Supporting Information for

In-Situ Atomic Reconstruction Engineering Modulating Graphene-Like MXene-Based Multifunctional Electromagnetic Devices Covering Multi-Spectrum

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Supplementary Figures and Tables

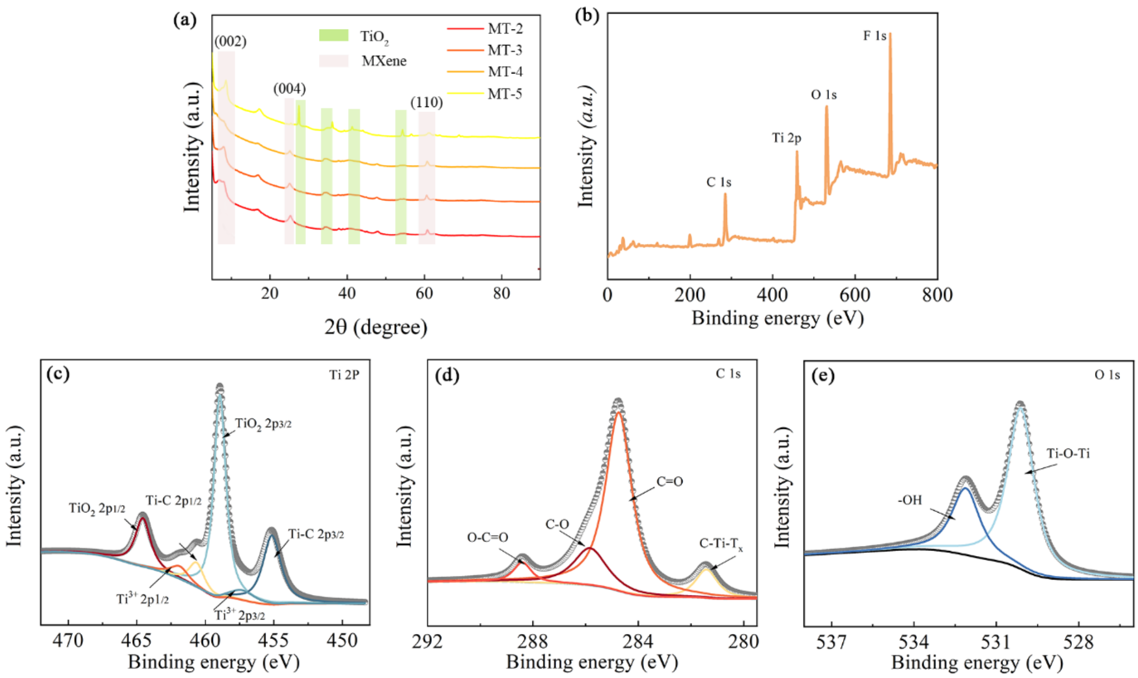

Fig. S1 a The XRD patterns of MT-2, MT-3, MT-4 and MT-5. **b** XPS wide scan (survey). High-resolution narrow scan on the **c** Ti 2*p*, C 1*s* **d**, and **e** O 1*s*, regions in the spectra

