# Supporting Information

## A novel cellulose-derived graphite carbon/ZnO composite by atomic layer deposition as over-wideband microwave absorbents

*Guangguang Guan* [a,b], *Xiaoqiang Li* [c], *Jiebai Li* [a,b], *Meng Chen*[d], *Hongpeng Liu*[d], *Wenbo Zhang*[e], *Jingyuan Wei*[f], *Yangtao Zhou* [a*]

[a] Shenyang National Laboratory for Materials Science, Institute of Metal Research, Chinese Academy of Sciences, Shenyang, 110016, PR China

[b] School of Materials Science and Engineering, University of Science and Technology of China, Shenyang, 110016, PR China

[c] Institute of Materials Science and Engineering, Beijing University of Technology, Beijing 100124, PR China

[d] K.H. Kuo Center for Material Characterization, Liaoning Academy of Materials, 280 Chuangxin Road, Shenyang 110167, China

[e] Yingkou Science and Technology Innovation Service Center, Yingkou, 115004, China

[f] Liaoning Academy of Analytical Sciences, Shenyang, 110015, China

***Corresponding author.**

E-mail addresses: ytzhou@imr.ac.cn (Y. Zhou).

**Raw Materials**

Microcrystalline cellulose (MCC), concentrated sulfuric acid ($H_2SO_4$), hydrochloric acid (HCl), sodium hydroxide (NaOH) and urea were purchased from Sinopharm Chemical Reagent Co., Ltd. All the chemical reagents were directly used as received without further purification.

**Characterization**

The surface morphology, microstructure and crystal structure of samples were characterized by field emission scanning electron microscopy (FE-SEM, Zeiss-Supra 35), transmission electron microscopy (TEM, FEI Tecnai F20 G2) operated at 200 kV and X-ray diffractometry (XRD, Rigaku Ultima IV, Japan, Cu Kα radiation, 30 kV, 15 mA, λ = 0.15406 nm, $2\theta$ = 10°–75°). The chemical compositions were recorded by Fourier transform infrared spectroscopy (FT-IR, Bruker VERTEX 70v) and X-ray photoelectron spectroscopy (XPS, Kratos Axis Ultra (DLD), Al Kα radiation source) operated at 15 kV and 10 mA. Photoelectrons of XPS were collected from a 300*300 μm analysis area at an emission angle of 45° and a basic pressure of $10^{-5}$ Pa. The samples were not sputter-etched prior to XPS analysis. The vector network analyzer (Agilent PNA N5224A) was utilized to obtain the relative complex permittivity and permeability in the frequency range of 2.0-18.0 GHz for the calculation of reflection loss (RL). The ring-like composite specimens ($\Phi_{in}$ = 3.04 mm; $\Phi_{out}$ = 7.00 mm) used for test samples were pressed the homogeneous mixtures of the products and paraffin wax (PW). In general, electromagnetic (EM) wave absorption properties and associated mechanisms of absorbing materials are mainly determined by the relative complex permittivity ($\varepsilon_r = \varepsilon' - j\varepsilon''$)/permeability ($\mu_r = \mu' - j\mu''$). It is well known that the contribution to $\varepsilon''$ can be categorized into two components: conduction loss ($\varepsilon_c''$) and polarization relaxations ($\varepsilon_p''$). According to Debye's theory, the overall value of $\varepsilon''$ can be expressed as:

$$\varepsilon'' = \varepsilon_p'' + \varepsilon_c'' = \frac{(\varepsilon_s - \varepsilon_\infty)2\pi f\tau}{1 + (2\pi f)^2\tau^2} + \frac{\sigma}{2\pi f\varepsilon_0} \tag{S1}$$

$$\varepsilon_c'' = \frac{\sigma}{2\pi f\varepsilon_0} \tag{S2}$$

Where $\varepsilon_\infty$, $\varepsilon_s$, $\tau$, $\sigma$, $f$, and $\varepsilon_0$ are the high-frequency limit relative permittivity, the static permittivity, the polarization relaxation time, the electrical conductivity, microwave frequency and the permittivity in vacuum, respectively.

The microwave absorption properties of EM absorbents are usually evaluated with the RL values, which can be calculated from the measured $\varepsilon_r$ and $\mu_r$ data according to the transmission line theory as follows:

$$Z_{in} = Z_0\left(\mu_r/\varepsilon_r\right)^{1/2}\tanh\left[j(2\pi f d/c)\left(\mu_r\varepsilon_r\right)^{1/2}\right] \tag{S3}$$

$$RL = 20\lg\left|\left(Z_{in} - Z_0\right)/\left(Z_{in} + Z_0\right)\right| \tag{S4}$$

where $Z_{in}$ is the input impedance of the absorber, $Z_0$ is the impedance of free space, $d$ is the thickness of the absorber, and $c$ is the speed of light in a vacuum. In general, the RL below –10 dB is comparable to the dissipation of 90% EM energy, which is considered to be suitable for practical application. Hence, the absorbing frequency range for RL below –10 dB is usually defined as EAB.

