Supporting Information

Ti_3C_2 MXenes with Modified Surface for High-Performance Electromagnetic Absorption and Shielding in the X-Band

Meikang Han, Xiaowei Yin*, Heng Wu, Zexin Hou, Changqing Song, Xinliang Li, Litong Zhang, and Laifei Cheng

Science and Technology on Thermostructural Composite Materials Laboratory, Northwestern Polytechnical University, Xi'an, 710072, China

*Corresponding author: yinxw@nwpu.edu.cn

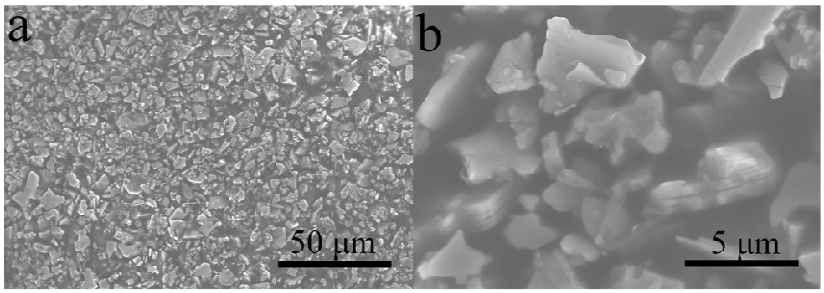

Figure S1. Cryo-fractured SEM images of MXenes/wax composites (a and b)

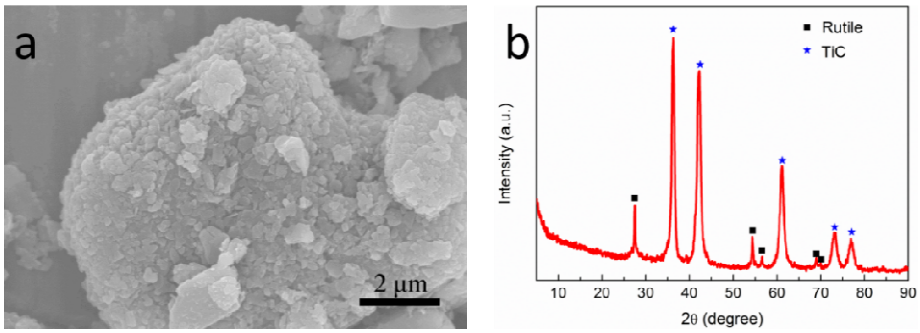

Figure S2. SEM image (a) and XRD pattern (b) of MXenes after annealing at 1000 °C

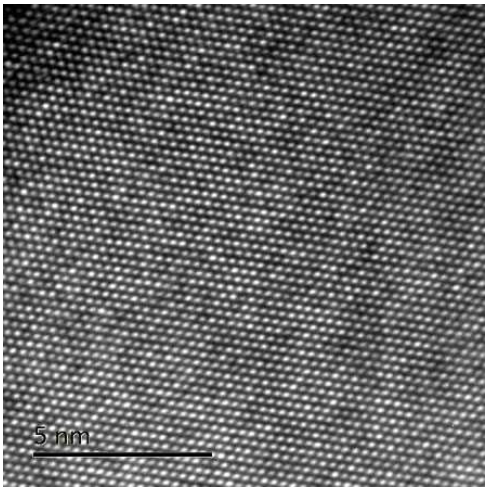

Figure S3. HRTEM image of $Ti_3C_2T_x$ sheets

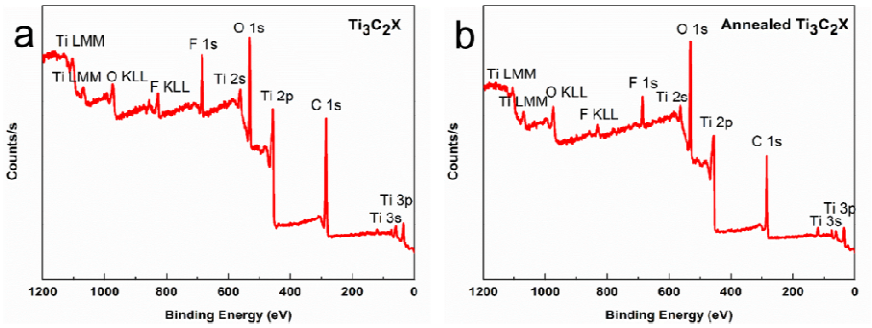

Figure S4. XPS spectra of $Ti_3C_2T_x$ MXenes before (a) and after (b) heat treatment