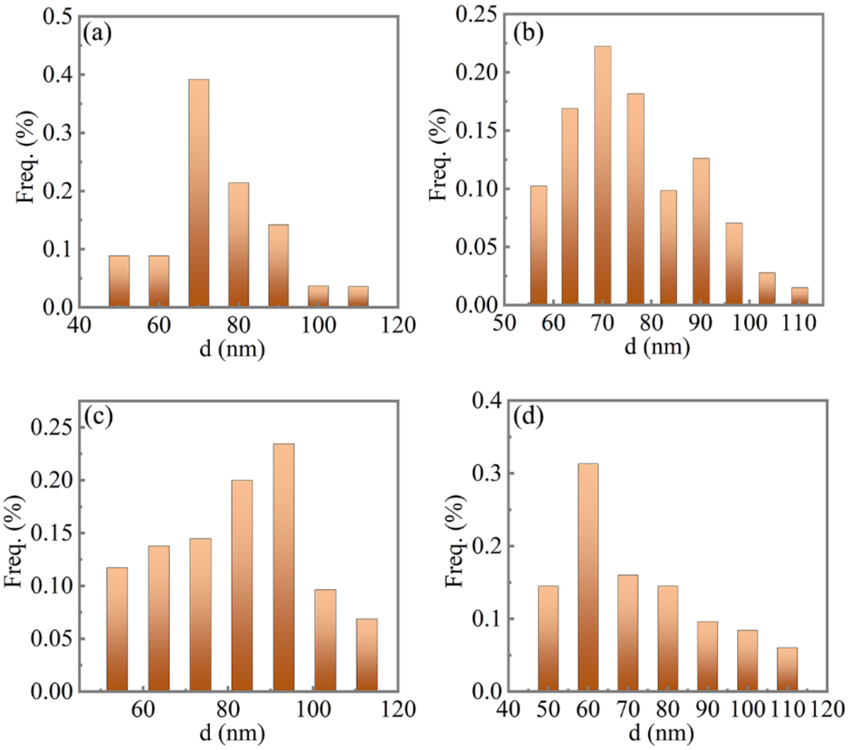

Fig. S2 TiO_2 particle size distribution map of **a** MT-2, **b** MT-3, **c** MT-4 and **d** MT-5

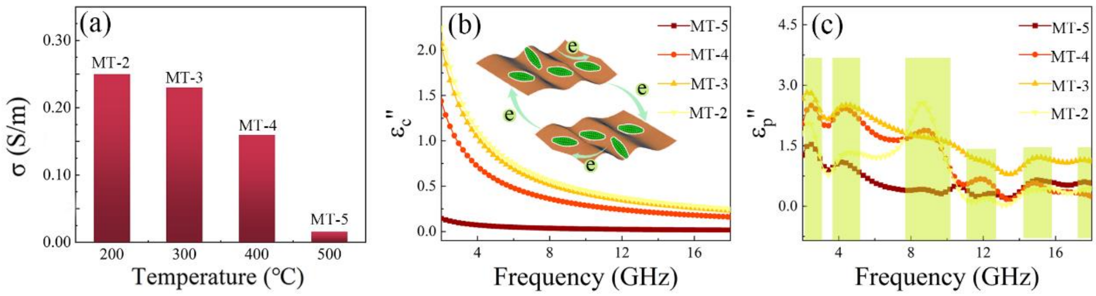

Fig. S3 a The conductivity of the MXene/TiO_2 hybrids with different calcination temperatures. **b** ε_c'' curves and **c** ε_p'' curves of MXene/TiO_2 hybrids versus frequency

