

Supplementary Information

Pressure-Triggered Dynamically Tunable TiO₂/CNFs@Co/C Aerogel Derived from MXene/PAN@ZIF-67 for Broadband Microwave Absorption

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The reflection loss is generally used to represent the absorption intensity of EMW by materials, which is the most important indicator to measure the electromagnetic wave absorption performance of materials. The RL of absorption materials can be calculated by the following Equation:

$$Z_{in} = Z_0 \sqrt{\frac{\mu_r}{\epsilon_r}} \tanh \left[j \left(\frac{2\pi f d}{c} \right) \sqrt{\epsilon_r \mu_r} \right] \quad (S1)$$

$$RL = 20 \lg \left| \frac{Z_{in} - Z_0}{Z_{in} + Z_0} \right| \quad (S2)$$

The relationship between ϵ' and ϵ'' can be expressed as follows:

$$\left(\epsilon' - \frac{\epsilon_s + \epsilon_\infty}{2} \right)^2 + (\epsilon'')^2 = \left(\frac{\epsilon_s - \epsilon_\infty}{2} \right)^2 \quad (S3)$$

Here, Z_{in} and Z_0 represent the impedance of the sample and free space, respectively; f , c , and d denote the frequency, speed of EMW, and sample thickness. Another critical parameter, the EAB, was also analyzed.

The magnetic loss properties of the samples can be evaluated through the relationship between the C_0 and frequency. which can be described as Equation:

$$C_0 = \mu'' (\mu')^{-2} f^{-1} = \frac{2\pi\mu_0 d^2 \sigma}{3} \quad (S4)$$

To Figure out the intrinsic contribution of conduction loss (ϵ_c'') and polarization loss (ϵ_p'') to the dielectric loss, the complex component including relaxation and conductance can be calculated by Debye theory, as presented in Equation:

$$\epsilon'' = \epsilon_p'' + \epsilon_c'' = (\epsilon_s - \epsilon_\infty) \frac{2\pi f \tau}{1 + (2\pi f)^2 \tau^2} + \frac{\sigma}{2\pi f \epsilon_0} \quad (S5)$$

High-performance EMW absorbers must satisfy two critical criteria: appropriate impedance matching and a high α . Optimal impedance matching (close to 1) ensures maximum EMW penetration into the material rather than surface reflection, while a high α facilitates rapid conversion of incident EMW energy into thermal dissipation. which can be calculated as following Equation (S6) and (S7):

$$\frac{Z_{in}}{Z_0} = \sqrt{\frac{\mu_r}{\epsilon_r}} \tanh \left[j \left(\frac{2\pi f d}{c} \right) \sqrt{\epsilon_r \mu_r} \right] \quad (S6)$$

$$\alpha = \frac{\sqrt{2\pi f}}{c} \times \sqrt{(\mu''\epsilon'' - \mu'\epsilon') + \sqrt{(\mu''\epsilon'' - \mu'\epsilon')^2 + (\mu'\epsilon'' + \mu''\epsilon')^2}} \quad (S7)$$

To evaluate the practical reliability of TTCFC, a square simulation model with a side length of 150 mm was established using CST Studio Suite 2022. It is generally accepted that the scattering directions of RCS value (σ) can be determined by theta and phi in spherical coordinates, which can be described as:

$$\sigma (\text{dB m}^2) = 10 \log \left(\left(4\pi S / \lambda^2 \right) |E_s / E_i|^2 \right) \quad (S8)$$

