Supplementary Information (SI) for Journal of Materials Chemistry A.

Supplementary Materials

Janus-Structured MXene Composite Films with Tannic Acid–Enhanced Strength and Environmentally Stable Electromagnetic Interference Shielding

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1 Preparation of aramid nanofiber (ANF) dispersion

ANF dispersion was obtained through the deprotonation and disintegration of macroscopic PPTA fibers. Specifically, 1.0 g of PPTA fibers and 1.5 g of KOH were added to 250 mL of DMSO. To facilitate the deprotonation process, a controlled amount of deionized water (DI) was introduced into the PPTA/KOH/DMSO suspension, followed by magnetic stirring at 35 °C for 4 h, resulting in a homogeneous dark red ANF dispersion. The resulting mixture was then thoroughly washed with excess DI water to remove residual KOH and DMSO. Finally, the purified ANF was re-dispersed in DI water to yield a uniform aqueous ANF dispersion.

2 Preparation of MXene nanosheet

$Ti_3C_2T_x$ MXene nanosheets were synthesized via selective etching of Ti_3AlC_2 powders in a LiF/HCl solution system. Specifically, 2.4 g of LiF and 1.5 g of Ti_3AlC_2 were added to 30 mL of 9 mol/L HCl and stirred at 35 °C for 48 h. The resulting mixture was subsequently washed repeatedly with deionized water (DI) and centrifuged at 3500 rpm until the pH approached 6. The exfoliated MXene nanosheets were then obtained by ultrasonic treatment of the sediment, followed by centrifugation at 4000 rpm for 1 h. Finally, MXene aqueous dispersions with a concentration of 5 mg/mL were prepared by dilution with DI water.

3 Formulas

The total (SE_T), reflection (SE_R), absorption (SE_A), and multiple internal reflections (SE_M) EMI shielding effectiveness, as well as the loss coefficients of reflection (R), transmission (T), and absorption (A), were calculated using the following equations:

$$R = |S_{11}|^2, T = |S_{21}|^2 \quad (1)$$

$$R + T + A = 1 \quad (2)$$

$$SE_R = -10log(1 - R) \quad (3)$$

$$SE_A = -10log\left(\frac{T}{1 - R}\right) \quad (4)$$

$$SE_T = SE_R + SE_T + SE_M \quad (5)$$

where the SE_M is considered negligible when the SE_T exceeds 10 dB.

To further compare the shielding performance of the materials, the EMI *SE* was normalized to eliminate the effects of thickness and density. The specific shielding effectiveness (*SSE*/t) is defined as follows:

$$SSE/t = \frac{SE_T}{density * thickness} \tag{6}$$

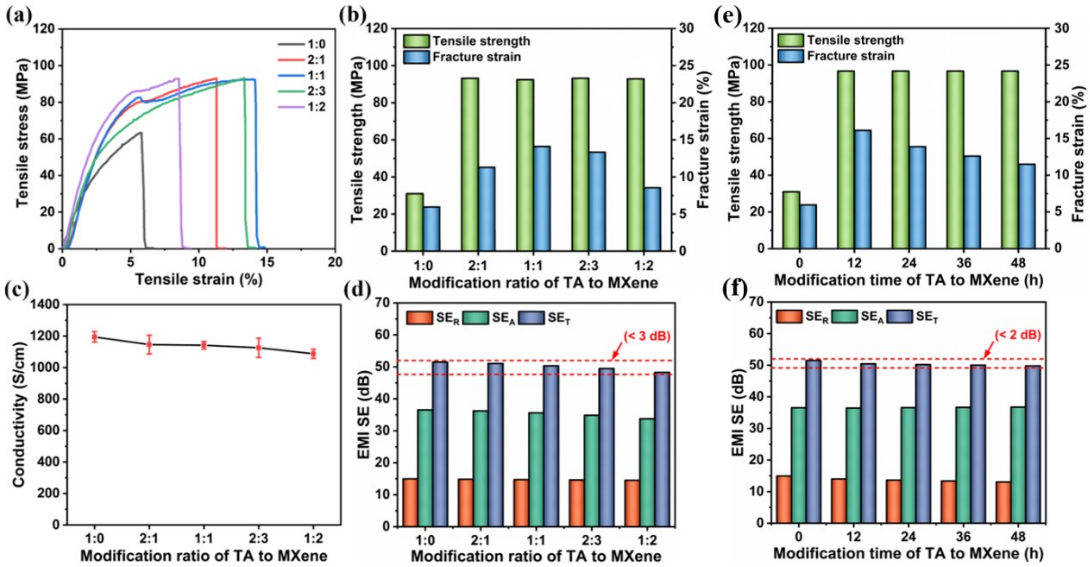

Fig. S1 The effect of TA-MXene ratio, modification time on different properties of MXene film.

