Electronic Supplementary Information

The novel ceramic-based microwave absorbents derived from gangue

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Table S1. Chemical composition of FeG composites (wt%).

	SiO_2	Al_2O_3	Fe_2O_3	Fe_3O_4	TiO_2	CaO	P_2O_5	L. O. I
FeG300	28.2	26.7	15.5	---	0.9	0.2	0.4	28.1
FeG400	27.8	25.2	---	22.3	0.5	0.1	0.3	23.8
FeG500	28.9	26.6	---	21.9	0.5	0.2	0.3	21.6
FeG600	28.8	26.9	---	22.1	0.6	0.1	0.4	21.1
FeG700	28.9	27.2	---	22.5	0.5	0.1	0.3	20.5

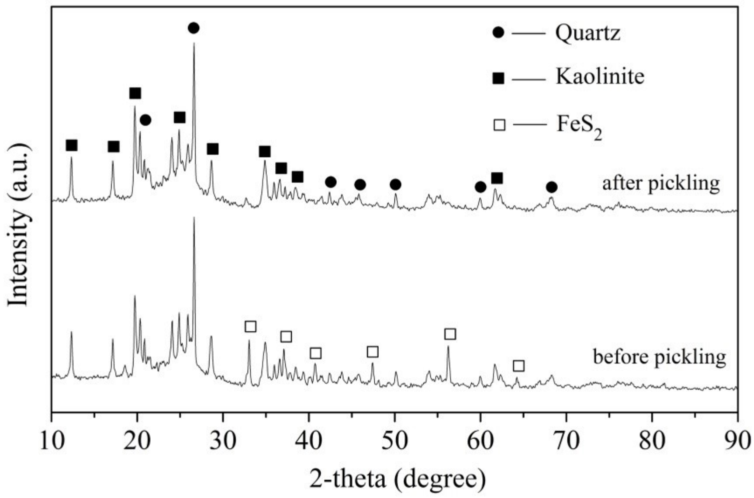


Figure S1. XRD patterns of the gangue before and after pickling.

To characterize the graphitization degree of FeG composites, the Raman spectra of FeG composites sintered at different temperatures are showed in Figure S2. It is found that there are two distinct broad peaks around 1350 cm^{-1} (D band) and 1580 cm^{-1} (G band). The D band corresponds to the sp^3 carbon atoms of disordered graphite and G band represents the sp^2 carbon atoms of graphitic carbon. The value of I_D/I_G represents the degree of graphitization of carbon, and the higher the ratio, the lower the degree of graphitization. It can be found that the I_D/I_G value shows an upward trend with increasing temperature, which indicates that more disordered graphite crystals are generated.

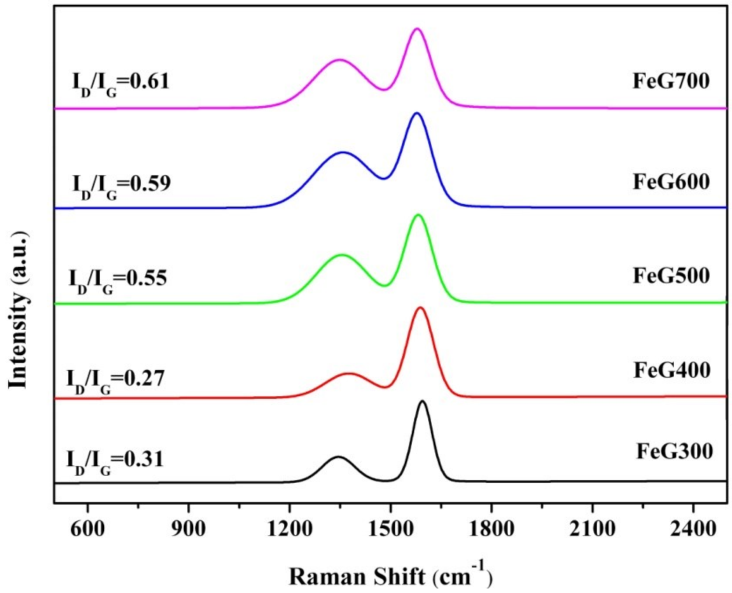


Figure S2 Raman spectra of FeG composites sintered at different temperatures.

The magnetization curves of the three representative samples are shown in Figure S3, and all the magnetization curves show the typical ferromagnetic behavior. It is found that the value of saturation magnetization (Ms) is 9.9, 31.5 and 18.1 emu/g, respectively, which is ascribed to the M_S of Fe_3O_4 is higher than Fe_2O_3. As for FeG700, because the formed Fe_3O_4 reacts with the matrix, leading to the magnetic constitute is consumed and the M_S is decreased.

