Supplementary information

Egg whites-derived carbon/magnetic nanoparticles/water-soluble graphene oxide composite with homogeneous structure as an excellent electromagnetic wave absorber

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SI-1: The synthesis of $Co_{0.2}Fe_{2.8}O_4$ nanoparticles

H_2O (300 ml), $FeCl_3{\cdot}6H_2O$ (1.9867 g, 7.35 mmol), $FeCl_2{\cdot}4H_2O$ (0.5845 g, 2.94 mmol), $CoCl_2{\cdot}6H_2O$ (0.1749 g, 0.74 mmol) were added to a 500 mL three-necked flask. With the protection of Ar, the solution was rapidly heated to 70 °C with a mechanical stirring (1000 rpm). Subsequently, $NH_3{\cdot}H_2O$ (13.5 mmol) was added to the mixed solution to adjust the pH to 10. And then it reacts at 70 °C for an hour, the products were collected by magnet and washed several times with deionized water and ethanol to remove impurities. The product is dried by a freeze dryer and stored in a cool place under vacuum and sealed conditions. Subsequently, the morphology of $Co_{0.2}Fe_{2.8}O_4$ nanoparticles was investigated by TEM as shown in **Fig S1**. Through observation, the $Co_{0.2}Fe_{2.8}O_4$ nanoparticles is spherical and have an average diameter about of 50 nm.

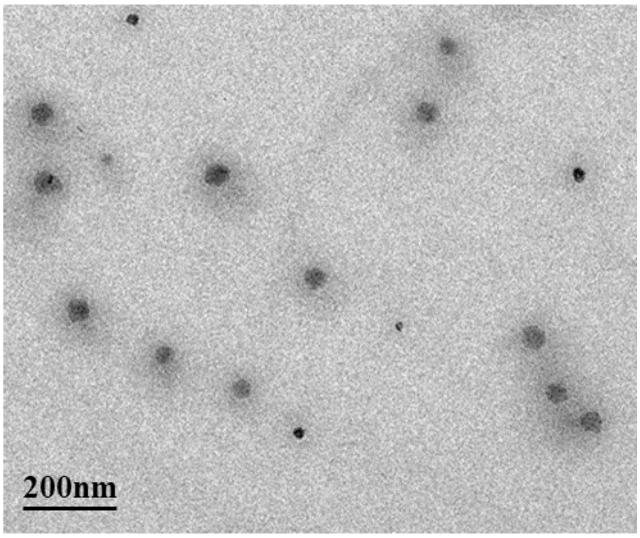

Fig. S1. The TEM image of the synthesized $Co_{0.2}Fe_{2.8}O_4$.

SI-2: Preparation of coaxial rings of paraffin matrix materials

First, A certain amount of EWC/MNPs/WSGO was put into a mortar, ground into powder, and bagged for storage. Then weigh 0.1 g EWC/MNPs/WSGO and 0.1 g paraffin, add them into the mortar and grind them vigorously to make them evenly mixed. Then the mixture was poured into a standard mold and compacted with a bench vice to obtain a coaxial ring with an outer diameter of 7.0 mm, an inner diameter of 3.04 mm, and a thickness of 2.0 mm.

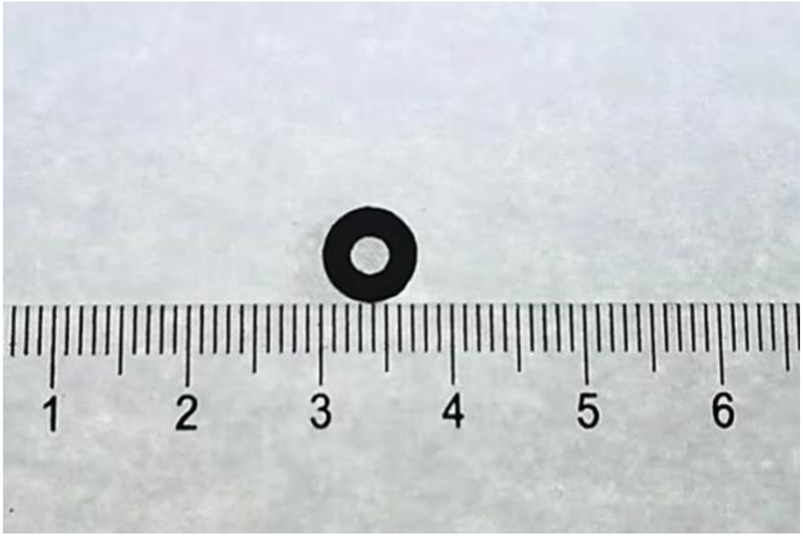

Fig. S2. The coaxial ring of materials with paraffin matrix for measurement of electromagnetic parameters and EMW absorption performances.

