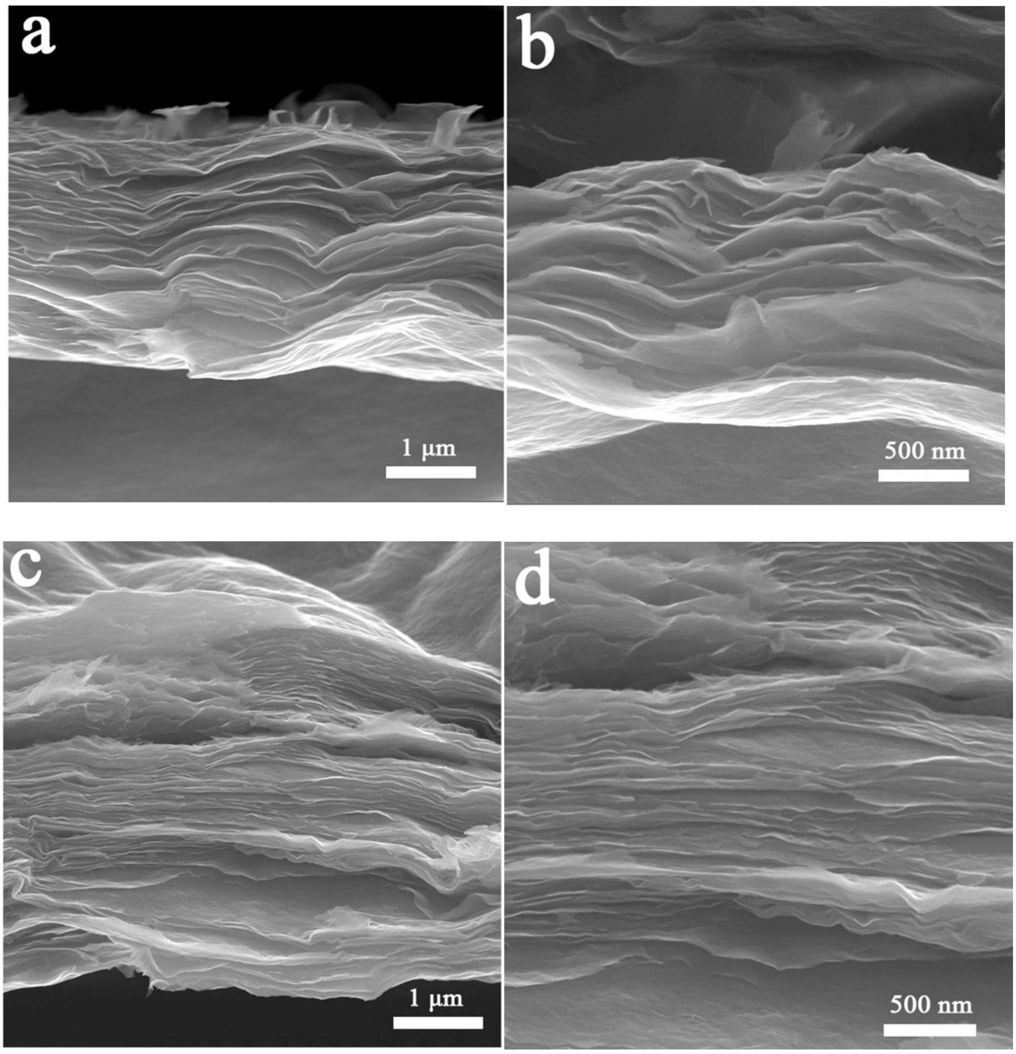

Fig S11. SEM images of $Ti_3C_2T_X$/rGO/$TA_{10/1/0}$ (a and b), $Ti_3C_2T_X$/rGO/$TA_{10/1/5}$ (c and d).

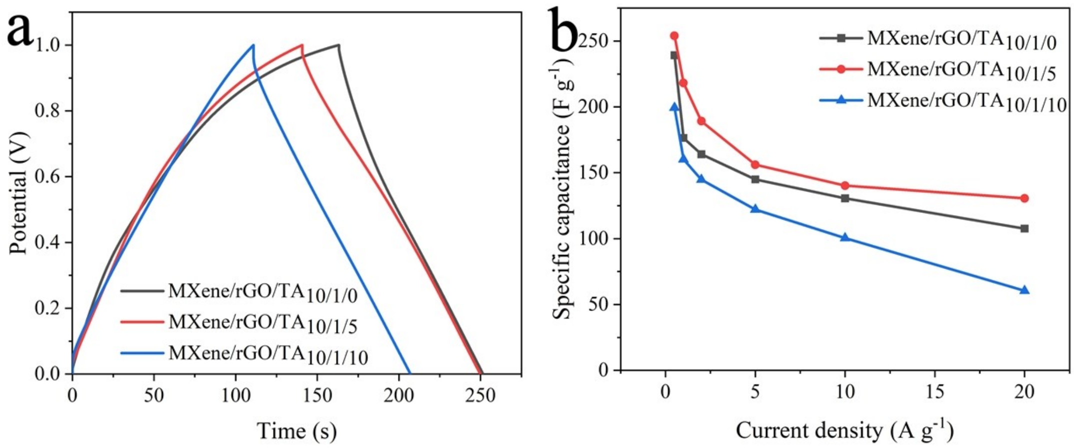

Fig S12. Electrochemical properties of supercapacitor constructed with as-prepared film. (a) GCD curves at a current density of 1 A g^{-1}. (b) Specific capacitance versus different current densities (1-20 A g^{-1})

