Electronic Supplementary Information ESI

**Electromagnetic and Microwave Absorbing Properties of Magnetic Nickel Ferrite Nanocrystals**

Weimo Zhu\textsuperscript{a}, Lei Wang\textsuperscript{a}, Rui Zhao\textsuperscript{b}, Jiawen Ren\textsuperscript{a}, Guanzhong Lu\textsuperscript{a} and Yanqin Wang\textsuperscript{a}\textsuperscript{*}

\textsuperscript{a} Key Lab for Advanced Materials, Research Institute of Industrial Catalysis, East China University of Science and Technology, Shanghai 200237, P. R. China.

Fax: 86 21 6425 3824; Tel: 86 21 6425 3824; E-mail: wangyanqin@ecust.edu.cn

\textsuperscript{b} Research Branch of Functional Polymer Composites, Institute of Microelectronic and Solid State Electronic, University of Electronic Science and Technology of China, Chengdu 610054, PR China E-mail: ruizhao@uestc.edu.cn

1. **Experimental and characterization section**

1.1 **Synthesis**

Sodium oleate (Chemical pure) and other analytical grade chemicals (including FeCl\textsubscript{3}·6H\textsubscript{2}O, NiCl\textsubscript{2}·6H\textsubscript{2}O, urea and ethanol) were purchased from Sinopharm Chemical Reagent Co.Ltd, and were used without further purification. The deionized water was self-made.

I) Synthesis of Ni\textsuperscript{2+}Fe\textsuperscript{3+}–oleate precursors

The precursors were synthesized by the coprecipitation of oleate anions with Ni\textsuperscript{2+}, Fe\textsuperscript{3+} metal cations. First, 4mmol FeCl\textsubscript{3}·6H\textsubscript{2}O and 2mmol NiCl\textsubscript{2}·6H\textsubscript{2}O were dissolved 10 mL deionized water to form solution I, and 16mmol sodium oleate was dissolved in 40 mL water/ethanol mixture solvent (1:3, v/v) to form solution II. Then solution I was dropped into solution II slowly with magnetic stirring to get oleate complex. The as-prepared precursors were washed by the above mentioned mixture solvent several times to remove the impurities and then dried in vacuum at 100 °C to obtain the pure Ni\textsuperscript{2+}Fe\textsuperscript{3+}–oleate complex. In order to facilitate the magnetic stirring...
and washing process, the synthesis of Ni$^{2+}$Fe$^{3+}$--oleate precursors can be operated at certain temperature, e.g. 60 °C.

II) Synthesis of NiFe$_2$O$_4$ nanocrystals

4.0 g self-made Ni$^{2+}$Fe$^{3+}$--oleate complex was put in the Teflon-lined stainless steel autoclave, and a certain amount of alkali solution was added. The alkali solution was made of 3.0 g urea and 40 mL water/ethanol mixture solvent (1:1, v/v). Then, the autoclave was sealed and heated at 180 °C for 6 hours. After cooling down to room temperature automatically, the product was collected by centrifugation, washed with deionized water and ethanol, and finally dried in vacuum at 50 °C.

1.2 Characterization

The synthesized NiFe$_2$O$_4$ was characterized by wide-angle X-ray diffraction (WAXRD) on a Rigaku D/MAX-2550VB/PC diffractometer (Cu K$\alpha_1$ radiation, $\lambda=1.5406\AA$), operated at 40kV and 100mA, Transmission electron microscopy (TECNAI 20S-TWIN) and commercial (SQUID) magnetometer. For the measurement of microwave absorption properties, the synthesized NiFe$_2$O$_4$ nanocrystals were mixed with paraffin (weight ratio=1:3) and then pressed into a toroidal sharp with outer diameter of 7mm and inner diameter of 3mm. The complex permittivity and complex permeability were measured by an Agilent Vector Network Analyzer 8720 in the frequency of 2-18GHz.

2. Transmission line theory and details of simulation results by using Matlab

(1) Transmission line theory

For a single-layer absorbing material backed by a perfect conductor, the input impedance ($Z_{in}$) at the air-material interface is given by

$$
\varepsilon_r \left( \varepsilon_r = \varepsilon^' - j\varepsilon^'' \right) \\
\mu_r \left( \mu_r = \mu^' - j\mu^'' \right) \\
Z_{in} = Z_0 \sqrt{\frac{\mu_r}{\varepsilon_r}} \tan \left( j \frac{2\pi fd}{c} \sqrt{\mu_r \varepsilon_r} \right)
$$

Where $d$ is the thickness of the absorber, $f$ is the frequency, $c$ is the velocity of light, $\mu_r$ is the complex permeability, and $\varepsilon_r$ is the complex permittivity. The reflection loss of normal incident electromagnetic wave at the absorber surface is given by
\[ R = 20 \log \left| \frac{Z_{\text{in}} - Z_0}{Z_{\text{in}} + Z_0} \right| \]

where \( Z_0 \) is the impedance of air.

(2) Details of simulation

The simulation program for calculating Reflection Loss by using Matlab software based on Transmission Line Theory.

(1) \% The determination of reflection loss.;
(2) \( D = \begin{bmatrix} \% the first data \% frequency (GHz) \epsilon' \epsilon'' \mu' \mu'' \\ 1. \ 0.500000 \ 225.039981 \ 1274.955 \ 0.901 \ 0.154 \\ 2. \ XXXXXXXXXXXXXXXXXXXXXXXXXXXX \end{bmatrix}; \)

(3) \% Note the match thickness;
(4) for \( m=1:201 \)
(5) \( Z_0=377; \)
(6) \( U_r=D(m,4)-i*D(m,5); \)
(7) \( E_r=D(m,2)-i*D(m,3); \)
(8) \( R=i*2*pi*D(m,1)/300000000*sqrt(U_r*E_r); \)
(9) \( Z_{\text{in}}=Z0*sqrt(U_r/E_r)*\tanh(R*H); \)
(10) \( T=(Z_{\text{in}}-Z0)/(Z_{\text{in}}+Z0); \)
(11) \( \text{Ref}(1,m)=20*log10(abs(T)); \)
(12) end
(13) \text{plot}(D(1:201,1),\text{Ref}(1,1:201))
(14) \% Note the match thickness
(15) \text{xlabel}(\text{Frequency/Hz});
(16) \text{ylabel}(\text{Reflection loss/dB});
(17) \text{A}=\text{ref};