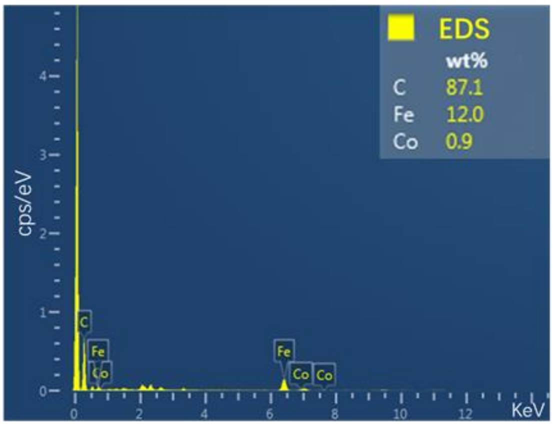

Fig. S3. The EDS elemental data for EWC/MNPs/WSGO-1.0.

SI-3: Thermogravimetric Analysis (TGA)

TGA was performed to further explore the content of metal nanoparticles in the composite absorbers, in air atmosphere, when the temperature rises to 450 ℃, the sample mass increases. This is because Fe and Co react with oxygen to form metal oxides under high-temperature conditions, increasing sample's mass. When the temperature is higher than 450 ℃, the carbon components in the sample begin to decompose. When the temperature is up to 750 ℃, the carbon components are completely decomposed, and the remaining components are only metal oxides. According to equation 1, the weight percentages of metal for EWC/MNPs/WSGO-0.0, EWC/MNPs/WSGO-0.5, EWC/MNPs/WSGO-1.0, EWC/MNPs/WSGO-2.0, EWC/MNPs/WSGO-4.0 were calculated as 15.90, 14.49, 12.18, 11.16 and 9.86 $wt\%$, respectively.

$$C_{(wt\%)} = \left(\frac{m_r}{m_i}\right) * 2 * \mathrm{A_M} \ / \ M_{M_3O_4} \qquad (1)$$

where $C_{(wt\%)}$ is the content of metal, m_r is the remaining weight, m_i is the initial weight of the sample, $\mathrm{A_M}$ is the atomic weight of the metal, and $M_{M_3O_4}$ is the molecular weight of M_3O_4. In the case of EWC/MNPs/WSGO-0.0, EWC/MNPs/WSGO-0.5, EWC/MNPs/WSGO-1.0, EWC/MNPs/WSGO-2.0, EWC/MNPs/WSGO-4.0, the average atomic weight of the Fe/Co alloy and the average molecular weight of the corresponding oxides are calculated based on the initial Fe/Co molar ratios of the preparation process for EWC/MNPs/WSGO and used in equation 1.

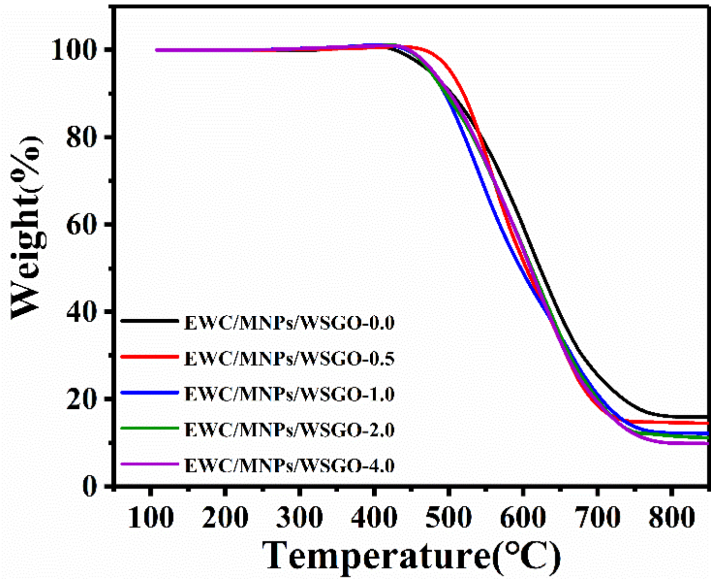

Fig. S4. TGA curves of EWC/MNPs/WSGO-0.0, EWC/MNPs/WSGO-0.5, EWC/MNPs/WSGO-1.0, EWC/MNPs/WSGO-2.0, and EWC/MNPs/WSGO-4.0 composites in air.

