Supplementary Information (SI) for Nanoscale.

Supporting Information

Shape memory composite membrane with widely programmable electromagnetic shielding effectiveness

Zhiyong Zeng[a], Jv Li[a], Chuanru Zheng[b], Hongmei Chen[b], Gang Liu[c], Jian Huang[d], Kun Qian[a], Fenghua Zhang[e] and Wenbing Li[a,*]

[a] College of Textile Science and Engineering, Jiangnan University, Wuxi 214122, P. R. China

[b] College of Chemistry and Materials Science, Sichuan Normal University, Chengdu 610066, P. R. China

[c] Department of Engineering Graphics and Software, East China Jiaotong University, Nanchang 330013, P. R. China

[d] Nanjing Fiberglass Research & Design Institute Co., Ltd, Nanjing 210012, P. R. China

[e] Centre for Composite Materials and Structures, Harbin Institute of Technology (HIT), Harbin 150080, P. R. China

[*] Corresponding author. E-mail address: wenbingli@jiangnan.edu.cn

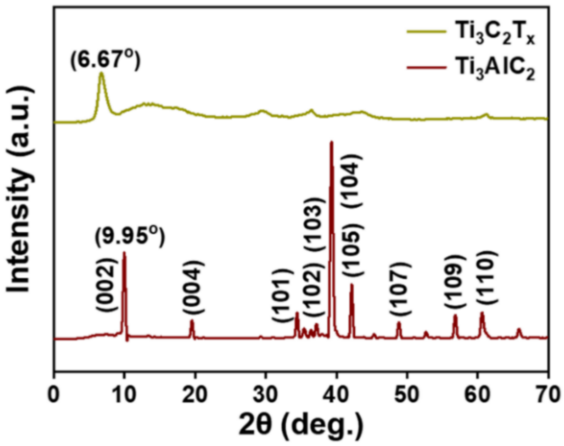

Fig. S1. XRD patterns of MXene before and after etching.

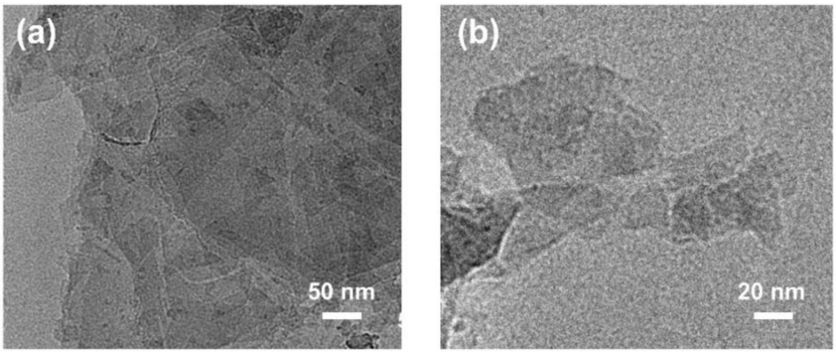

Fig. S2. (a, b) TEM images of etched MXene at different magnifications.

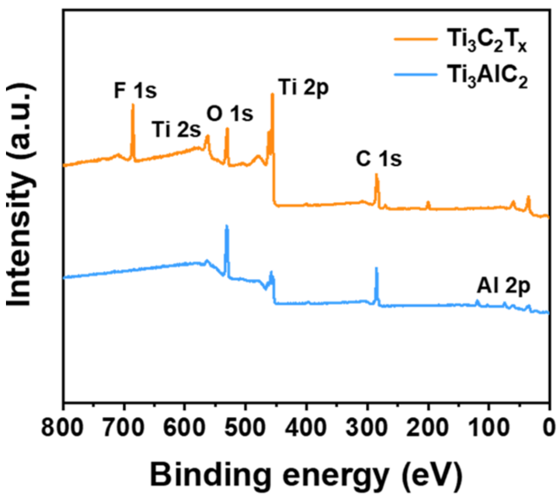

Fig. S3. XPS survey spectra of Ti_3AlC_2 and exfoliated $Ti_3C_2T_x$.

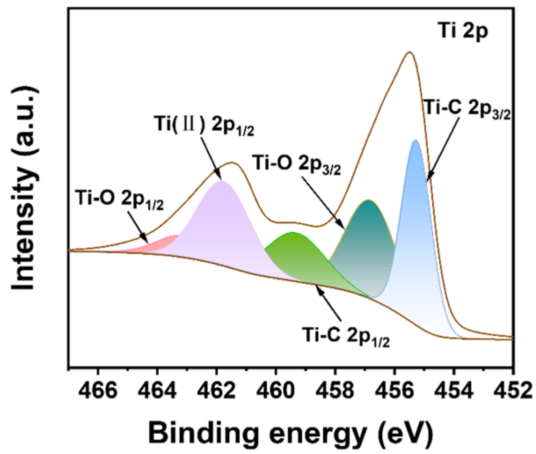

Fig. S4. High-resolution Ti 2p spectra of MXene.