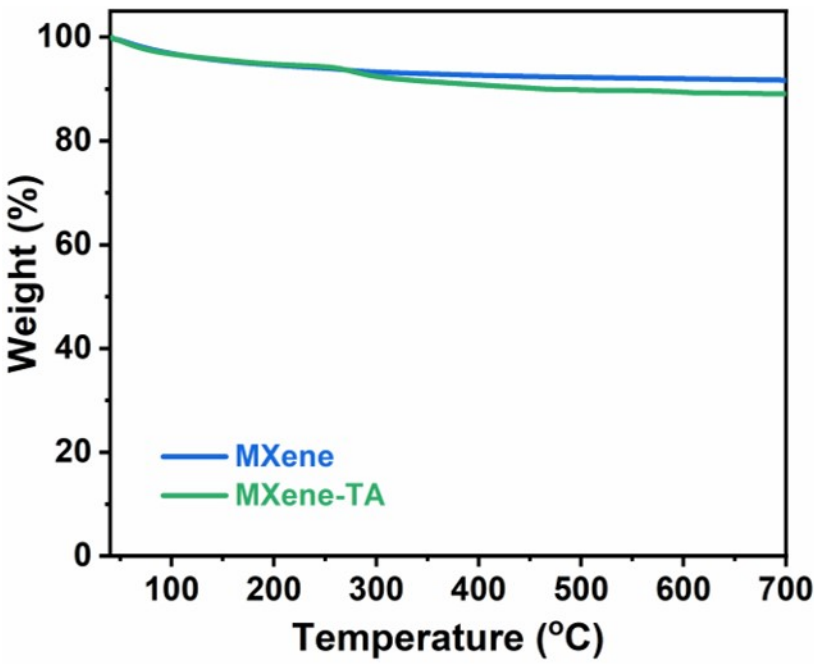

Fig. S2 TGA curves of MXene and MXene-TA.

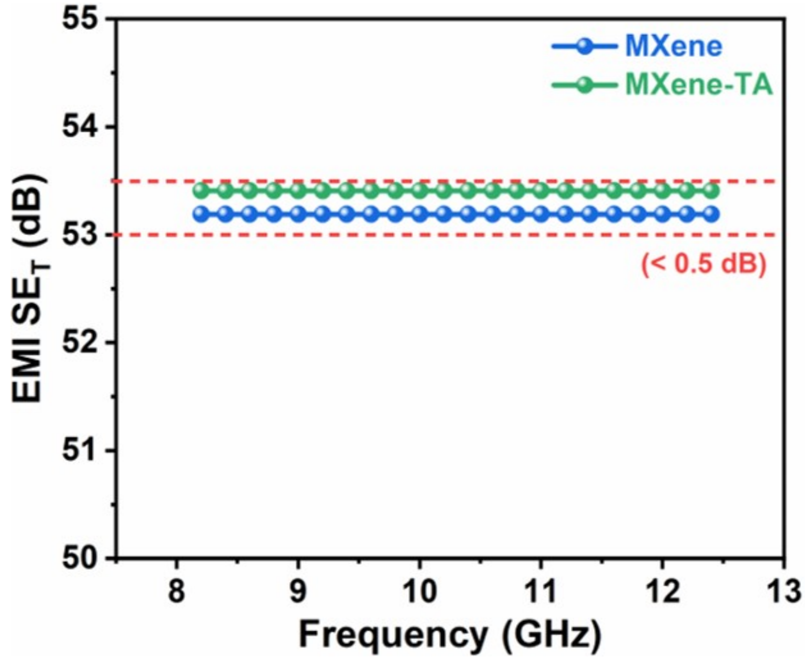

Fig. S3 EMI SE$_T$ values for MXene and MXene-TA.

