Electronic Supplementary Information

Uniform Fe_3O_4 coating on flower-like ZnO nanostructures by atomic layer deposition for electromagnetic wave absorption

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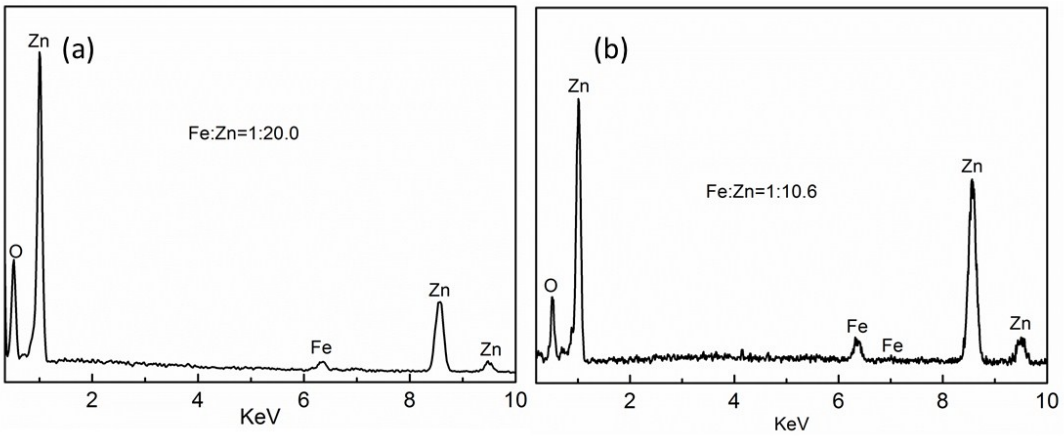

Fig. S1 EDS of ZnO@500-Fe_3O_4 and ZnO@1000-Fe_3O_4.

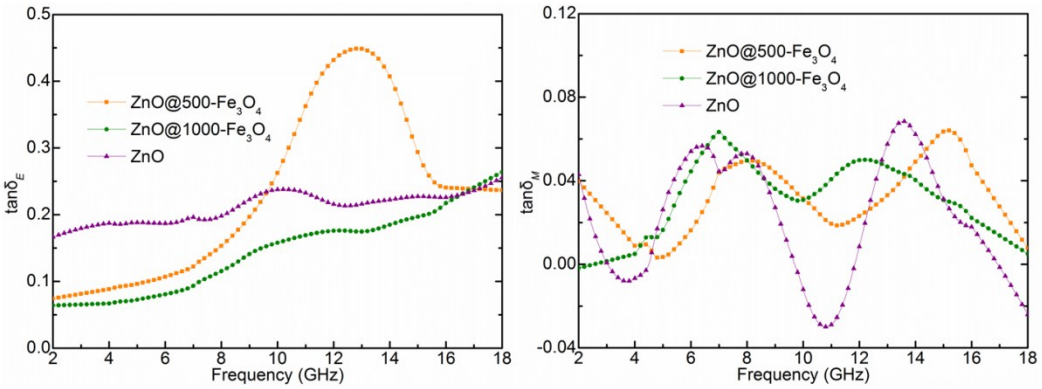

Fig. S2 The frequency dependence of dielectric loss and magnetic loss tangents of the ZnO–paraffin and ZnO@Fe_3O_4–paraffin.

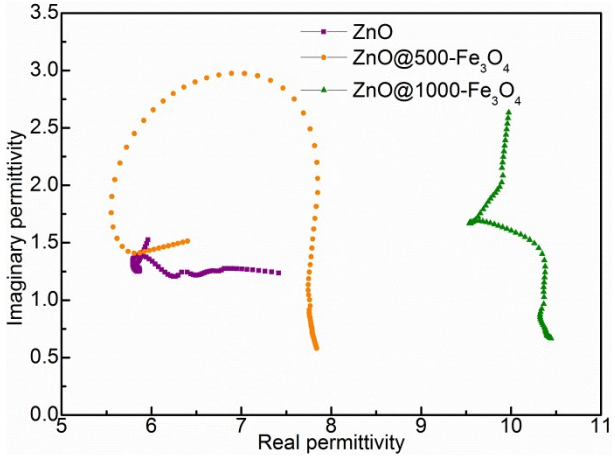

Fig. S3 Typical Cole–Cole semicircles (ε'' versus ε') for the ZnO–paraffin and ZnO@Fe_3O_4–paraffin in the frequency range of 2–18 GHz.

Conventionally the relaxation process which can be described by the Cole-Cole semicircle has an important influence on permittivity behaviors of microwave absorption materials. According to the Debye dipolar relaxation[1], the relative complex permittivity (ε_r) can be expressed by the following equation,

$$\varepsilon_r = \varepsilon' + i\varepsilon'' = \varepsilon_\infty + \frac{\varepsilon_s - \varepsilon_\infty}{1 + i\omega\tau_0} \quad (1)$$

where τ_0, ε_s, and ε_∞ are the relaxation time, the static dielectric constant, and the dielectric constant at infinite frequency, respectively. From eq 1, it can be deduced that

$$\varepsilon' = \varepsilon_\infty + \frac{\varepsilon_s - \varepsilon_\infty}{1 + (\omega\tau_0)^2} \quad (2)$$

$$\varepsilon'' = \frac{\omega\tau_0(\varepsilon_s - \varepsilon_\infty)}{1 + (\omega\tau_0)^2} \quad (3)$$

According to eqs 2 and 3, the relationship between ε' and ε'' can be further deduced,

$$(\varepsilon' - \frac{\varepsilon_s + \varepsilon_\infty}{2})^2 + (\varepsilon'')^2 = (\frac{\varepsilon_s - \varepsilon_\infty}{2})^2 \quad (4)$$

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 relaxation process. Plots of ε'' versus ε' for ZnO and ZnO@Fe_3O_4 composites are shown in Fig. S3, where four superimposed Cole-Cole semicircles are found for all the ZnO@Fe_3O_4 samples.

Reference

[1] Frenkel, J.; Doefman, J. Spontaneous and induced magnetisation in ferromagnetic bodies. Nature 1930, 126, 274–275.