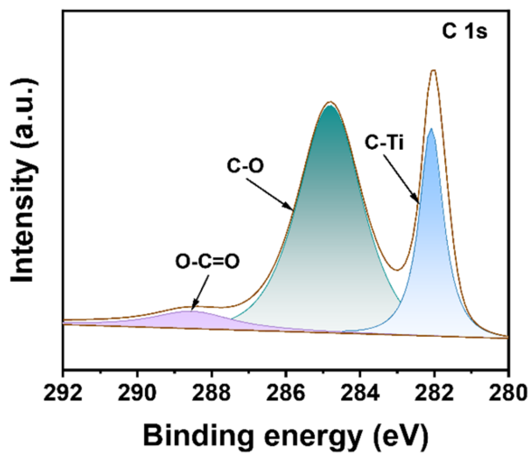

Fig. S5. High-resolution C 1s spectra of MXene.

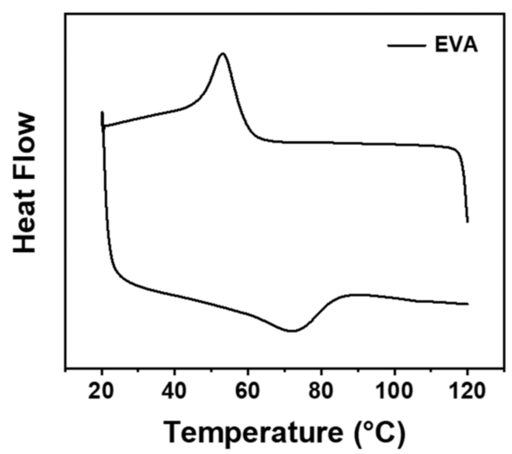

Fig. S6. DSC curves of EVA fiber membrane.

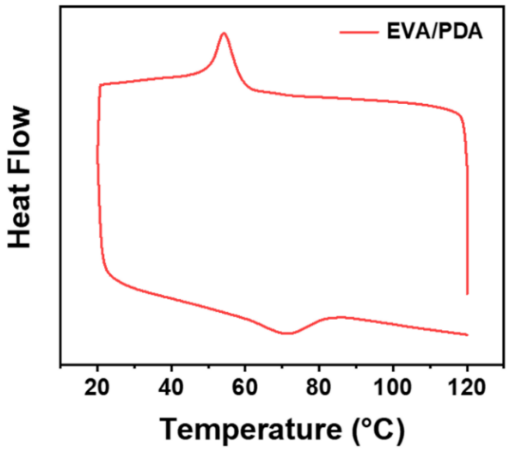

Fig. S7. DSC curves of EVA/PDA composite membrane.

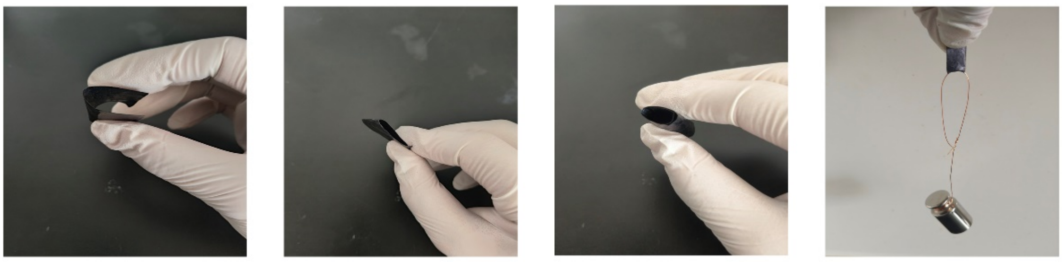

Fig. S8. Digital images of EVA/PDA/MXene-30-6 composite membrane during bending, folding, curling, and lifting a 100 g weight.

