Preparation and Property of Wireless Charging Magnetic Coupling Component Used Core-Shell Magnetic Nanoparticle

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Abstract. In order to improve the performance of magnetically coupled material, this paper illustrates the synthesis of Core-shell magnetic nanoparticle exploiting microwave plasma. Result shows that the core w is comprised of pure Fe and shell is comprised of ferric oxide .The radius and thickness of core is about 8nm and 2nm respectively. Obtained nanoparticle shows great dispersity. The result of mathematical model calculation which obtained from Core-shell magnetic particle is consistent with the experiment result.

1 Introduction

An urgent need for wireless charging promote magnetic material and magnetic component[1], because special doping Ferrite Magnetic material has great magnetic property, which is important to Magnetically coupled component. Research shows that magnetic nanoparticle doped Ferrite material has high Magnetic flux density and low high-frequency loss, which are suitable for wireless charge system. However, magnetic nanoparticle shows properties of reunion and oxidation, both do damage to stability. An efficient solution is that coating a dense, anti-oxidated, easy and stable dispersed shell on the surface of nanoparticle. The key points of exploring high-performance magnetic nanoparticle are synthesize Core-shell magnetic nanoparticle and stable dispersion, both are hot topics now[2-10].

This paper illustrates the research on the synthesis of Core-shell magnetic nanoparticle using microwave plasma. We are looking forward to synthesizing magnetic particle with good dispersity and build mathematical model of Core-shell magnetic nanoparticle which can illustrate their property.

2 Experiment

DT4 pure Fe is used as raw material; Low-temperature plasma nanoparticle generator, which take advantage of microwave plasma, is used in the process where nanoparticle is synthesized, so all the processes including production, capture, stable dispersion work under normal temperature, normal pressure, oxygen free and air tightness constantly.

Then, Core-shell magnetic nanoparticleis obtained after in-situ epitaxial growth of anti-oxidatedshell. D/max-2500/PC X ray diffractometer, TECNAIG2 transmission electron microscope, Quanta 250FEG scanning electron microscope is used in physical and chemical analysis.

3 Result and analysis

3.1 Microstructure

Fi.1 is TEM image of Core-shell magnetic nanoparticle, Fig.2 is EDS image.Fig.3 is TEM diffraction pattern of magnetic nanoparticle. Fig.4 is XRD spectrum of magnetic nanoparticle.
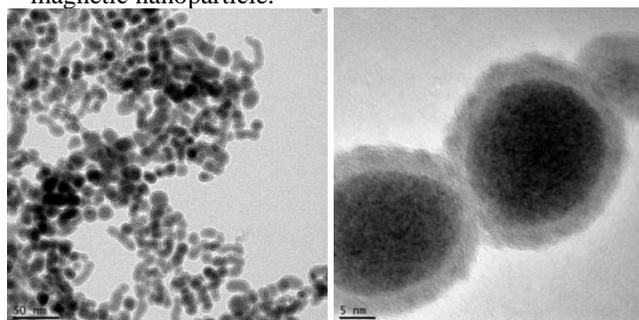

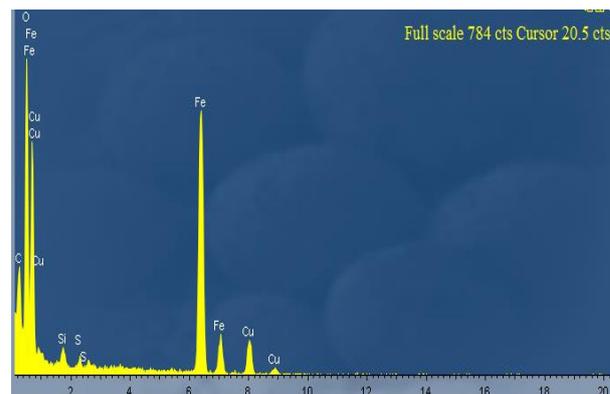**Fig.1.** TEM image of Core-shell magnetic nanoparticles

