Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C.

Cobalt magnetic particles and carbon composite microtubes as high-performance electromagnetic wave absorber

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Electronic Supplementary Information (ESI)

S1. SEM images of cotton fibers

The pristine absorbent cotton fibers used in this work have a diameter at around 20 μm as shown in Fig. S1a and S1b, and were used to fabricate PCMT/Co and CMT/Co. The received cotton fibers were washed and dried for further use.

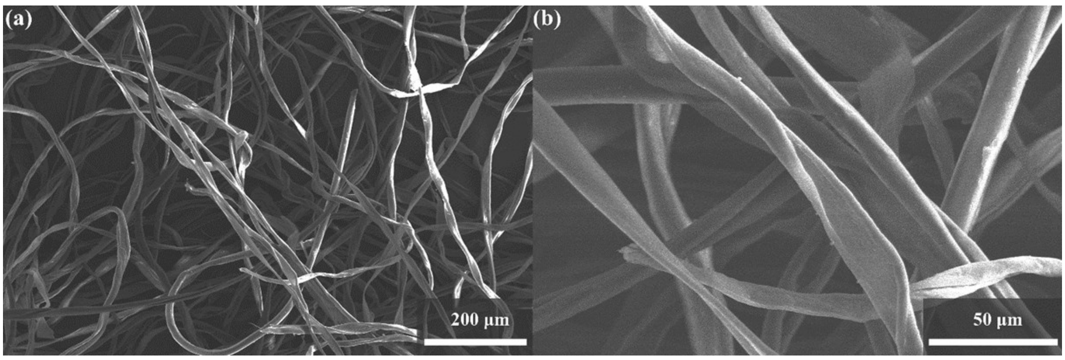

Fig. S1. SEM images of the pristine absorbent cotton fibers used in this work for the synthesis of PCMT/Co and CMT/Co with different magnification.

S2. TGA and DTG curves of cotton fibers in nitrogen gas atmosphere

Fig. S2 shows the TGA and DTG curves of cotton fibers in nitrogen atmosphere. As demonstrates by DTG, the main thermo degradation process of cotton fibers occurs at around 366 °C. Under the protection of nitrogen gas, cotton fibers can translate into carbon materials with a residual weight ratio of higher than 12.8%. Therefore, cotton fibers can be suitable candidate for the synthesis of carbon materials.

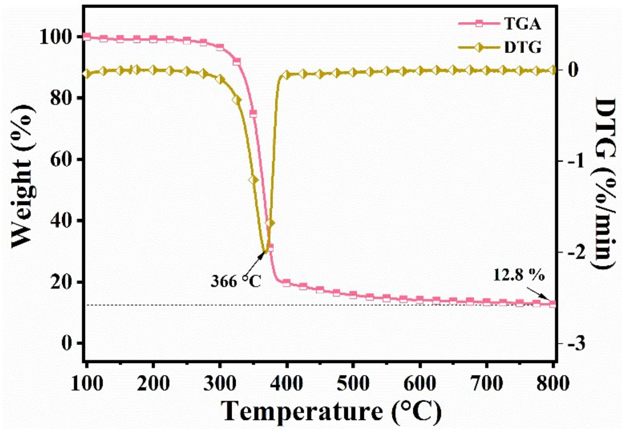

Fig. S2. The TGA and DTG curves for cotton fibers measured in nitrogen gas atmosphere.

S3. The synthesis of cotton fibers based carbon microtubes (CMT)

The cotton fibers based carbon microtubes were synthesized with a method similar to that of CMT/Co. Firstly, the obtained cotton fibers were washed with distilled water for three times and dried at 80 °C for 12 hours. Then the cotton fibers were pyrolyzed in a tubular furnace under a flowing argon gas atmosphere with a proper heating and cooling procedure (25~1000 °C, 5 °C min^{-1}; 1000 °C, 2 hours; 1000~300 °C, 5 °C min^{-1}). After cooling to room temperature, the final products were collected for further use. As shown in Fig. S3a and S3b, CMT has a hollow characteristic in microstructure.