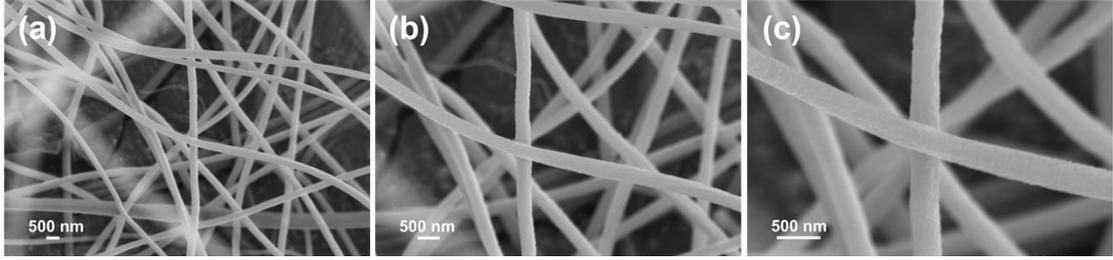


Figure S1. SEM images of (a-c) CF

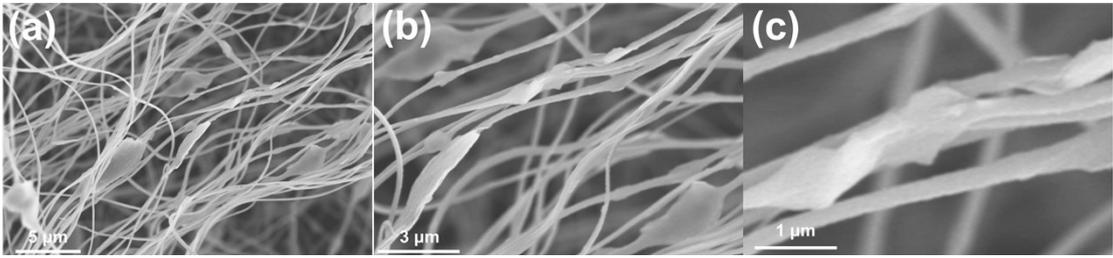


Figure S2. SEM images of (a-c) TTCF

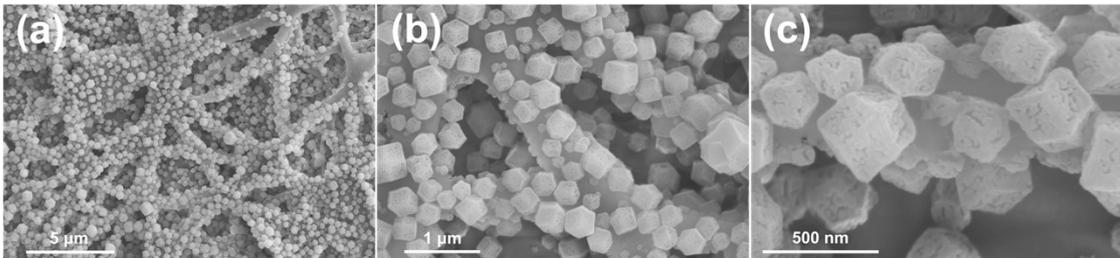


Figure S3. SEM images of (a-c) CFC

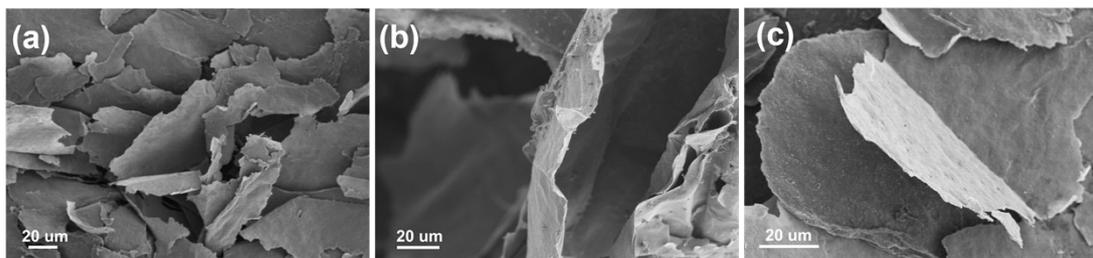


Figure S4. SEM images of (a-c) Ti₃C₂T_x MXene