Fig.2. EDS image of Core-shell magnetic nanoparticles

From images we can see, the magnetic nanoparticles obtained from the mentioned process have uniform grain

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size. The nanoparticle, which consists of an inner dense center encapsulated inside a light colored shell, has grain size vary from 5nm to 10nm. After in-situ epitaxial growth process for magnetic nanoparticle, controllable in-situ growth of anti-oxidated shell is available on the surface of magnetic nanoparticle's crystal nucleus. The obtained Core-shell magnetic nanoparticle has great densification. Also, energy spectrum analysis shows that the shell is comprised of Fe_3O_4 and core is comprised of pure Fe.
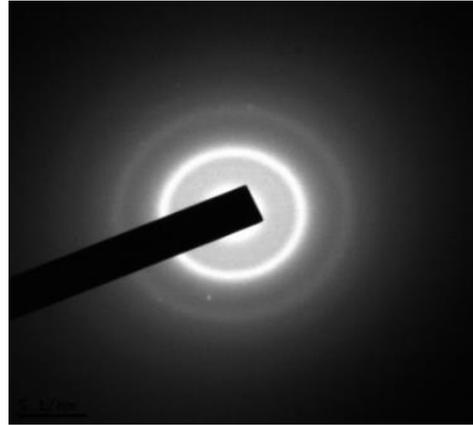

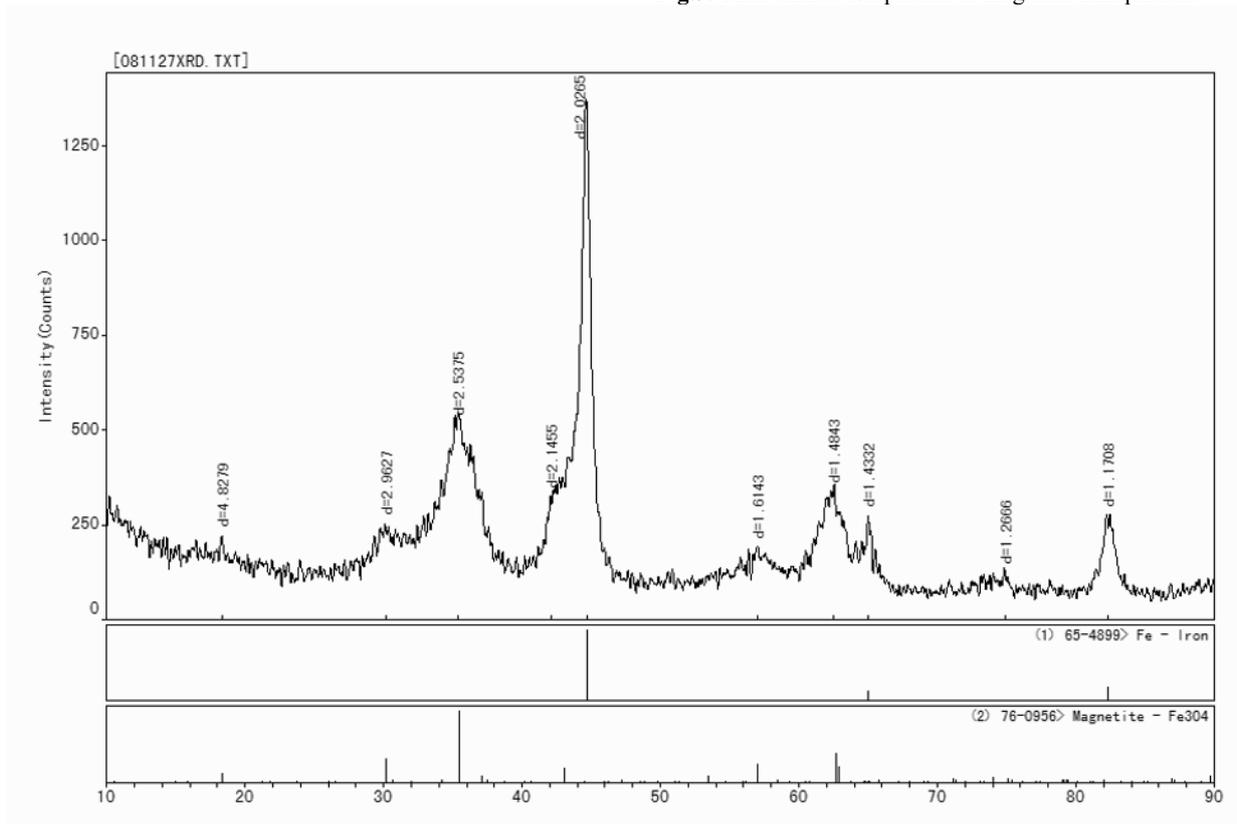**Fig.3.** TEM diffraction pattern of magnetic nanoparticle