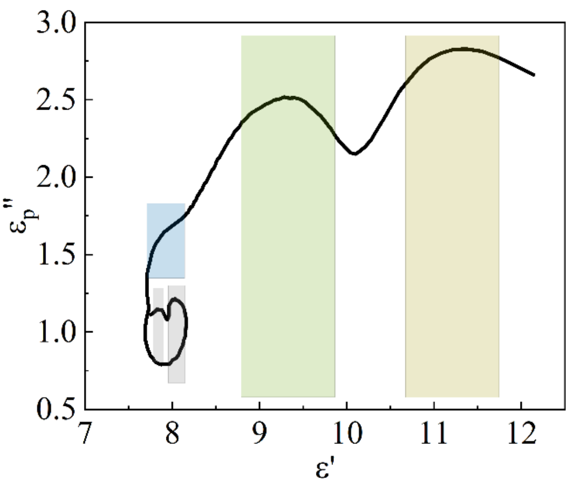

Fig. S4 Cole-Cole plots of MT-3

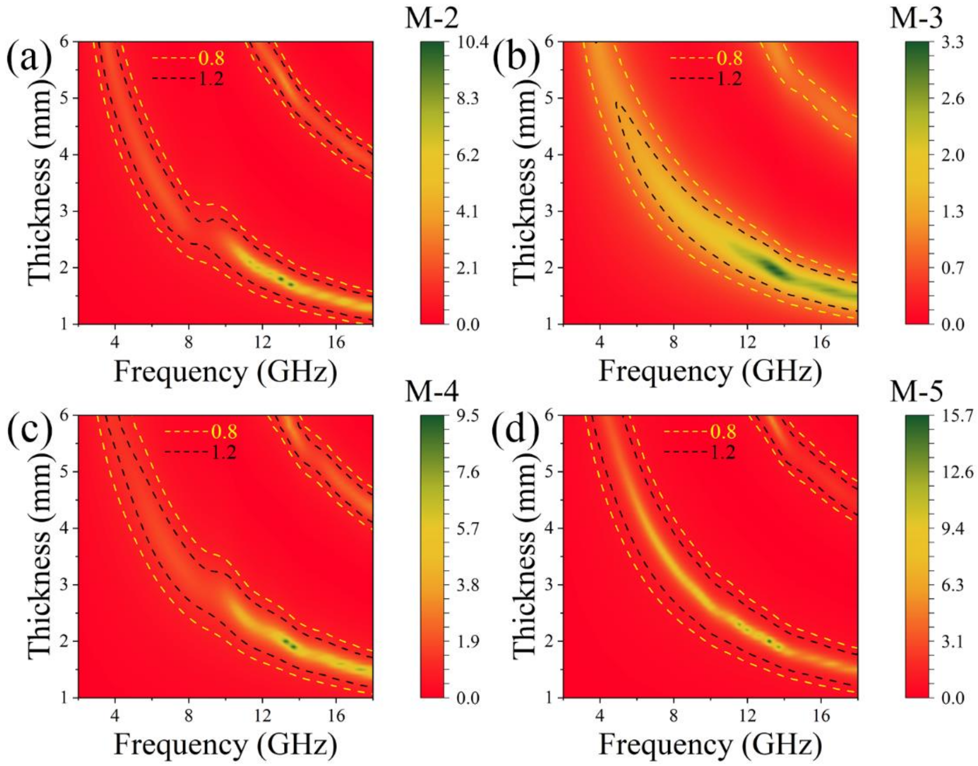

Fig. S5 Impedance matching of **a** MT-2, **b** MT-3, **c** MT-4 and **d** MT-5 versus frequency and thickness

