Supporting Information

Synthesis of nitrogen-doped graphene aerogel modified by magnetic Fe_3O_4/Fe/C frameworks as an excellent dual-band electromagnetic absorber

Baohua Liu[a,1], Jing Xu[a,1], Ruiwen Shu[a,b*]

[a]*School of Chemical Engineering, State Key Laboratory of Mining Response and Disaster Prevention and Control in Deep Coal Mines, Anhui University of Science and Technology, Huainan 232001, China*

[b]*Joint National-Local Engineering Research Centre for Safe and Precise Coal Mining, Anhui University of Science and Technology, Huainan 232001, China*

*Corresponding Author:

Ruiwen Shu, Email: rwshu@aust.edu.cn

[1]The authors contributed equally to this work.

Experimental section

Characterization

Crystal structure was characterized by X-ray diffraction (XRD, LabX XRD-6000, Japan) with Cu-Kα radiation (λ = 0.154 nm) in the scattering range (2θ) of 15.0–80.0^{o} at a scanning rate of 2.0 ^{o}/min. The surface chemical composition and elemental valence states were characterized by X-ray photoelectron spectroscopy (XPS, Thermo ESCALAB 250XI, USA). The micromorphology was observed by a field emission scanning electron microscopy (FESEM, Hitachi-Su8020, Japan) and a field emission transmission electron microscopy (FETEM, FEI-TF20, USA) equipped with the energy dispersive spectrometer (EDS) device. The magnetic properties were measured by vibrating sample magnetometer (VSM, Nanjing NanDa Instrument Plant HH-20, China) at room temperature.

Electromagnetic parameters including the relative complex permittivity ($\varepsilon_r = \varepsilon'-j\varepsilon''$) and permeability ($\mu_r = \mu'-j\mu''$) were acquired using the vector network analyzer (VNA, Keysight-E5080B, USA) using the coaxial-line method in the frequency range of 2.0–18.0 GHz. The specimens were prepared by uniformly mixing the samples with paraffin wax at a filler loading ratio of 15.0 wt.%, and then pressed the mixtures into a toroidal-shaped ring with an outer diameter of 7.0 mm, an inner diameter of 3.04 mm and the thickness of 2.0 mm. It should be mentioned that the actual power level in dBm units of the incident electromagnetic radiation was used for the measurement of electromagnetic parameters.

The electromagnetic wave (EMW) absorption performance of absorbers was evaluated by the reflection loss (*RL*), which could be calculated by the following equations according to the transmission line theory:[1-3]

$$RL(\text{dB}) = 20\lg\left|\frac{Z_{\text{in}} - Z_0}{Z_{\text{in}} + Z_0}\right| \tag{S1}$$

$$Z_{\text{in}} = Z_0\sqrt{\frac{\mu_{\text{r}}}{\varepsilon_{\text{r}}}}\tanh\left[j\left(\frac{2\pi fd}{c}\right)\sqrt{\mu_{\text{r}}\varepsilon_{\text{r}}}\right] \tag{S2}$$

Herein Z_0 represents the impedance of air, Z_{in} signifies the input impedance of the sample, ε_r is the relative complex permittivity, μ_r is the relative complex permeability, d is the thickness of the absorber, c is the velocity of light in free space and f is the frequency. Generally, the EMW absorbers with $RL \leq$ -10.0 dB are considered to be suitable for the practical application.[1-3]

The computer simulation technology (CST) Studio Suite 2020 was used to simulate the radar cross section (RCS) under far-filed response of an EMW absorber. A double layer cuboid model was established on the x-o-y plane which was using perfect electronic conductor (PEC) and samples as the substrate and the coverings, respectively. The frequency of 16.0 GHz was selected as the filed detection frequency. Theta and phi were the scattering directions in spherical coordinates, separately. The directional far-filed response was calculated using the RCS of the simulated samples, which could be defined by the following formula:[4]

$$\sigma\left(\text{dBm}^2\right) = 10\log\left(\frac{4\pi S}{\lambda^2}\left|\frac{E_{\text{s}}}{E_{\text{i}}}\right|\right)^2 \tag{S3}$$

Where S denotes the area of the simulation model, λ is the wavelength of incident wave. E_s and E_i refer to the electric filed intensity of scattered wave and incident wave at the receiving position, severally.

References

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