Fig.4. XRD spectrum of magnetic

3.2 Dispersity of Magnetic nanoparticle

Fig.5 is the TEM image of Core-shell magnetic nanoparticle after dispersion, stable dispersion can be seen from the image. Also, the great sphericity of ferric core enable in-situ epitaxial growth of ferric oxide which comprises shell on core and then produce a ceramic-liked dense layer, so Core-shell magnetic nanoparticle synthesized has great mobility, which is important for stable dispersion. The main application of this particle is dopant for soft magnetic component since the great mobility and dispersity is good for dopant doping in main base material for shaping process.
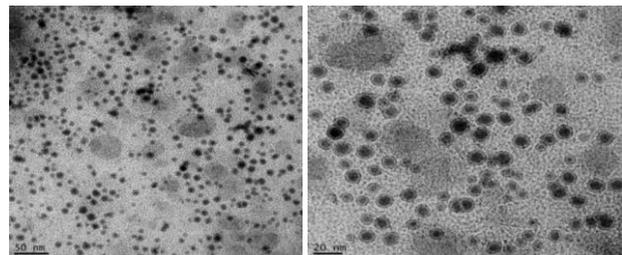

Fig.5. TEM image of Core-shell magnetic nanoparticle after dispersion

4 Characterization and Model building of Core-shell magnetic nanoparticle

Core-shell magnetic nanoparticle has high specific surface area, large surface energy, high surface activity

and is unsaturated, so this nanoparticle is totally different with normal particle. Compared with past research which focused on synthesis, structure and application, this paper based on basic concept of magnetization, build and characterize the mathematical model of Core-shell magnetic nanoparticle in order to rich the mechanism research of Core-shell magnetic nanoparticle.

Assume that ρ_l, m_l, V_l is density, mass and volume of Core-shell nanoparticle respectively.

ρ_c, m_c, V_c is density, mass and volume of space between particles respectively.

ρ_d, m_d, V_d is density, mass and volume of surfactant respectively.

ρ_m, m_m, V_m is density, mass and volume of core respectively.

ρ_o, m_o, V_o is density, mass and volume of magnetic shell respectively.

r is radius of core.

δ_1 is the thickness of shell structure.

δ_2 is the thickness of surfactant.

n-V_l is the number of magnetic particle per volume.

n^* is density of particles.

M_s is the saturation magnetization of magnetic particle.

I ischaracteristic saturation magnetization for material.208emu/g for Fe.