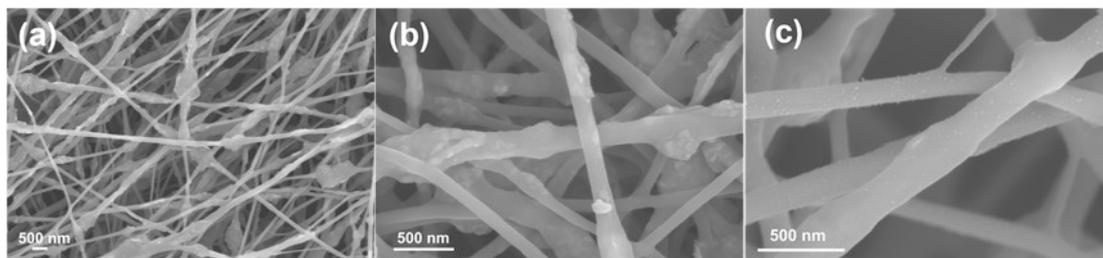


Figure S5. SEM images of (a-c) Ti₃C₂T_x MXene/PAN

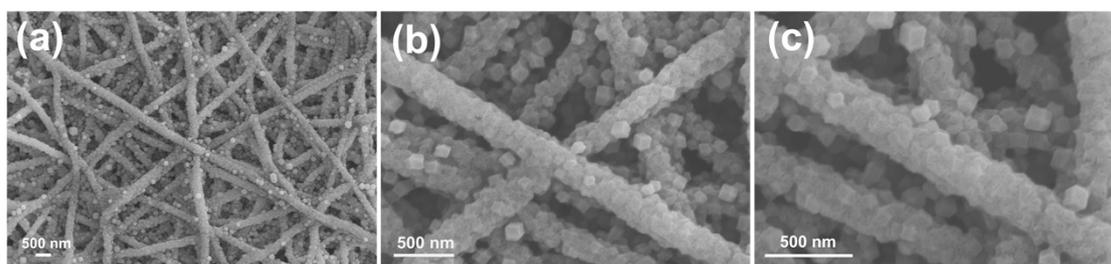


Figure S6. SEM images of (a-c) Ti₃C₂T_x MXene/PAN@ZIF-67

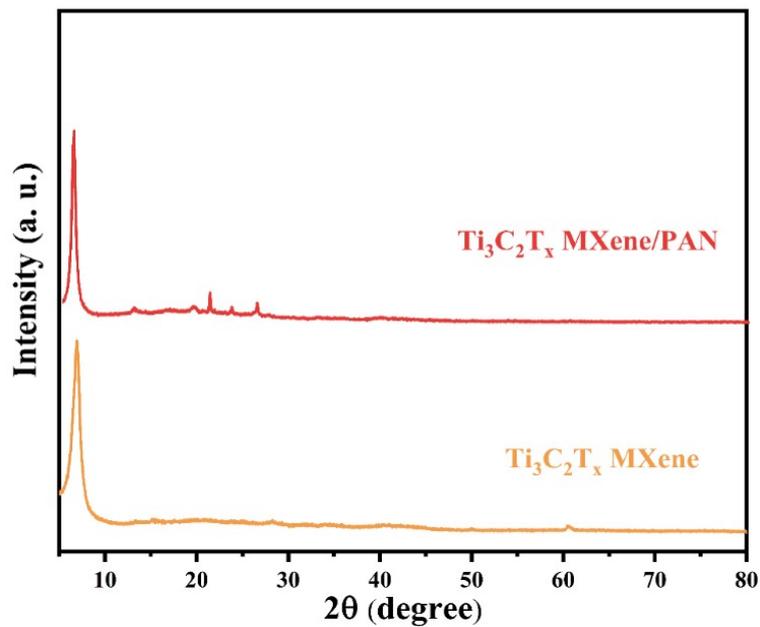


Figure S7. XRD patterns of $\text{Ti}_3\text{C}_2\text{T}_x$ MXene and $\text{Ti}_3\text{C}_2\text{T}_x$ MXene/PAN.