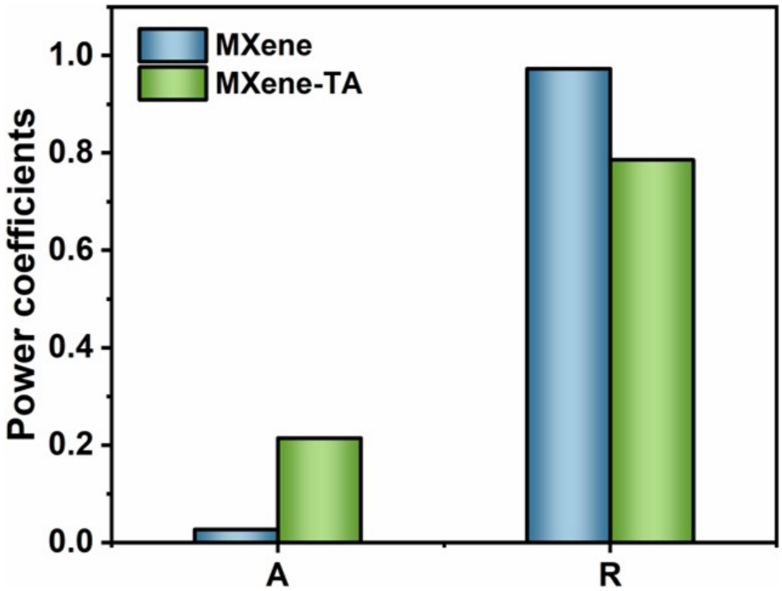

Fig. S4. Loss coefficients of MXene and MXene-TA.

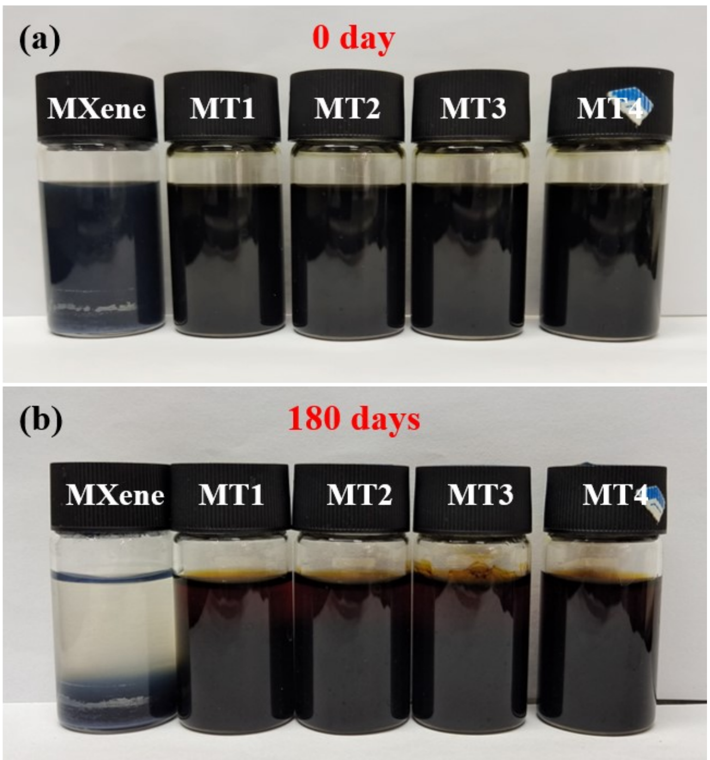

Fig. S5 Comparison of aqueous dispersions of MXene and MXene-TA after 180 days of storage (MT1, MT2, MT3, and MT4 corresponded to the dispersions with the mass ratios of TA to MXene of 2:1, 1:1, 2:3, and 1:2).