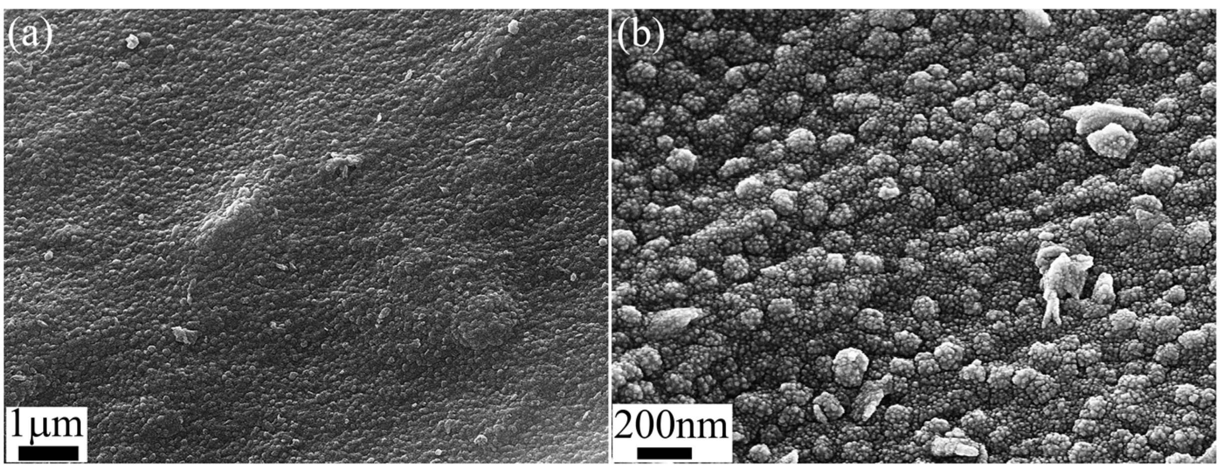


**Fig. S1.** SEM image of CGC@ZnO sample.

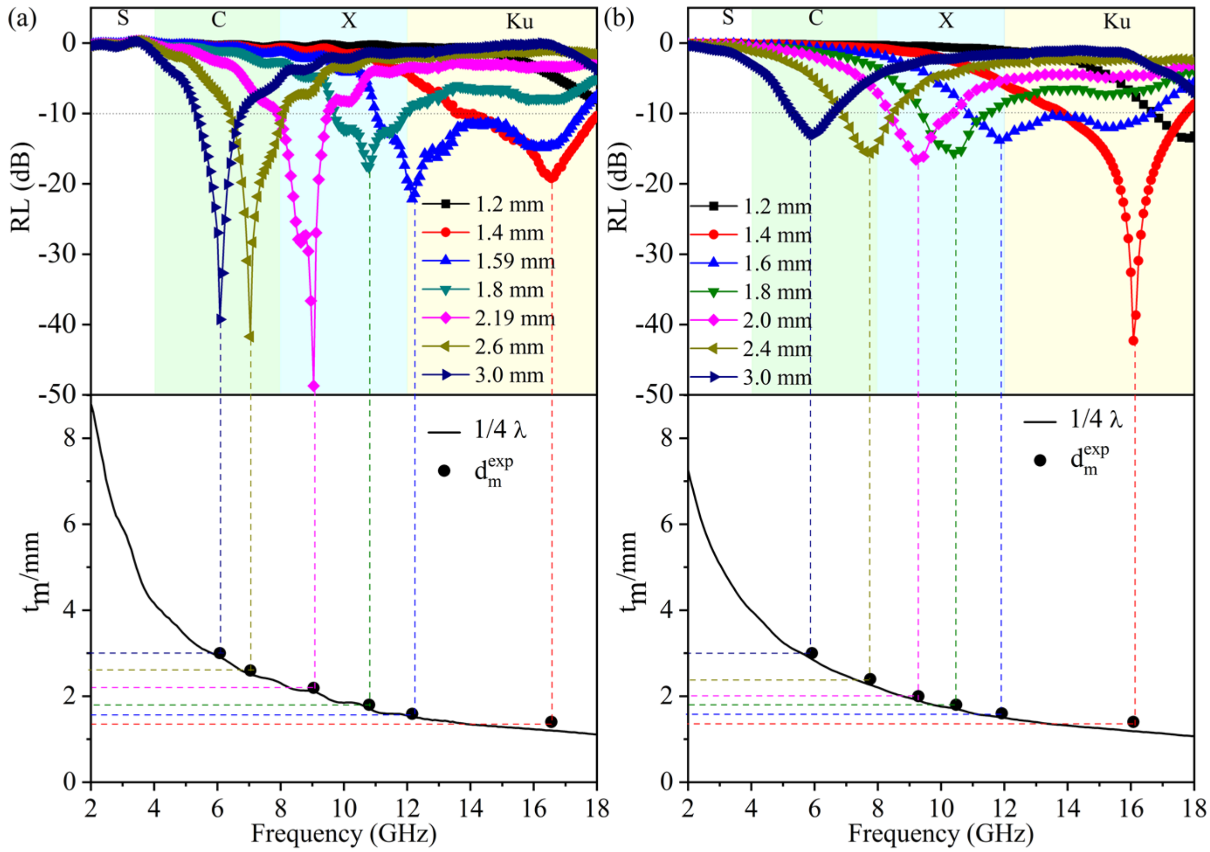


**Fig. S2.** Frequency dependence of matching thickness at λ/4 curves for (a) CZ-3 and (b) CZ-4.

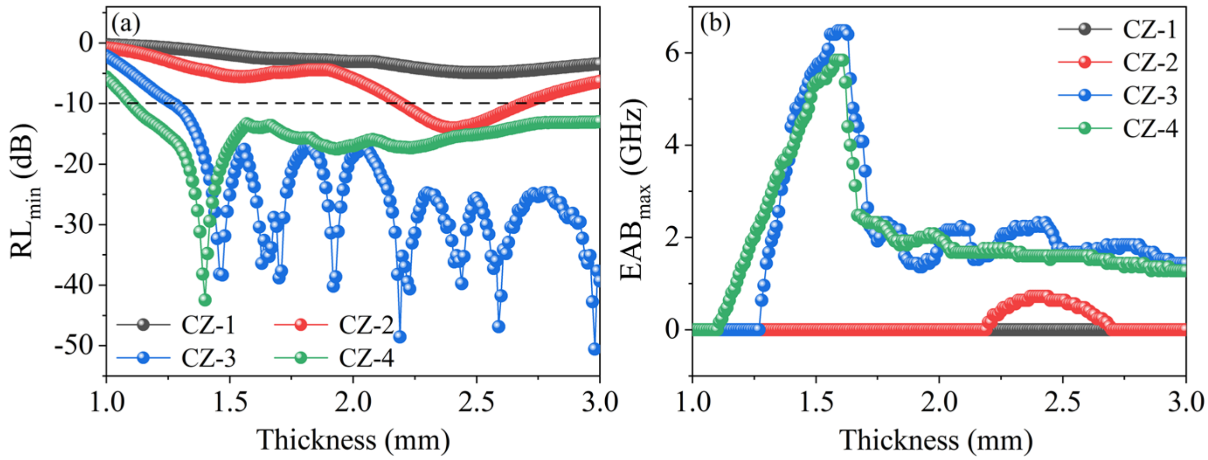