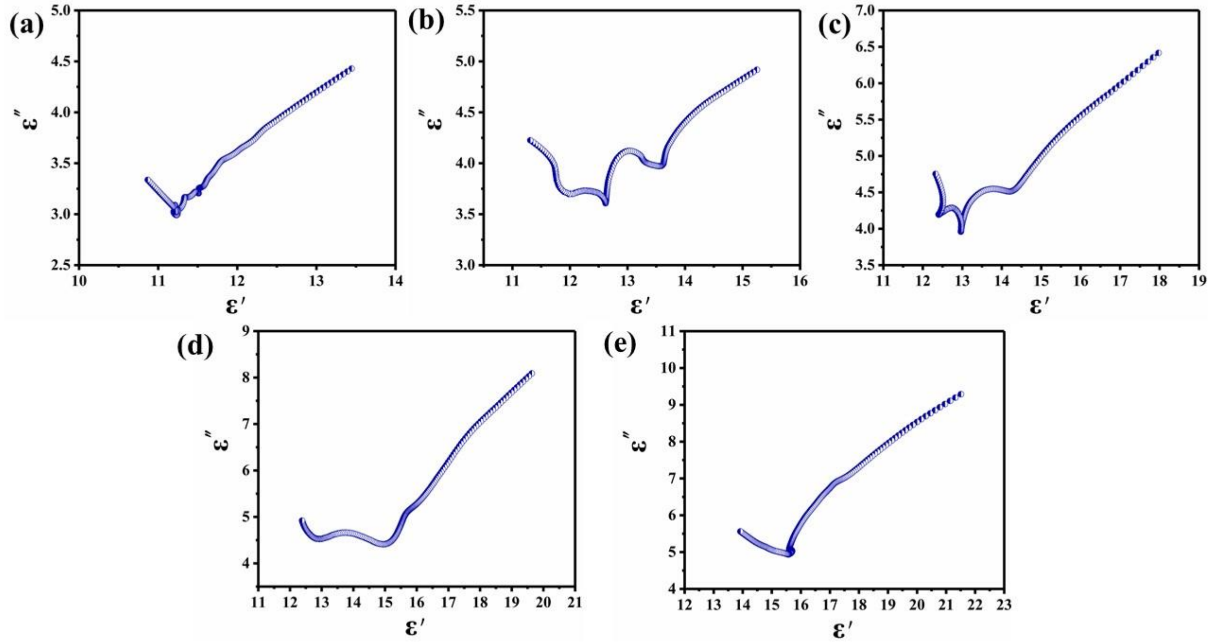

Fig. S5. Cole–Cole plot of EWC/MNPs/WSGO-0.0 (a), EWC/MNPs/WSGO-0.5 (b), EWC/MNPs/WSGO-1.0 (c), EWC/MNPs/WSGO-2.0 (d), and EWC/MNPs/WSGO-4.0 (e).