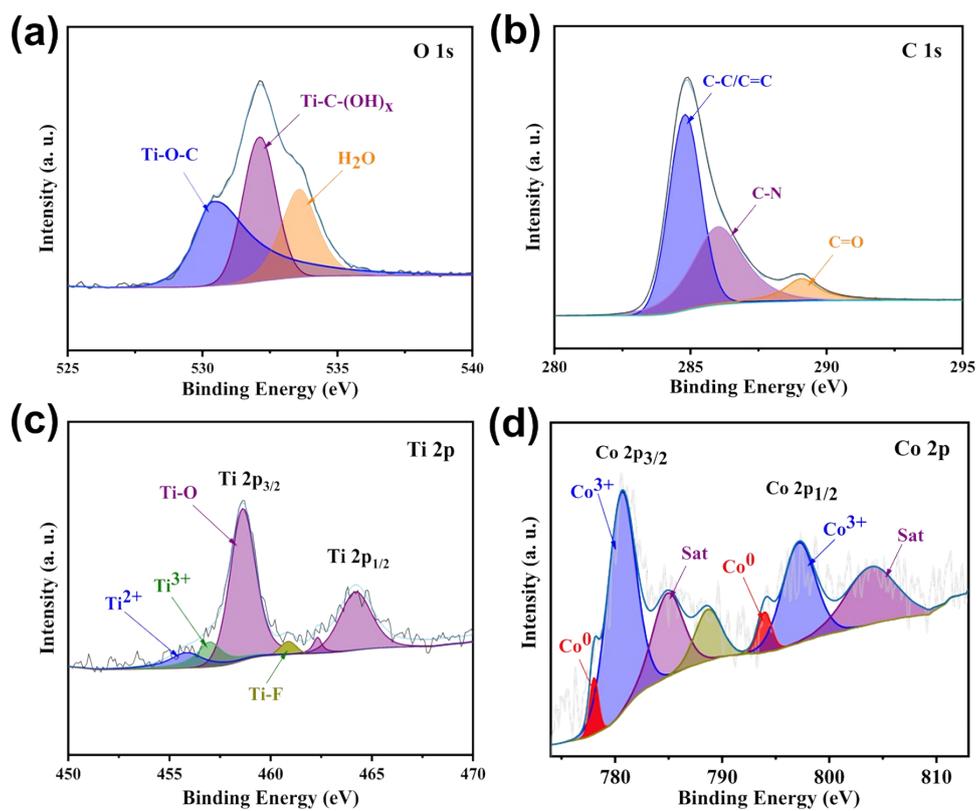


Figure S8. High-resolution XPS spectrum of (a-d) TTCFC

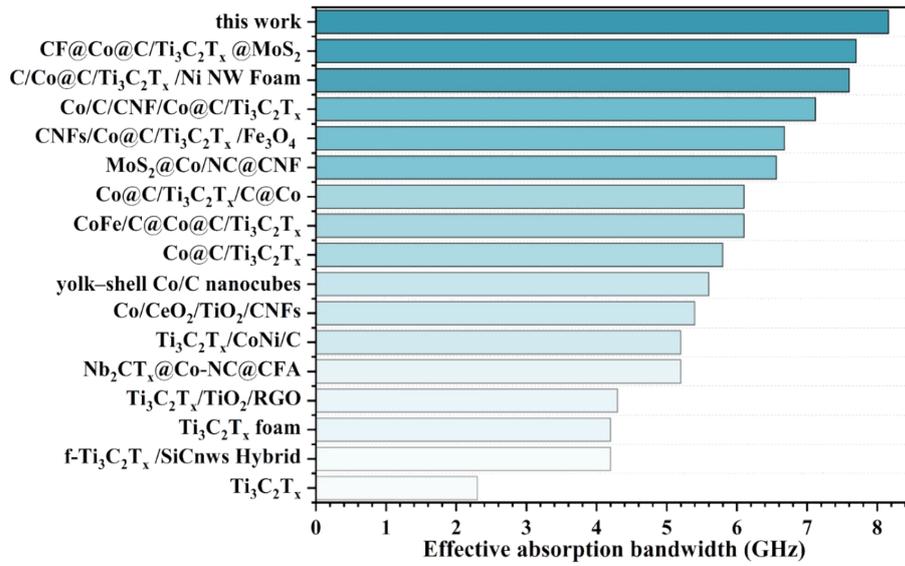


Figure S9. EAB comparison diagram of other sample

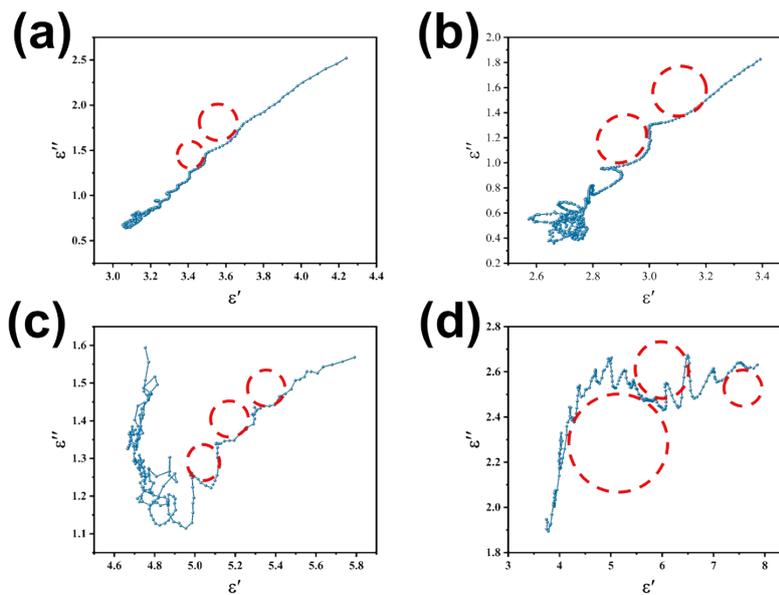


Figure S10. Cole-Cole curves of (a) CF, (b) CFC, (c) TTCF, and (e) TTCFC

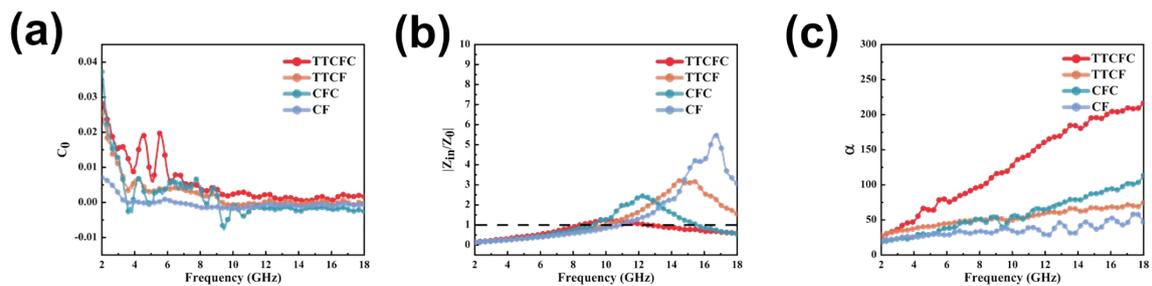