**Fig. S3.** (a) $RL_{min}$ and (b) $EAB_{max}$ of the four samples at different thicknesses.

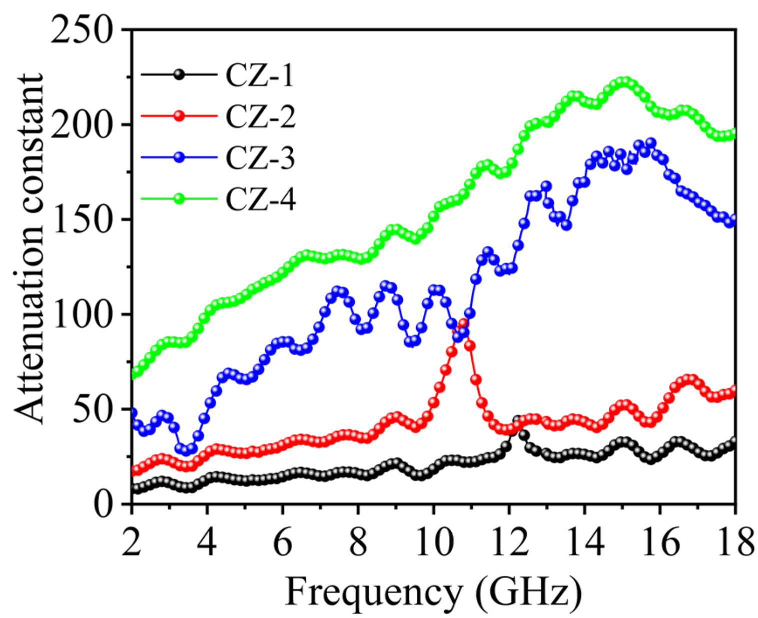


**Fig. S4.** Attenuation constant α of the CZ-1, CZ-2, CZ-3 and CZ-4.