Electronic Supplementary Information

Enhanced microwave absorption of ZnO coated with Ni nanoparticles produced by atomic layer deposition

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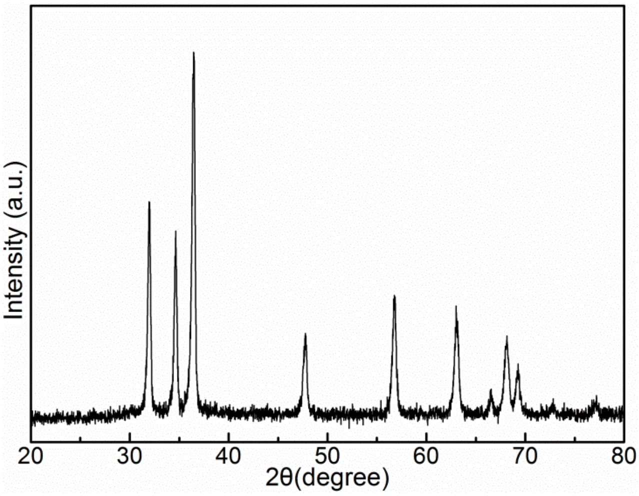


Fig. S1 XRD pattern of ZnO@NiO composites.

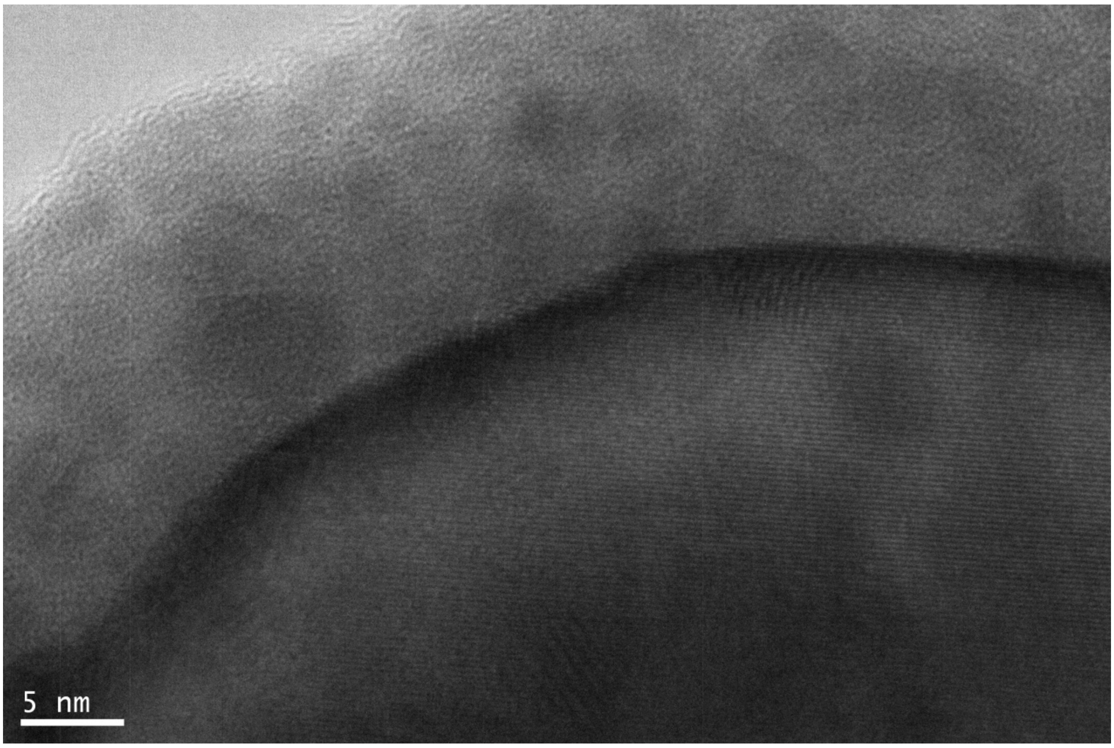


Fig. S2 HRTEM image of ZnO@NiO.

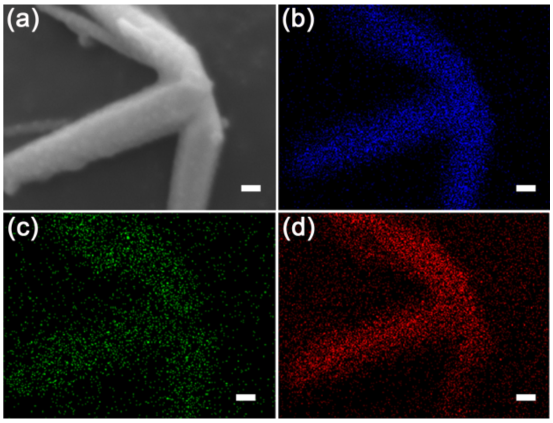


Fig. S3 (a) SEM of the ZnO@NiO and corresponding elemental mapping images of (b) Zn, (c) Ni and (d) O. Scale bar: 600 nm.