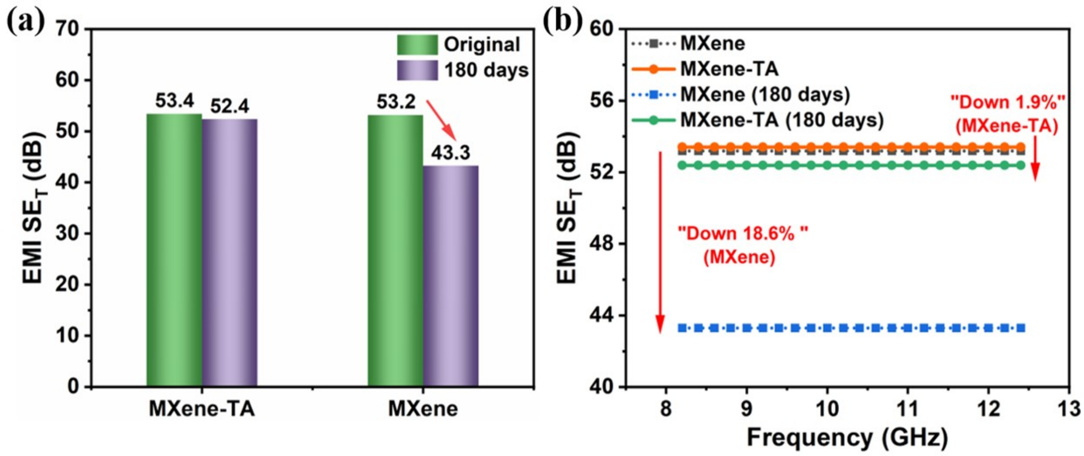

Fig. S6 Comparison of EMI SE_T values before and after 180 days of storage for MXene and MXene-TA.

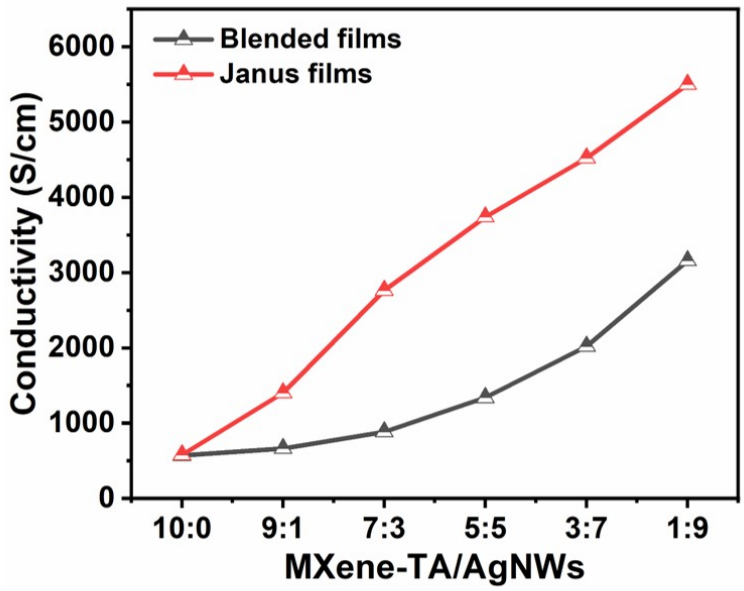

Fig. S7 Comparison of electrical conductivity of blended and Janus structured composite films.