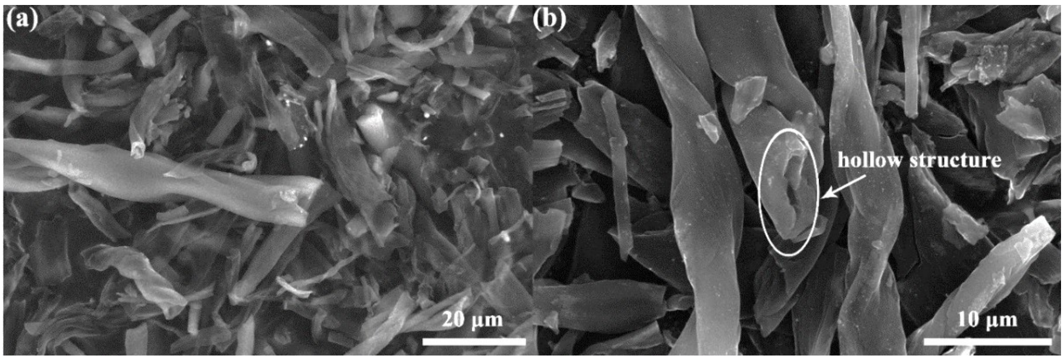

Fig. S3. SEM image of the cotton-based carbon microtubes (CMT) with different magnification.

S4. EDS and TEM of PCMT/Co and CMT/Co

As shown in Fig. S4a and Fig. 4b, the particles on the surface or even in the carbon matrix are cobalt element-based material. Therefore, according to the result of XRD, EDS and XPS, these particles in CMT/Co and PCMT/Co are Co metal particles. In EM field, Co particles can improve the EM matching condition of the synthesized absorbers and generate magnetic loss. Moreover, as demonstrated by TEM (Fig. S4c and Fig. S4d) and SEM (Fig. 3), Co particles were encapsulated in the carbon matrix or partially exposed outside the carbon matrix.

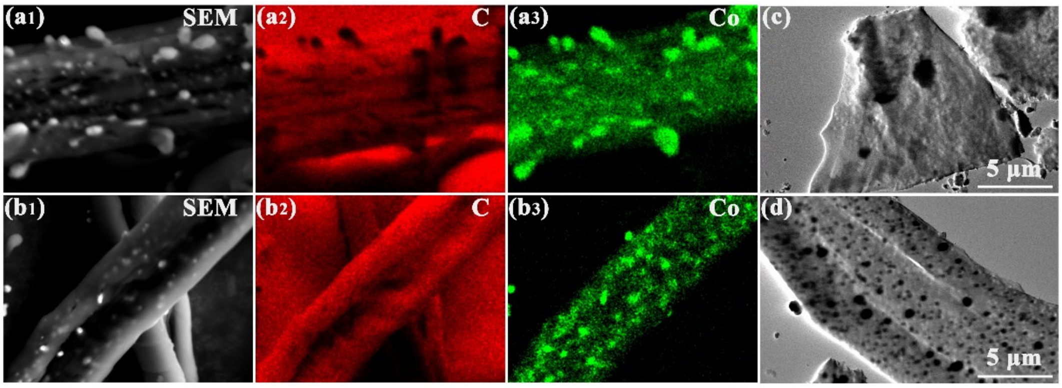

Fig. S4. (a1~a3) EDS mapping information of PCMT/Co; (b1~b3) EDS mapping information of CMT/Co; (c) TEM image of PCMT/Co and (d) TEM image of CMT/Co.

S5. Diameter of Co metal particles in PCMT/Co and CMT/Co

As shown in Fig. S5, the Co metal particles in CMT/Co and PCMT/Co have an average diameter of 1.8 μm and 1.6 μm, respectively.

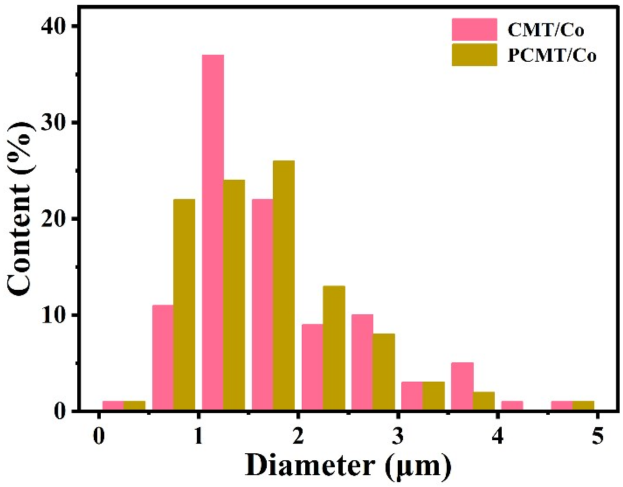

Fig. S5. The diameter information of Co metal particles in the synthesized PCMT/Co and CMT/Co.