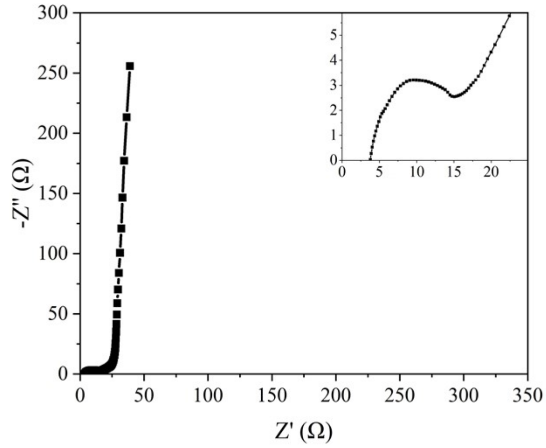

Fig S13. The EIS curves of flexible supercapacitors at room temperature.

Table S1. Different molar ratio hydrogels S 2p XPS data

Sample	S 2p 1/2	S 2p 3/2	Area ratio
$PSH_{2\text{-}8}$	167.64 (eV)	168.79 (eV)	1.054
$PSH_{4\text{-}6}$	167.47 (eV)	168.61 (eV)	1.135
$PSH_{6\text{-}4}$	167.33 (eV)	168.47 (eV)	1.326
SBMA	167.18 (eV)	168.38 (eV)	1.553
$PSH_{4\text{-}6/LiCl(6)}$	167.15 (eV)	168.20 (eV)	0.756

Table S2. Summary of ionic conductivity of different conductive hydrogel at room temperature.

Components	Conducting ions	Conductivity (S m^{-1})	Refs
SBMA-HEA	LiCl	14.6	1
SBMA-PAM	NaCl	3.674	2
SBMA-CNF	$ZnSO_4$	2.46	3
SBMA-PVA-PAM	$ZnCl_2$	1.57	4
PVA-Thioctic acid	$AlCl_3$	~0.23	5
TBOT-BA	LiTFSI	0.134	6
PAMPS-PAAm	LiCl	2.29	7
PVA-CNF	NaCl	3.2	8
PAMPS-MC	KOH	10.5	9
PAO/PEI	KOH	22.35	10
PVA/glycerol	CH_3COONa	8.127	11
SBMA-HEAA	LiCl	25.8	Our Work

Table S3. Summary of antifreezing hydrogel electrolytes and supercapacitors

Electrode material	Electrolyte components	Conductivity (S m^{-1})	Capacitance	Refs
Activated carbon	SBMA-HEA/LiCl	1.26 at -40℃	134 mF cm^{-2} at -30℃	12
Activated carbon	SBMA-AA/$ZnCl_2$	1.56 at -60℃	~50 F g^{-1} (0.5 A g^{-1}) at -60℃	13
Activated carbon	SBMA-AM/EG	0.151 at -50℃	62 F g^{-1} (62.5 mA g^{-1}) at -50℃	14
Activated carbon	SBMA-AM-AMPS	3.4 at room temperature	12.5 F g^{-1} (0.5 A g^{-1}) at -10℃	15
Carbon nanotubes	PVA/P(SBMA-AM)/ $CaCl_2$	0.28 at -40℃	-	16
-	SBMA-AM-PVA/LiCl	7.95 at -45.3℃	-	17
Polypyrrole	MMT-AM/$EMIMBF_4$	0.518 at -30℃	~35 mF cm^{-2} at -30℃	18
Polyaniline	PVA/H_2SO_4/Glycerol	1.71 at -40℃	268 mF cm^{-2} at -20℃	19
Graphene	VC-PVA PEDOT:PSS/EG	4.0 at -30℃	212.6 F g^{-1} (0.1 A g^{-1}) at -20℃	20
Activated carbon	HPC/PVA/ Glycerol/$LiClO_4$	0 .57 at -40℃	143.6 F g^{-1} (2 A g^{-1}) at -40℃	21
Graphene	PVA/EG/$Zn(Tf)_2$	0.353 at -40℃	202.8 F g^{-1} (0.2 A g^{-1}) at -20℃	22
Activated carbon	Carrageenan-PVA/EG	3.18 at -40℃	113.6 F g^{-1} (3 A g^{-1}) at -40℃	23
Activated carbon	Carrageenan-AM/LiCl/KCl	1.9 at -40℃	73.4 F g^{-1} (1 A g^{-1}) at -40℃	24
Activated carbon	PAMPS-AM/EG	0.1 at -30℃	55.5 F g^{-1} (1 A g^{-1}) at -20℃	25
Activated carbon	Silk backbone/ EG/ChCl/$ZnCl_2$	0.363 at -20℃	242.9 F g^{-1} (0.2 A g^{-1}) at -18℃	26
$Ti_3C_2T_X$/rGO/TA	SBMA-HEAA/LiCl	2.21 at -40℃	133 F g^{-1} (0.5 A g^{-1}) at -40℃	Our Work

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