Figure S11. (a) C_0 , (b) impedance matching from CF to TTCFC, (c) attenuation constant

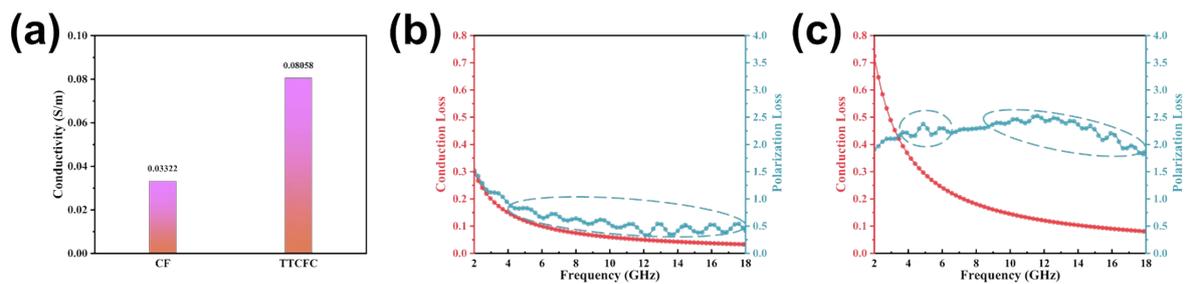


Figure S12. (a) Conductivity and (b, c) conduction loss curve and polarization loss curve of CF and TTCFC

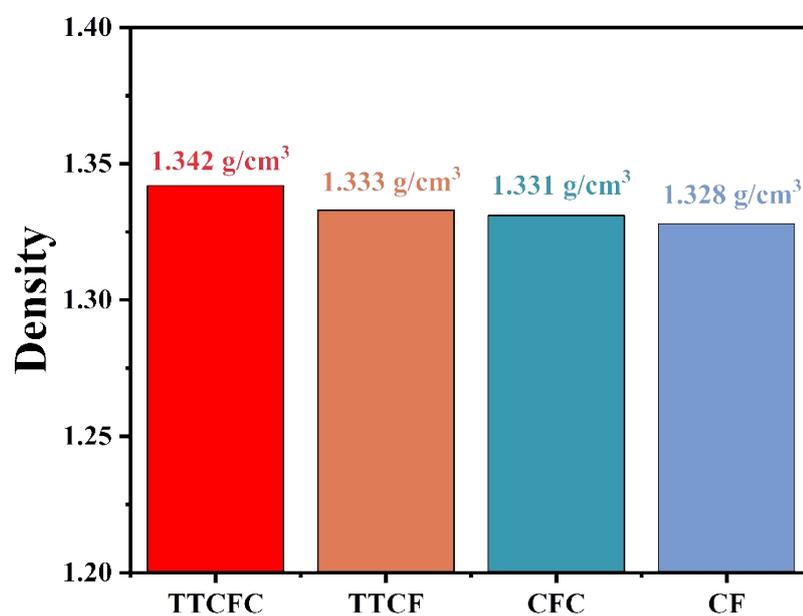


Figure S13. Density of CF, CFC, TTCF and TTCFC composites.