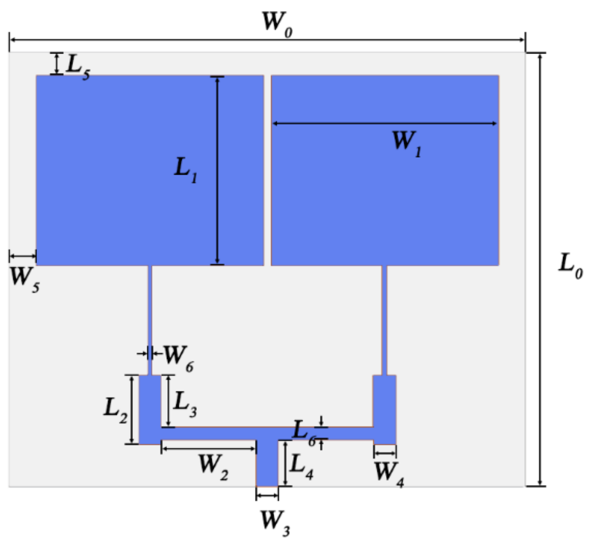

Fig. S6 The proposed 1 × 2 patch antenna array. The detailed dimensions of the four antennas are as follows: W_0 = 227.25 mm/69.00 mm/62.385 mm/55.00 mm, W_1 = 72.6 mm/29.00 mm/26.8 mm/24.2 mm, W_2 = 30.465 mm/12.18 mm/11.285 mm/10.155 mm, W_3 = 7.11 mm/2.84 mm/2.63 mm/2.37 mm, W_4 = 38.16 mm/4.32 mm/3.26 mm/2.345 mm, W_5 = 8.7 mm/3.5 mm/3.25 mm/2.9 mm, W_6 = 1.32 mm/0.53 mm/0.49 mm/0.415 mm, L_0 = 138.42 mm/55.355 mm/51.24 mm/46.14 mm, L_1 = 60.75 mm/24.24 mm/22.5 mm/20.25 mm, L_2 = 22.11 mm/8.84 mm/8.19 mm/7.37 mm, L_3 = 15.00 mm/6.00 mm/5.56 mm/5.505 mm, L_4 = 15.00 mm/6.00 mm/5.56 mm/5.00 mm, L_5 = 7.125 mm/2.88 mm/2.65 mm/5.275 mm, L_6 = 4.08 mm/1.63 mm/1.51 mm/1.36 mm. The thickness of copper radiation patch and ground plate is 0.018 mm

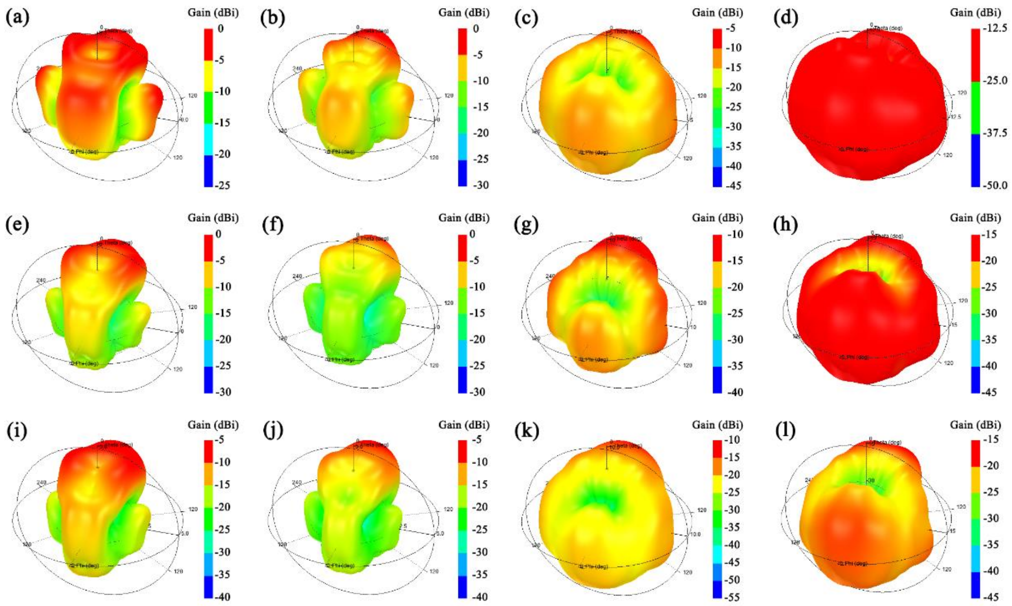

Fig. S7 The 3D radiation patterns of **a** MT-5, **b** MT-4, **c** MT-3, **d** MT-2 antenna with a substrate thickness of 0.4 mm. The 3D radiation patterns of **e** MT-5, **f** MT-4, **g** MT-3, **h** MT-2 antenna with a substrate thickness of 0.7 mm. The 3D radiation patterns of **i** MT-5, **j** MT-4, **k** MT-3, **l** MT-2 antenna with a substrate thickness of 1.0 mm