Table S1. Atomic concentration of elements in surface layers of $Ti_3C_2T_x$ MXenes before and after heat treatment

sample	**element**			
	Ti	C	O	F
$Ti_3C_2T_x$	12.8	55.21	23.49	8.5
Annealed $Ti_3C_2T_x$	15.26	48.25	29.9	6.59

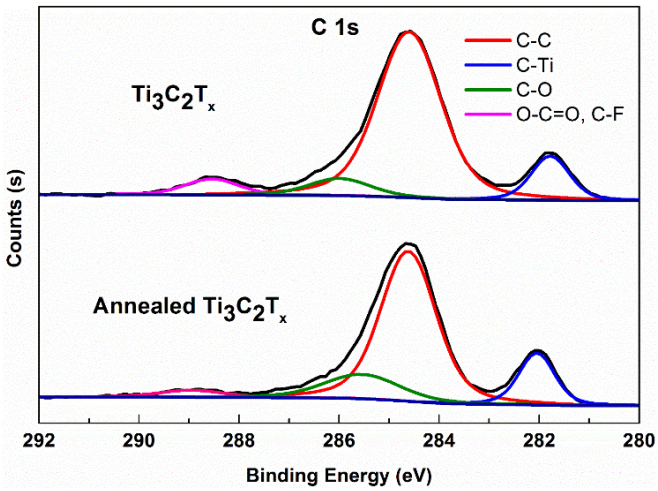

Figure S5. High-resolution C 1s spectra of $Ti_3C_2T_x$ MXenes before and after annealing