S6. The porous structure of PCMT/Co measured by nitrogen adsorption-desorption

As shown in Fig. S6, PCMT/Co has a hierarchically porous structure including micropores (<2 nm), mesopores (2~50 nm) and macropores (>50 nm) in its porous structure.

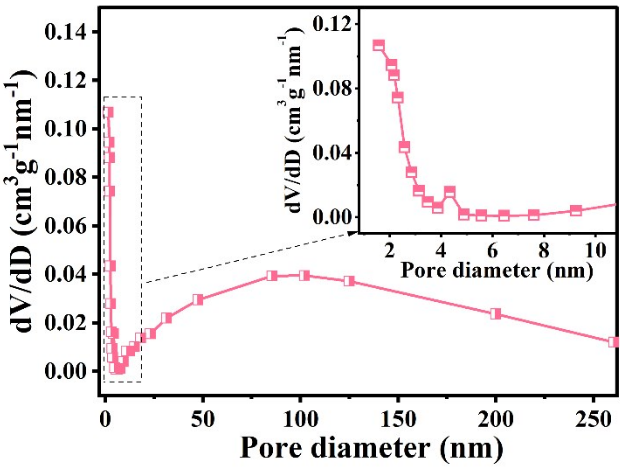

Fig. S6. The pore size distribution of PCMT/Co measured by nitrogen adsorption-desorption.

S7. Magnetic properties of PCMT/Co and CMT/Co

The curves of magnetization (*M*) vs. applied field (*H*) shown in Fig. S7 give a clear evidence for the ferromagnetic property of PCMT/Co and CMT/Co. The saturated magnetization (M_s) of PCMT/Co and CMT/Co can reach 34.9 emu g^{-1} and 28.4 emu g^{-1}, respectively.

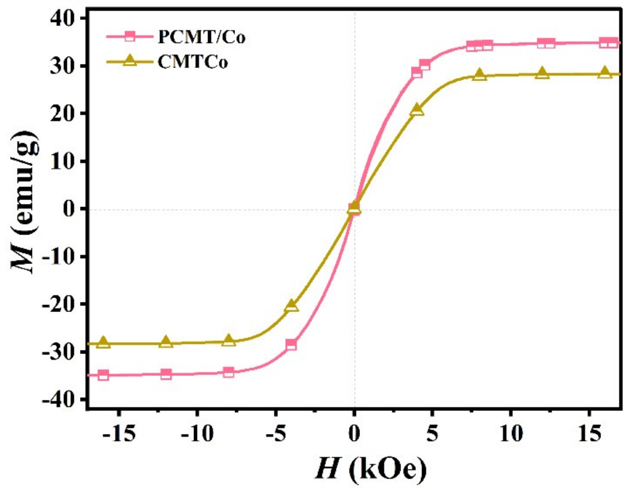

Fig. S7. M-H loop for the synthesized cotton based EMW absorbers PCMT/Co and CMT/Co.

S8. TGA curves of PCMT/Co, CMT/Co and CMT in air atmosphere

The TGA curves of CMT, CMT/Co and PCMT/Co were shown in Fig. S8. In an air atmosphere, as demonstrate by the TGA of CMT, carbon can react with oxygen at a 100% completion (Reaction 2). At the same time, under an air atmosphere, the carbon and Co metal particles in CMT/Co and PCMT/Co translates into CO_2 and CoO according to Reaction 1 and Reaction 2, respectively. As the residual weight of CMT/Co and PCMT/Co are 33.5% and 42.9%, the Co metal particles content in HCF/Co and PHCF/Co are 26.3% and 33.7% according to the weight ratio equation, respectively.

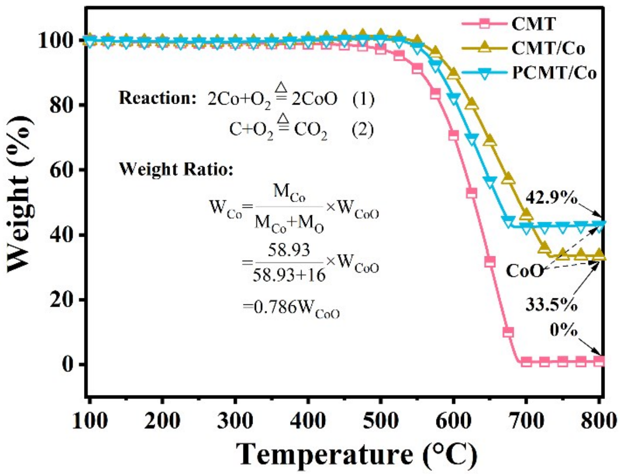

Fig. S8. The TGA curves for PCMT/Co, CMT/Co and CMT measured in nitrogen gas atmosphere.