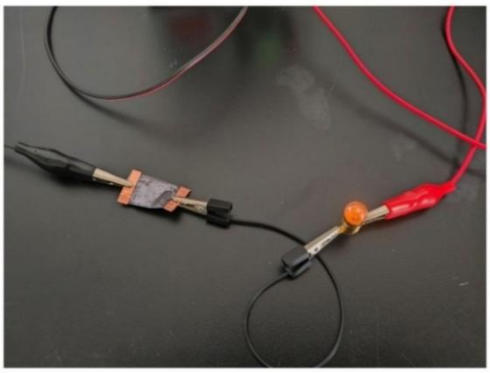

Fig. S9. Digital image of EVA/PDA/MXene-30-6 composite membrane lighting up a small bulb.

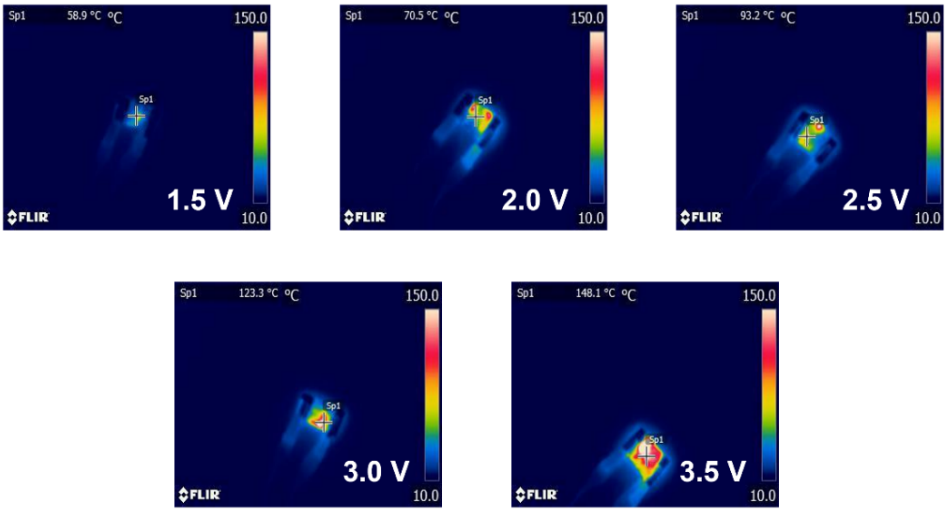

Fig. S10. Thermal infrared images of the EVA/PDA/MXene-30-6 composite membrane driven by different voltages.

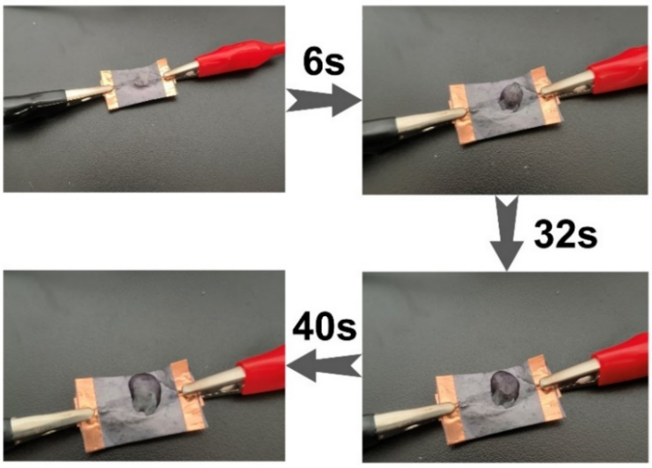

Fig. S11. De-icing process of EVA/PDA/MXene-30-6 composite membrane.

Table S1. The comprehensive comparative analysis of MXene-based electromagnetic shielding materials versus traditional electromagnetic shielding materials [1-7].

	MXene-based electromagnetic shielding materials	**Traditional electromagnetic shielding materials**
cost	Relatively high, but expected to decrease with technological advancements and large-scale production	The costs of materials such as metallic copper and aluminum are relatively low, and their supply chains are mature. The costs of materials like conductive polymers vary depending on their type and performance, but they are generally competitive
weight	Extremely low, with significant advantages	Metallic copper, aluminum, and other such materials are relatively heavy, whereas conductive polymers and similar materials are relatively lighter, but they may still fail to meet extremely high lightweight requirements
shielding effectiveness	Excellent, with high specific surface area and high electrical conductivity, and the specific shielding effectiveness depends on the MXene content and composite method	Metallic copper, aluminum, and other such materials achieve shielding by reflecting electromagnetic waves, with limited absorption capacity in high-frequency bands or specific absorption requirements. The shielding effectiveness of materials like conductive polymers varies depending on their type and performance, and usually requires increasing thickness or compositing to enhance the effect

Table S1 (Continued)