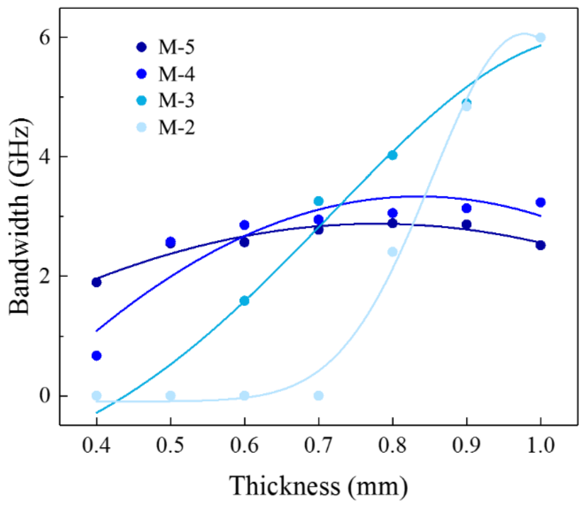

Fig. S8 The bandwidth of four antennas with different substrate thicknesses

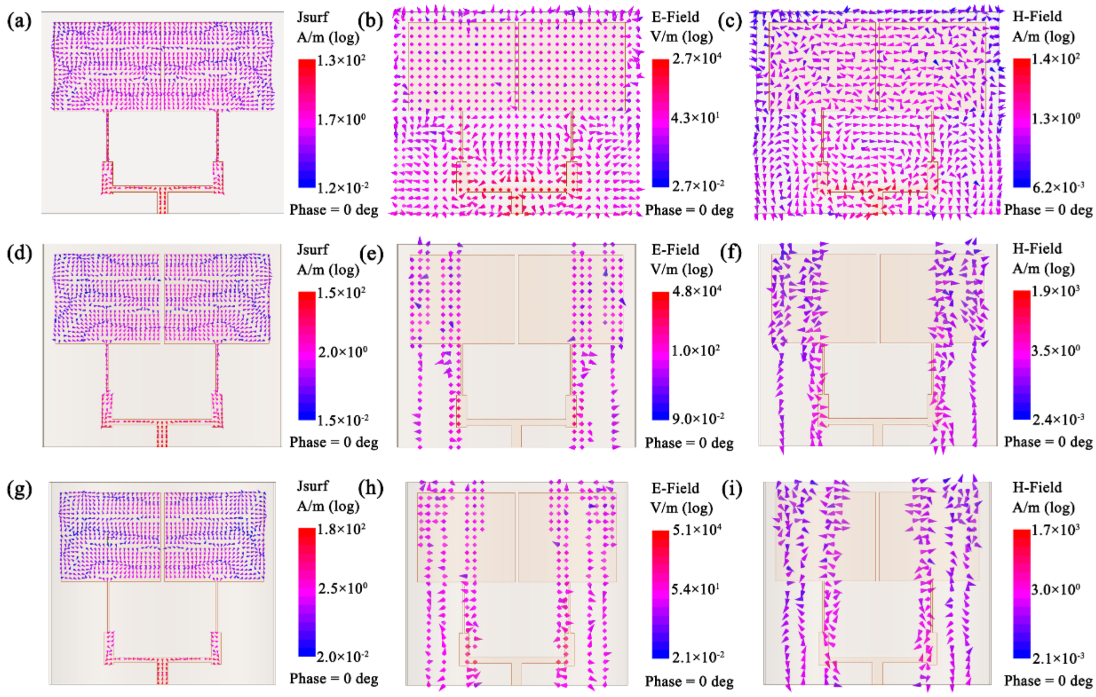

Fig. S9 a The surface current distribution, **b** E-field distribution, and **c** H-field distribution of unbending antenna at 15 GHz. **d** The surface current distribution, **e** E-field distribution, and **f** H-field distribution of bending antenna with R = 80 mm at 15 GHz. **g** The surface current distribution, **h** E-field distribution, and **i** H-field distribution of bending antenna with R = 40 mm at 15 GHz