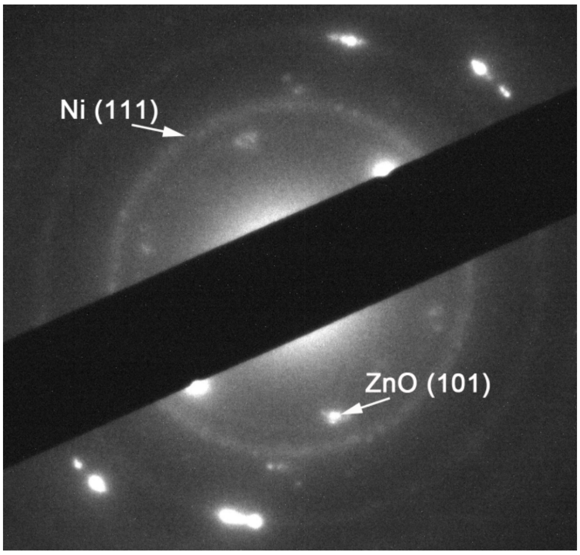


Fig. S4 SAED pattern of an individual ZnO@Ni nanorod.

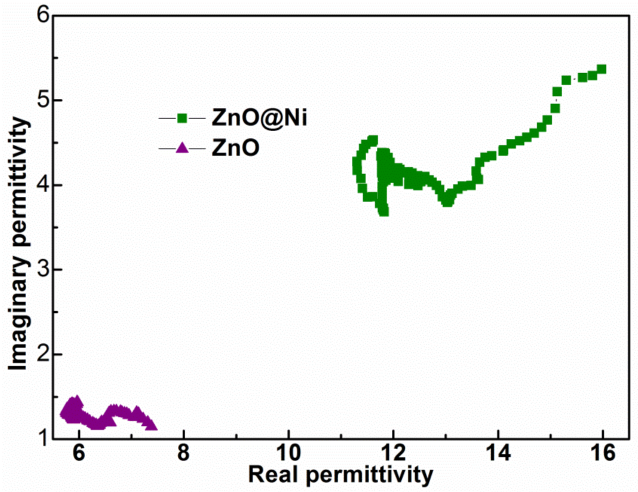


Fig. S5 Typical Cole–Cole semicircles (ε'' versus ε') for ZnO and ZnO@Ni composites in the frequency range of 2–18 GHz.

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

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

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

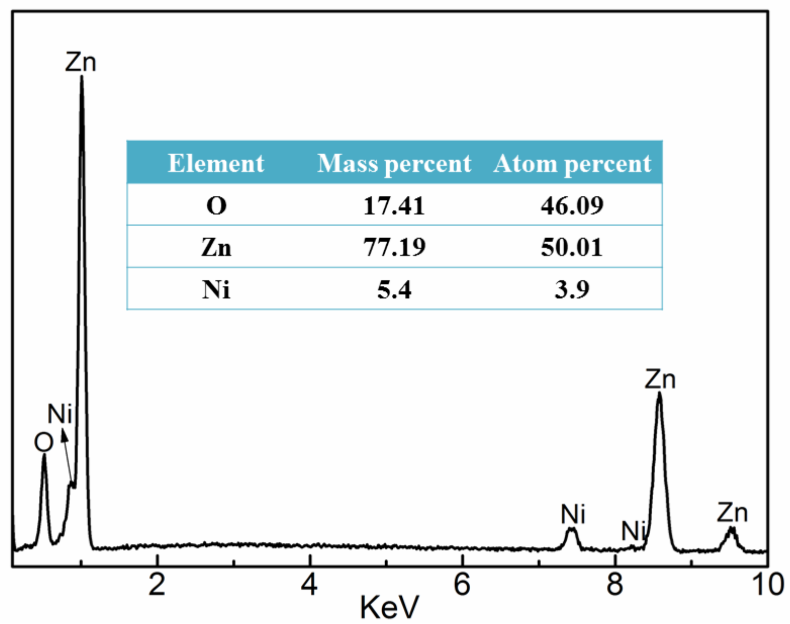
According to eqs 2 and 3, the relationship between ε' and ε'' can be further deduced,

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

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@Ni composites are shown in Fig. S5, where four superimposed Cole-Cole semicircles are found for the ZnO@Ni sample.

Reference

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



Element	Mass percent	Atom percent
O	17.41	46.09
Zn	77.19	50.01
Ni	5.4	3.9

Fig. S6 EDS of ZnO@Ni.