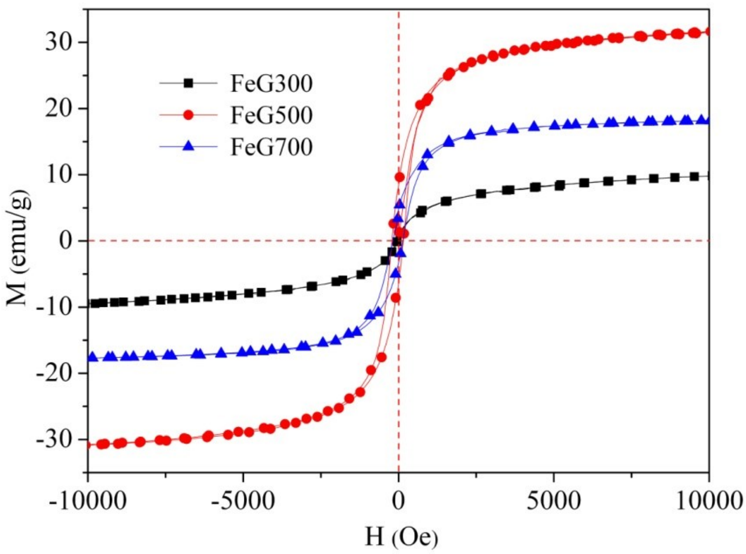
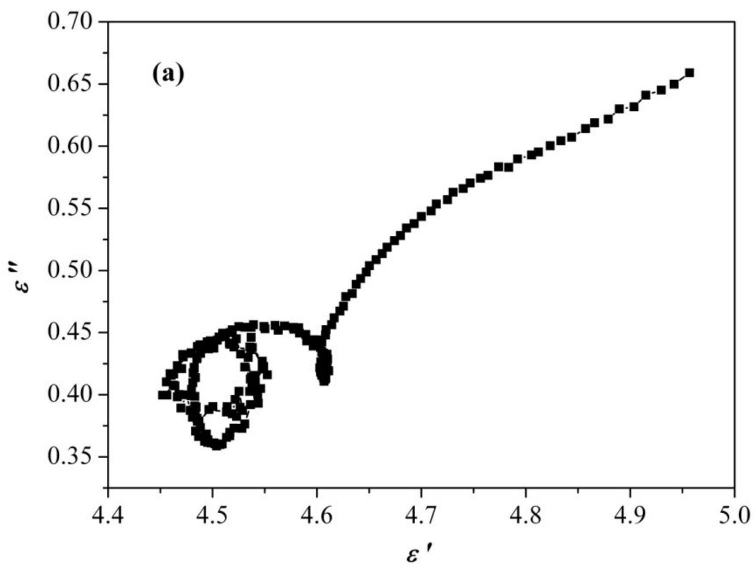


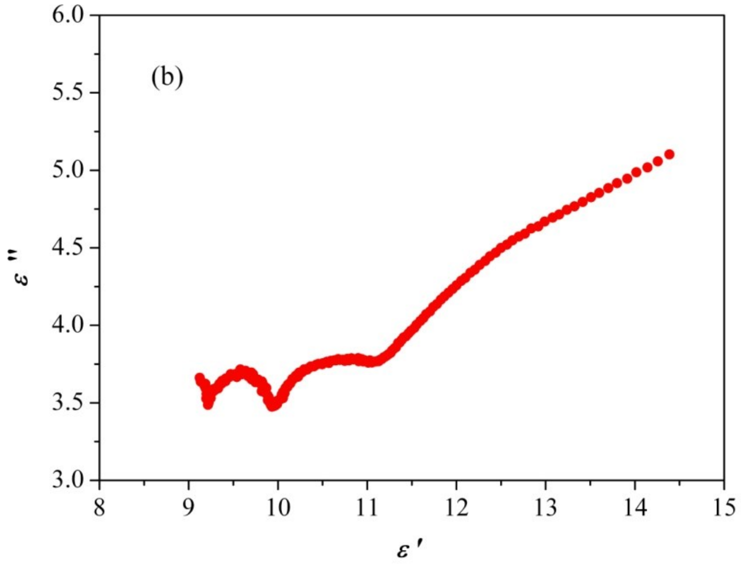
Figure S3 Magnetic hysteresis loops of the samples.

Many studies revealed that Debye dipolar relaxations were beneficial to microwave absorption. According to the Debye theory, the relationship between ε' and ε'' is derived as following formula:

$$\left(\varepsilon' - (\varepsilon_s + \varepsilon_\infty)/2\right)^2 + \left(\varepsilon''\right)^2 = \left((\varepsilon_s - \varepsilon_\infty)/2\right)^2$$

where ε_s and ε_∞ are the static dielectric constant, and the dielectric constant at infinite frequency, respectively. Thus the plot of ε' versus ε'' would be a single semicircle, which is usually defined as the Cole-Cole semicircle, and each semicircle corresponds to one Debye dipolar relaxation. Figure S4 shows ε'-ε'' curves of FeG300, FeG500 and FeG700 in the frequency range 2-18 GHz. Obviously, there are four semicircles for each curve, suggesting that there may be four dielectric relaxation processes. It is proved that the interface polarization effect contributes to the absorbing wave.





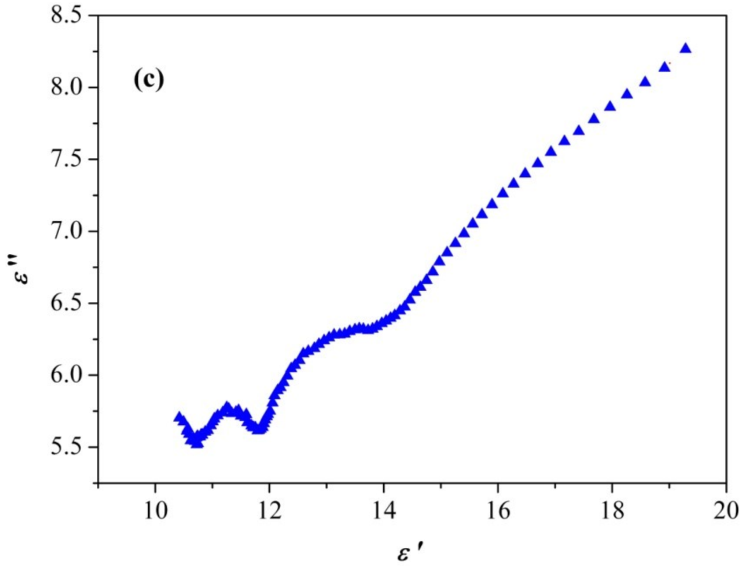


Figure S4. Typical Cole-Cole semicircles (ε' versus ε'') for FeG300(a), FeG500(b) and FeG700 (c) in the frequency range of 2-18 GHz.