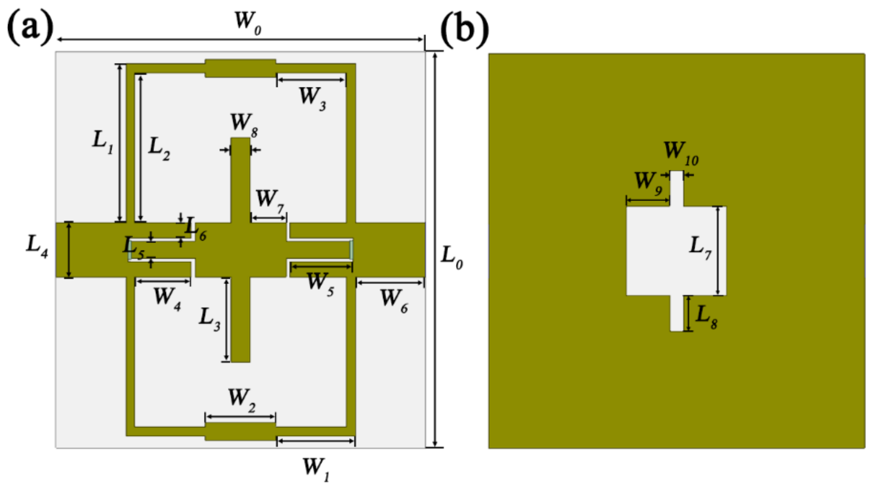

Fig. S10 a The top view and **b** bottom view of the UWB bandpass filter. The detailed dimensions of the bandpass filter are as follows: W_0 = 10.5 mm, W_1 = 2.26 mm, W_2 = 2.00 mm, W_3 = 2.01 mm, W_4 = 1.61 mm, W_5 = 1.80 mm, W_6 = 1.61 mm, W_7 = 1.03 mm, W_8 = 0.54 mm, W_9 = 1.21 mm, W_{10} = 0.38 mm, L_0 = 11.00 mm, L_1 = 4.42 mm, L_2 = 4.17 mm, L_3 = 2.37 mm, L_4 = 1.50 mm, L_5 = 0.51 mm, L_6 = 0.41 mm, L_7 = 2.50 mm, L_8 = 1.00 mm. The thickness of copper radiation patch and ground plate is 0.035 mm

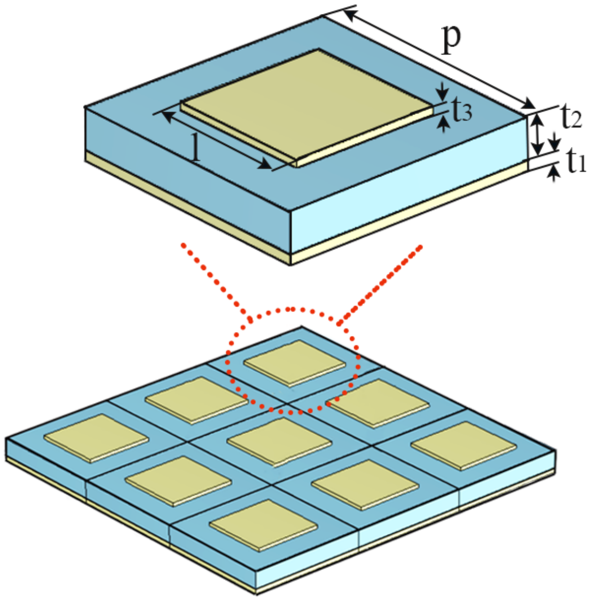

Fig. S11 The detailed dimensions of the infrared stealth device are as follows: p= 1000 nm, l =570 nm, t_1 = 40 nm, t_2 = 150 nm, t_3 =30 nm