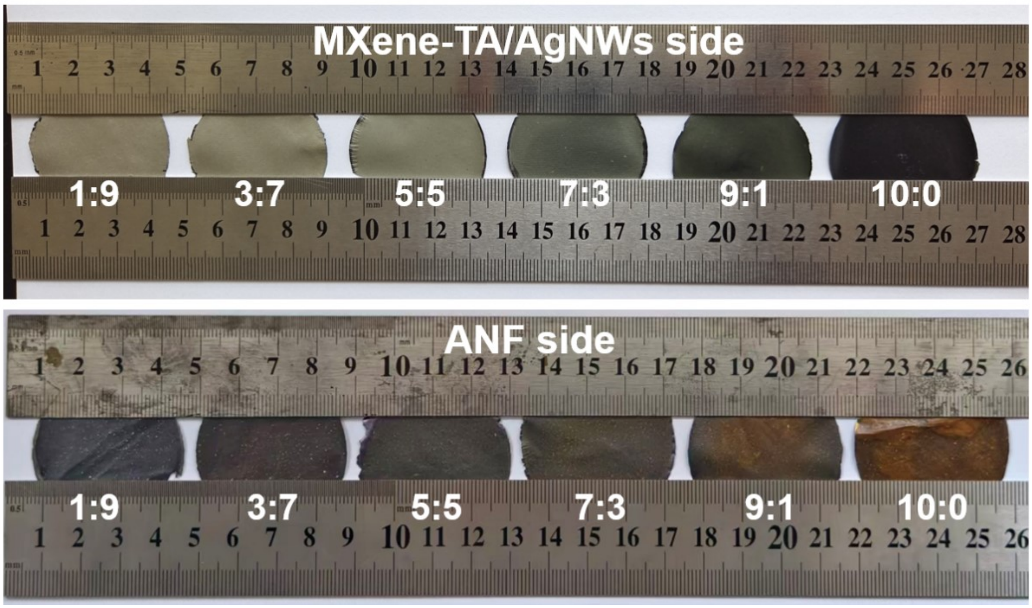

Fig. S8 Optical photographs of both sides of the Janus-structured composite film at different MXene-TA/AgNWs ratios.

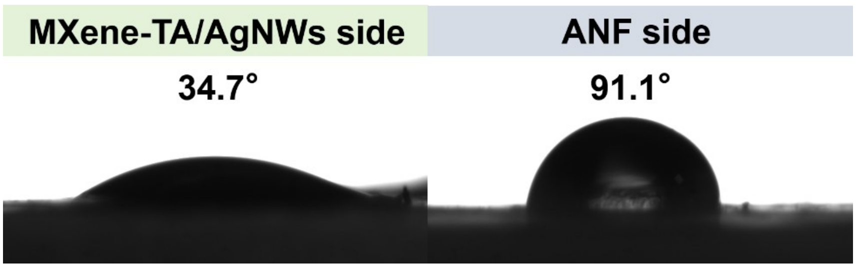

Fig. S9 The contact angle image on both sides of the Janus-structure composite membrane at a ratio of MXene-TA/AgNWs of 1:9.

Table. S1 Sample names and composition of MXene-TA/AgNWs/ANF composite films.

Materials	ANF（mg）	MXene-TA（mg）	AgNWs（mg）
MT/$Ag_{10:0}$	20	30	0
MT/$Ag_{9:1}$	20	27	3
MT/$Ag_{7:3}$	20	21	9
MT/$Ag_{5:5}$	20	15	15
MT/$Ag_{3:7}$	20	9	21
MT/$Ag_{1:9}$	20	3	27

Note: ANF concentration was 1 mg/mL, MXene-TA concentration was 5 mg/mL, and AgNWs concentration was 1 mg/mL.

Table. S2 Comparison of EMI shielding performance and SSE/t value of J-MTAgA composite films and other EMI shielding materials.

Materials	Thickness (mm)	EMI SE_T (dB)	SSE/t ($dB \cdot cm^2 \cdot g^{-1}$)	Ref.
MXene	0.76	75	9904	1
ANF/GN	2	31.55	3878.78	2
GnP/ANF	0.021	47	11060	3
CNT/Fe_3O_4	0.09	91	1176	4
MXene/CNF	0.05	50	9177	5
CNF/MXene	0.035	40	7029	6
Cotton/MXene	1.36	25.23	2301.95	7
BF/ANF/CNT	0.048	24.6	12504	8
MXene@AgFDs	0.055	69	12500	9

GF/MXene/ANF	0.1	41	3818	[10]
Ag/MXene/ANF	0.34	62	11923	[11]
Elastomer/MXene	1	49	392	[12]
PANI/MXene/CF	0.55	26	2463.64	[13]
PE@PET/MXene	0.058	50.44	10606	[14]
MXene/CNT/ANF	2	69	8060.7	[15]
MXene/(ANF/PVA)	0.12	70	13790	[16]
CNF/MXene/AgNWs	0.026	46.65	10543.18	[17]
WPU/MXene/$NiFe_2O_4$	0.04	64.7	15620	[18]
MXene/CuNWs/ANF	0.043	46.67	9120.6	[19]
MXene/CMC-Na	0.2	45.8	11595	[20]
h-MXene/ANF	0.12	78.9	15703	[21]
MXene/h-AgNWs/ANF	0.093	88.2	18160	[22]
MXene-TA/AgNWs/ANF	0.03	90.5	21611	This work

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