Density and radius are already known, so the relationship of M_S, n, r can be obtained, according to the basic concept of magnetization:

$$M_S = \frac{I \times m_m}{m_l} = \frac{I \times \rho_m \times V_m}{V_l \times \rho_l} \tag{1}$$

$$m_m + m_0 + m_c + m_d = m_l \tag{2}$$

$$m_m = n \times \frac{4}{3}\pi r^3 \times \rho_m \tag{3}$$

$$m_o = n \times \frac{4}{3}\pi\left[(r+\delta_1)^3 - r^3\right] \times \rho_o \tag{4}$$

$$m_d = n \times \frac{4}{3}\pi\left[(r+\delta_1+\delta_2)^3 - (r+\delta_1)^3\right] \times \rho_d \tag{5}$$

$$m_c = V_c \times \rho_c \tag{6}$$

$$V_m = n \times \frac{4}{3}\pi r^3 \tag{7}$$

$$V_d = n \times \frac{4}{3}\pi\left[(r+\delta)^3 - r^3\right] \tag{8}$$

$$\rho_l = \frac{m_m + m_o + m_d + m_c}{V_l} \tag{9}$$

$$n^* = \frac{n}{V_l} \tag{10}$$

$$r + \delta_1 = R \tag{11}$$

From (1) to (11) :

$$M_s = \frac{I \times \rho_m \times n \times 4\pi r^3}{3\rho_l V_l} = \frac{I \times \rho_m \times n \times 4\pi r^3}{3\rho_l V_l} \tag{12}$$

$$\rho_l = \{n\frac{4}{3}\pi r^3 \rho_m + n\frac{4}{3}\pi[R^3 - r^3]\rho_o + n\frac{4}{3}\rho_d\pi[(R+\delta_2)^3 - R^3]$$
$$+ \rho_c[V_l - n\frac{4}{3}\pi(R+\delta_2)^3]\}/V_l \tag{13}$$

$$n = \frac{3M_s\rho_l V_l}{4\pi d\rho_m r^3} \tag{14}$$

Put (12) into (13):

$$\rho_l = \rho_c + \frac{3M_s\rho_l\{\frac{4}{3}\pi r^3\rho_m + \frac{4}{3}\pi[R^3 - r^3]\rho_o + \frac{4}{3}\rho_d\pi[(R+\delta_2)^3 - R^3] - \frac{4}{3}\pi\rho_c(R+\delta_2)^3\}}{4\pi d\rho_m r^3} \tag{15}$$

$$r = \left[\rho_l M_s \frac{(R+\delta_2)^3(\rho_d - \rho_c) + R^3(\rho_o - \rho_d)}{\rho_m I(\rho_l - \rho_c) + M_s\rho_l(\rho_o - \rho_m)}\right]^{\frac{1}{3}} \tag{16}$$

$$\delta_1 = R - \left[\rho_l M_s \frac{(R+\delta_2)^3(\rho_d - \rho_c) + R^3(\rho_o - \rho_d)}{\rho_m I(\rho_l - \rho_c) + M_s\rho_l(\rho_o - \rho_m)}\right]^{\frac{1}{3}} \tag{17}$$

$$n^* = \frac{n}{V_l} = \frac{3M_s\rho_l}{4\pi d\rho_m r^3} \tag{18}$$

MS is known by vibrating sample magnetometer. Other known parameters are showed in Table 1:

Table 1. Known parameters of Core-shell magnetic nanoparticle

ρ_l(g/cm^3)	ρ_c(g/cm^3)	ρ_d(g/cm^3)	ρ_m(g/cm^3)	ρ_0 (g/cm^3)
1.6	0.69	0.91	7.86	5.24
δ_2(cm)	M_s(emu/g)	I (emu/g)	V_1 (mm^3)	R/cm
2×10^{-7}	50	208	0.06	10×10^{-7}

Calculated results :

r = 7.6 nm
δ_1 = 2.3 nm
n^* = 2.5×10^{16} /mm^3

The result is consistent with what is obtained from TEM image.

5 Conclusions

(1) Synthesis Core-shell magnetic nanoparticle using microwave plasma.
(2) Obtained magnetic nanoparticle shows great dispersity.
(3) The calculation result of mathematic model is consistent with what is obtained from experiment.

Acknowledgement

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