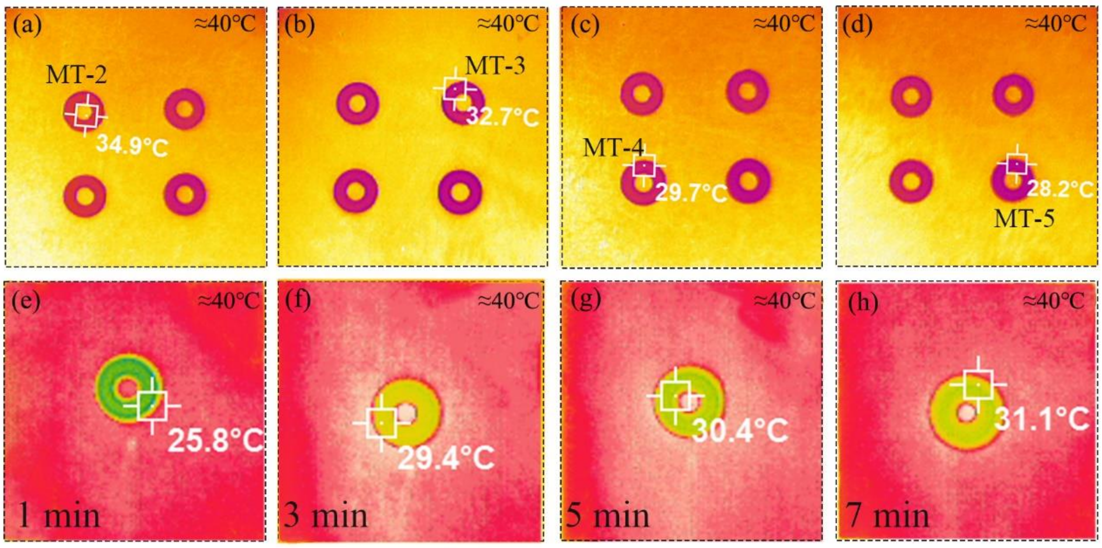

Fig. S12 a-d Thermal infrared images of MXene/TiO_2 hybrids with different calcination temperatures captured at 2 min. Thermal infrared images of MT-5 captured at **e** 1, **f** 3, **g** 5, **h** 7 min, respectively.

Table S1 The key parameters of previous reported the same-type electromagnetic device

Materials	Antennas		Filter		Infrared stealth	
	S_{11} (dB)	effective bandwidth (<-10dB)	Passband bandwidth	suppression outside the band	Minimum emissivity	effective bandwidth
MXene [S1]	-48	3.25GHz				
$Ti_3C_2T_x$ [S2]	−24.25	0.06GHz				
Graphene Microlaminates [S3]	-51	1.6				
MXene-SWNT [S4]	-36dB	0.35GHz				
Graphene nanoplates [S5]			0.75	-62.5dB		
Graphene flakes [S6]			0.25	-57		
Graphene-assembled film [S7]			1	-42		
ITO/dielectric/ITO sandwiched structure [S8]					0.52	2.5 GHz
Metasurface [S9]					0.2	8-14 μm
Ceramic substrate [S10]					0.22	3-14 μm
Hybrid metasurface [S11]					0.32	3-14 μm
PTFE top-covered multi-layer composite structure [S12]					0.196	8–14 μm
FeAl mixture [S13]					0.15	8–14 μm
Carbon nanotube film [S14]	-37.8	0.752				
Carbon nanotube film [S14]	-25.9	0.67				
Carbon nanotube film [S 14]	-35.6	0.698				
This work	-63.2	2.7	5.44	53.4	0.027	6-14 μm

Table S2 Minimum and average emissivity of MXene with different calcination temperatures

Sample	MT-2	MT-3	MT-4	MT-5
Minimum emissivity	0.036	0.035	0.032	0.027
Average emissivity	0.188	0.152	0.124	0.077

Table S3 Average visible light absorptivity of MXene with different calcination temperatures

Sample	MT-2	MT-3	MT-4	MT-5
Average absorptivity	36.3	54.5	57.7	78.2

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