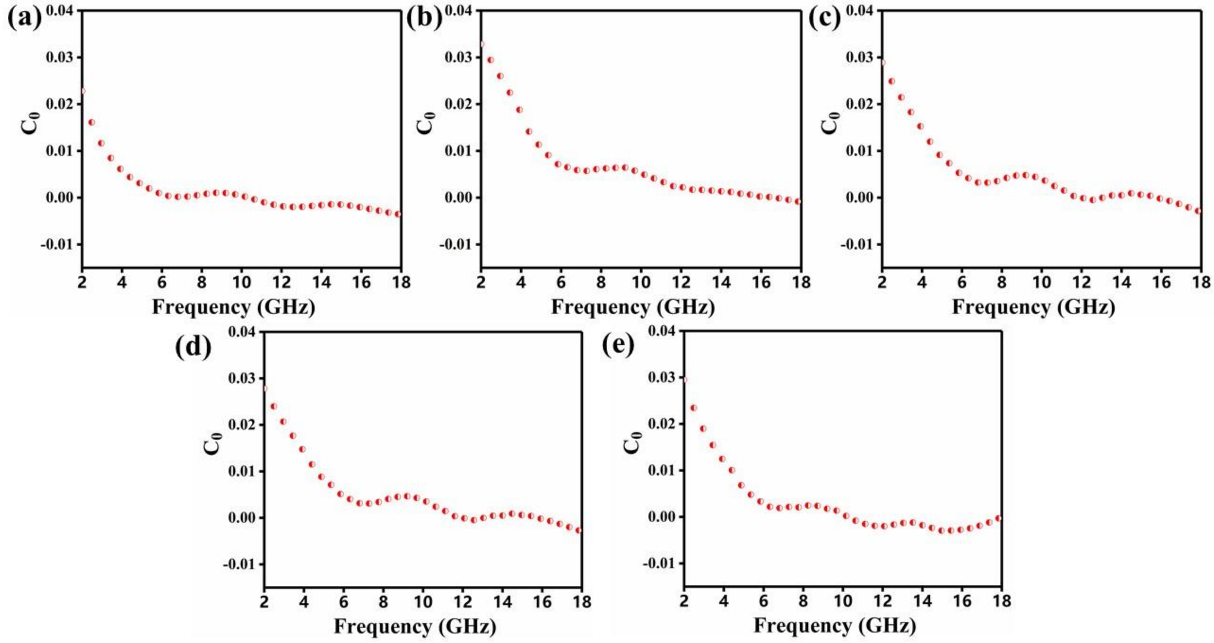

Fig. S6. the value of the eddy current (C_0, $\mu''(\mu')^{-2}f^{-1}$) of EWC/MNPs/WSGO-0.0 (a), EWC/MNPs/WSGO-0.5 (b), EWC/MNPs/WSGO-1.0 (c), EWC/MNPs/WSGO-2.0 (d), and EWC/MNPs/WSGO-4.0 (e).

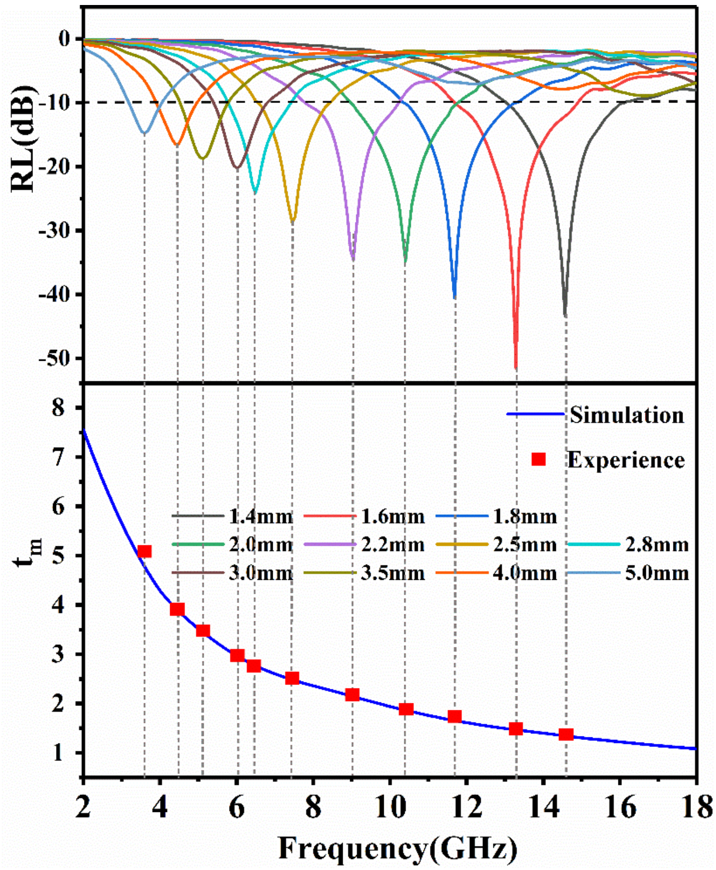

Fig. S7. (a) The RL-Frequency curves of EWC/MNPs/WSGO-1.0 in 2–18 GHz with the absorber content of 50 wt%; (b) Relationship between simulation thickness and peak frequency of EWC/MNPs/WSGO-1.0.