Electronic Supplementary Information ESI

Electromagnetic and Microwave Absorbing Properties of Magnetic Nickel Ferrite Nanocrystals

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1. Experimental and characterization section

1.1 Synthesis

Sodium oleate (Chemical pure) and other analytical grade chemicals (including $FeCl_3 \cdot 6H_2O$, $NiCl_2 \cdot 6H_2O$, 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^{2+} $Fe^{3+}{}_2$–oleate precursors

The precursors were synthesized by the coprecipitation of oleate anions with Ni^{2+}, Fe^{3+} metal cations. First, 4mmol $FeCl_3 \cdot 6H_2O$ and 2mmol $NiCl_2 \cdot 6H_2O$ were dissolved10 mL deionized water to form solution I, and16mmol 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 $Ni^{2+}Fe^{3+}{}_2$-oleate complex. In order to facilitate the magnetic stirring and washing process, the synthesis of $Ni^{2+}Fe^{3+}{}_2$–oleate precursors can be operated at certain temperature, e.g. 60 °C.

II) Synthesis of $NiFe_2O_4$ nanocrystals

4.0 g self-made $Ni^{2+}Fe^{3+}{}_2$–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 $NiFe_2O_4$ was characterized by wide-angle X-ray diffraction (WAXRD) on a Rigaku D/MAX-2550VB/PC diffractometer (Cu $K\alpha_1$ radiation, λ=1.5406*Å*), operated at 40*kV* and 100*mA*, Transmission electron microscopy (TECNAI 20S-TWIN) and commercial (SQUID) magnetometer. For the measurement of microwave absorption properties, the synthesized $NiFe_2O_4$ nanocrystals were mixed with paraffin (weight ratio=*1:3*) and then pressed into a toroidal sharp with outer diameter of 7*mm* and inner diameter of 3*mm*. The complex permittivity and complex permeability were measured by an Agilent Vector Network Analyzer 8720 in the frequency of 2-18*GHz*.

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

$$\varepsilon_r \ (\varepsilon_r = \varepsilon' - j\varepsilon'')$$

$$\mu_r \ (\mu_r = \mu' - j\mu'')$$

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

Where d is the thickness of the absorber, f is the frequency, c is the velocity of light, μ_r is the complex permeability, and ε_r is the complex permittivity. The refection loss of normal incident electromagnetic wave at the absorber surface is given by

$$R = 20\log\left|\frac{Z_{in} - Z_0}{Z_{in} + Z_0}\right|$$

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 = [% the first data % frequency (GHz) ε′ ε″ μ′ μ″

1. 0.500000 225.039981 1274.955 0.901 0.154
2. XXXXXXXXXXXXXXXXXXXXXXXXXXXXX

（experimental data）];

(3) H=0.005; % 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 (Ur*Er);

(9) Z_{in}=Z0*sqrt (U_r/E_r)*tanh (R*H);

(10) T= (Zin-Z0) / (Zin+Z0);

(11) Ref (1,m) =20*log10 (abs (T));

(12) end

(13) plot (D (1:201,1) ,ref (1,1:201))

(14) title ('Reflection loss of composites for varying the thickness of the absorbant. ');% Note the match thickness

(15) xlabel ('Frequency/Hz');

(16) ylabel ('Reflection loss/dB');

(17) A=ref';