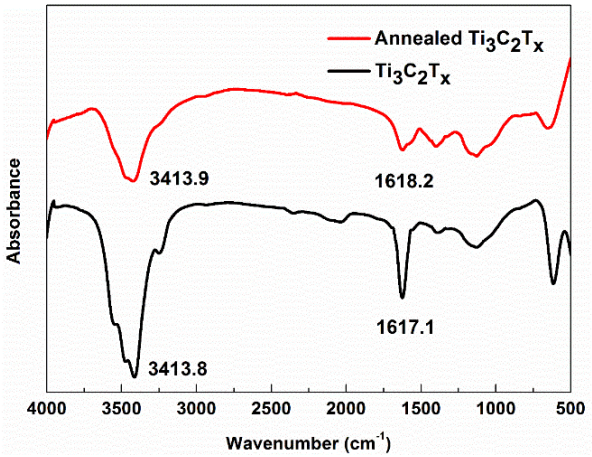

Figure S6. FTIR spectra of $Ti_3C_2T_x$ MXenes before and after annealing

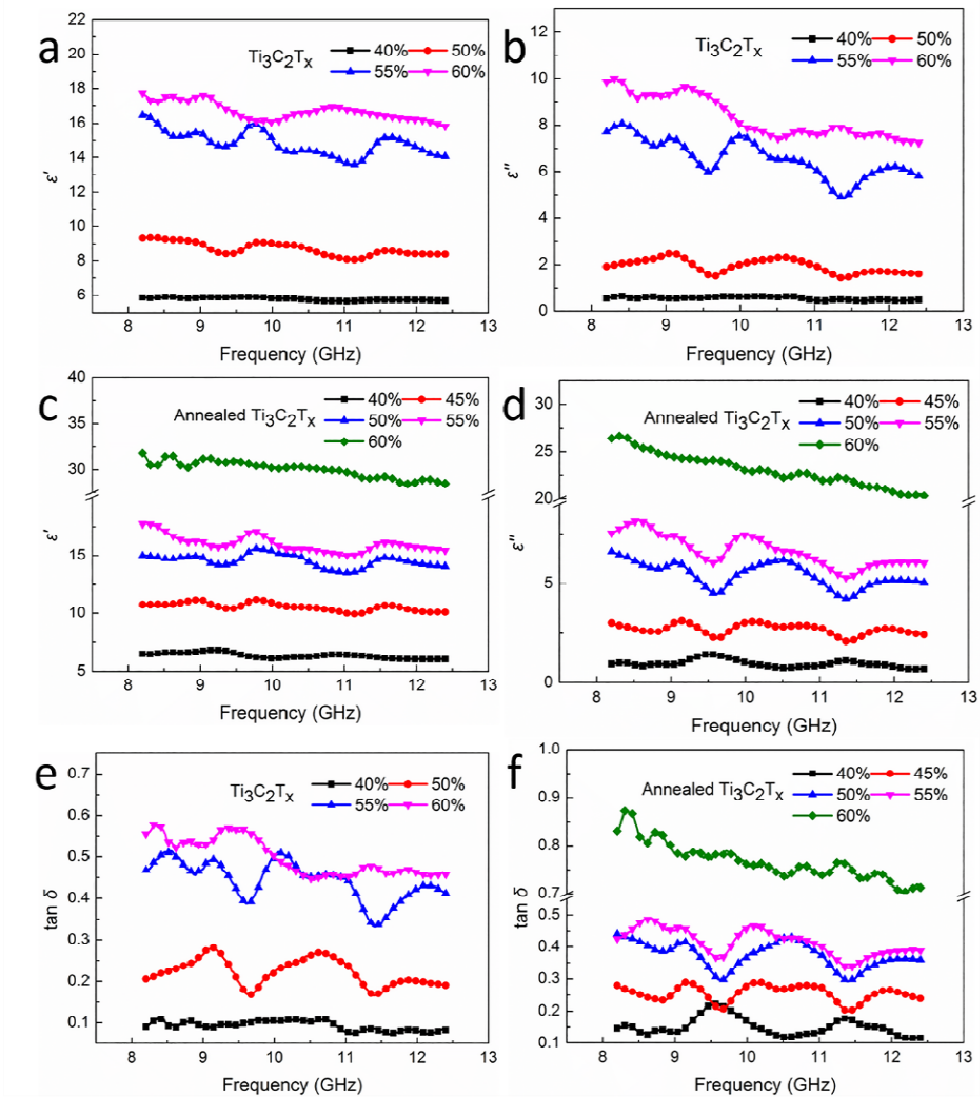

Figure S7. The real (a, c) and imaginary part (b, d) of permittivity, and the tangent loss (e, f) as a function of frequency for the samples of $Ti_3C_2T_x$ and annealed $Ti_3C_2T_x$ in wax matrix

For evaluating the EM wave absorbing performance of $Ti_3C_2T_x$ powders before and after annealing, the reflection coefficient is calculated using the relative complex permittivity. The equations which are based on the model of metal backplane and transmission line theory are as follows:

$$RC(\text{dB})=20\cdot\log_{10}\left|(Z_{in}-1)/(Z_{in}+1)\right| \quad (1)$$

$$Z_{in}=\sqrt{\frac{\mu}{\varepsilon}}\tanh(j2\pi\sqrt{\mu\varepsilon}fd/c) \quad (2)$$

where Z_{in} is the normalized input impendence of the microwave absorption layer, ε and μ are the relative permittivity and permeability of the samples, f is the EM wave frequency, d is the thickness of the samples, c is the light velocity in vacuum. When RC value is <-10 dB (denoted effective absorption), more than 90% of the EM wave energy is absorbed. The corresponding frequency range (RC < -10 dB) is defined as the effective absorption bandwidth.

The EMI shielding performance were investigated based on S parameters (S11 and S21). The transmission power (T; T = $|S21|^2$), reflectivity power (R; R = $|S11|^2$) and absorption power (A) meet the equation of A+R+T=1. EMI shielding effectiveness (SE_{total}), reflection effectiveness (SE_R), multiple reflection effectiveness (SE_{MR}) and absorption effectiveness (SE_A) associated with the incident wave P_I and transmitted wave P_T, could be described as:

$$SE_{total} = SE_R + SE_T + SE_{MR} \approx SE_R + SE_T \quad (3)$$

$$SE_{total} = -10\log_{10}(P_T/P_I) \quad (4)$$

$$SE_R = -10\log_{10}(1-R) \quad (5)$$

$$SE_T = -10\log_{10}[T/(1-R)] \quad (6)$$

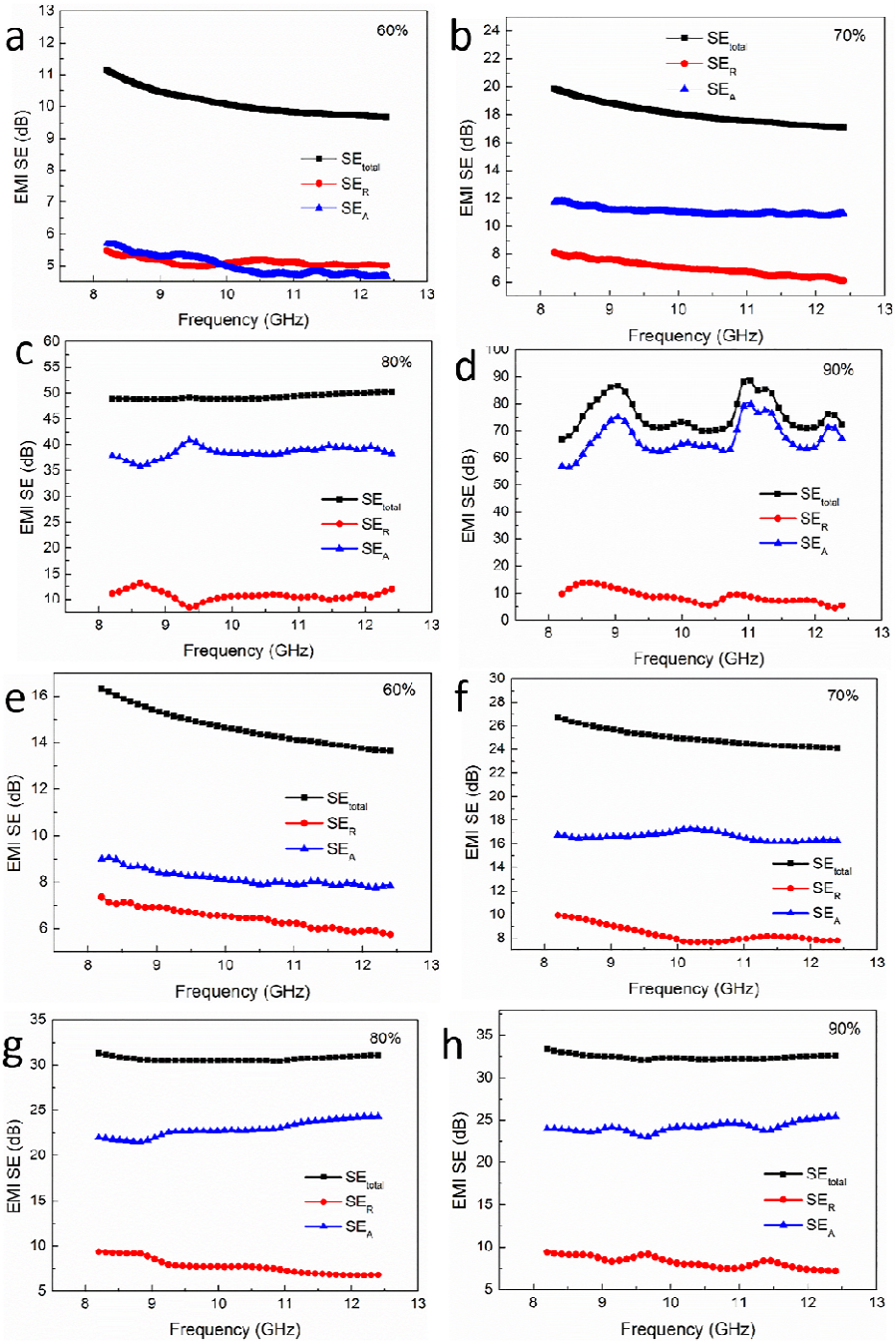

Figure S8. The EMI SE_{total}, SE_R and SE_A for the samples of $Ti_3C_2T_x$ (a,b,c and d) and annealed $Ti_3C_2T_x$ (e, f, g and h) in wax matrix with different mass ratio as a function of frequency