	MXene-based electromagnetic shielding materials	Traditional electromagnetic shielding materials
shielding mechanism	Involving multiple mechanisms such as absorption, reflection, and scattering, the shielding mechanism can be optimized by compositing different materials	Metallic copper, aluminum, and other such materials primarily shield through reflection mechanisms, whereas conductive polymers and similar materials exhibit diverse mechanisms that may include the formation of conductive networks, scattering, and absorption
stability	Easily oxidized in air, but stability can be improved through compositing and surface modification; stability in extreme environments requires further research	Metallic copper, aluminum, and other such materials are stable at room temperature, but may corrode or experience performance degradation in high-temperature and high-humidity environments; the stability of materials such as conductive polymers varies depending on their type and performance, and may require the addition of stabilizers or surface treatment
other factors	It exhibits good processability and design flexibility, holding promising application prospects in fields such as flexible electronic devices and wearable electronics	Metallic copper, aluminum, and other such materials have good processability but poor flexibility; whereas materials like conductive polymers exhibit good flexibility but may have limited processability, and their electrical conductivity may be unstable

Table S2. The electromagnetic shielding performance of the composite fiber membrane developed in this study was compared with that of traditional electromagnetic shielding materials [1-7].

Filler	Matrix	Loading	SE (dB)	d (mm)	Ref.
Cu、Ni	MG	20 mg/ml	35	0.02	[1]
Cu、Ni	PDMS	15 mg/ml	35.4	2	[2]
Cu	PES	/	59.7	0.3	[3]
Cu、Ag	PLA	8.7 vol%	101.8	0.5	[4]
CNT、Ag	PSA、PU	2 mg/ml	90.5	/	[5]
Ag	PDMS	1.69 mg/ml	75	/	[6]
PANI	PVDF	30 wt%	44.7	1.2	[7]
MXene	EVA	30 mg/ml	74.7	0.25	This work

Notes: MG–metallic glass; PDMS–polydimethylsiloxane; PES–polyether sulfone; PLA–polylactic acid; PSA–polysulfonamide; PU–polyurethane; PANI–polyaniline; PVDF–polyvinylidene fluoride.

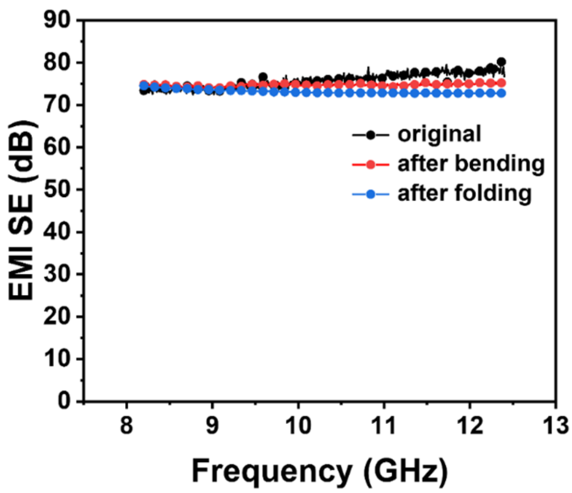

Fig. S12. Electromagnetic shielding effectiveness of the EVA/PDA/MXene-30-6 composite membrane after undergoing 100 cycles of bending and folding.

References

[1] Z. Ma, J. Li, J. Zhang, A. He, Y. Dong, G. Tan, M. Ning, Q. Man and X. Liu, *J. Mater. Sci. Technol*., 2021, **81**, 43-50.

[2] J. Huang, D. Sun, G. Li, X. Wang, H. Ma, W. Zhang, Z. Chen, H. Li and C. Gui, *Compos*. *Sci*. *Technol*., 2022, **228**, 109636.

[3] H. Zhao, Y. Huang, Y. Han, J. Yun, X. Wang, L. Jin, Y. Zheng and L. Chen, *Chem*. *Eng*. *J*., 2022, **440**, 135919.

[4] D. Kin, Y. Lee and K. Ahn, *Compos*. *Commun*., 2022, **30**, 101093.

[5] J. Wang, S. Zhang, R. Liu, Y. Zhang, X. Huang, X. Ning, G. Dou and J. Ming, *Sustain*. *Mater*. *Techno*., 2024, **41**, e01088.

[6] Q. Wang, S. Zhu, H. He, J. Du, W. Li, Z. Kang and D. Chen, *Prog*. *Org*. *Coat*., 2022, **169**, 106919.

[7] M. Chen, M. Li, Y. Gao, S. He, J. Zhan, K. Zhang, Y. Huo, J. Zhu, H. Zhou, J. Fan, R. Chen and H. Wang, *Nano Lett*., 2024, **24**, 2643-2651.