S9. The EMW attenuation performance of CMT and PCMT

The EWW attenuation performance of CMT was shown in Fig. S9a. As CMT only has dielectric loss component, it is hard to get a fine EM matching condition and obtain a strong EMW attenuation ability. At a filler loading of 15 wt%, the minimum RLs are smaller than -15 dB. Comparing with the EMW absorption performance of CMT/Co and PCMT/Co, the EMW absorption ability of CMT is not satisfying. Therefore, magnetic component in CMT/Co and PCMT/Co play an important role in the improvement of EMW absorption performance. The EWW attenuation performance of PCMT was shown in Fig. S9b. At a filler loading of 15 wt%, PCMT shows a better EMW absorption performance compared with CMT. At 1.2 mm, the minimum RL can reach -24 dB. Generally speaking, the porous microstructure caused multiple interfaces can enhance the intensity of interfacial polarization in EM field. Considering the difference in microstructure and EMW absorption between CMT and PCMT, the porous microstructure plays an important role in promoting the EMW absorbing ability.

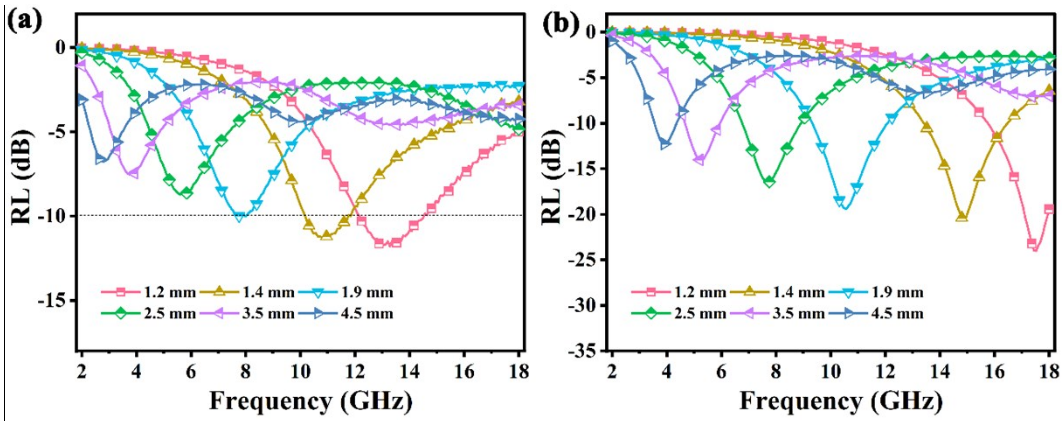

Fig. S9. EMW absorption performance of (a) CMT and (b) PCMT in 2~18 GHz at 15 wt% loading.

S10. The eddy current and typical Core-Core semicircles of PCMT/Co and CMT/Co

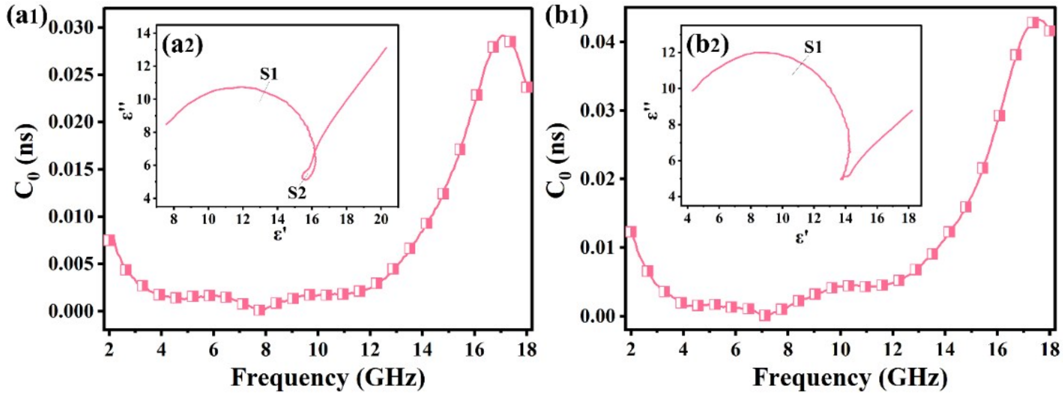

Fig. S10. The eddy current C_0 of (a1) PCMT/Co and (b1) CMT/Co. The typical Core-Core semicircles of (a2) PCMT/Co and (b2) CMT/Co.