Study on the Properties of Ni-Zn Ferrites Prepared by Using Nano-Size ZnO

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Keywords: Ni-Zn Ferrite, Power loss, Permeability, Resistivity, Microstructure

Abstract. The present work reported and discussed the results of investigation of employing nano-ZnO and general ZnO (AR grade) to prepare $Ni_{0.5}Zn_{0.5}Fe_2O_4$ ferrites. The samples were prepared by using conventional ceramic processing route and sintered between 1150-1250°C. The comparison of sintered samples made by employing nano-ZnO and made by employing general ZnO powder shows that the use of nano-ZnO could increase the chemical activity of starting materials, improve the densification and homogeneity of sintered bodies, enhance the electrical and magnetic properties of Ni-Zn ferrites.

Introduction

Ni-Zn ferrites are used widely as magnetic devices in telecommunication and electronic industries because they possess excellent magnetic properties suitable for working at high frequency[1-4].. Particularly, they can be produced by simple ceramic processing without the requirement of controlling sintering atmosphere.

It is well known that the properties of ferrite are mainly controlled by composition, starting materials and employed processing method. Recently, many commercial nano-chemicals have been produced with the development of nanotechnology. However, little systematic study has been carried out on the effects of using nano-chemicals on the processing of Ni-Zn ferrites, especially their magnetic and electrical properties. The present work shows the results of investigation on the influence of employing nano-ZnO in a typical Ni-Zn ferrite composition, comparison of its sintered density, resistivity, power loss and microstructure with the Ni-Zn ferrites produced by using general chemicals.

Experimental Procedures

Sample Preparation. The ferrite samples used in this study were based on a typically commercial formula: $Ni_{0.5}Zn_{0.5}Fe_2O_4$. All starting materials were analytic grade oxides, the average particle size of nano-ZnO is about 60 nm. They were mixed in deionised water with agate balls for 20 hours by ball milling. After drying, granules were obtained by passing the dried powders through a screen having an aperture mesh of nominally 0.3mm. The small disc shape samples (12mm diameter, 3mm height.) and the toroid samples (25mm outside diameter, 18mm inside diameter, and 3mm height) were pressed by a uniaxial press at 80MPa. The samples were sintered at temperatures over the range 1150-1250°C for 2 hours in air, with both heating and cooling rates at 3°C/min. The samples prepared by general chemicals were designated as C samples, and the samples prepared by nano-ZnO were designated as N samples.

Characterization. The sintered densities of the samples were determined according to the mass and volume of sample. Before electrical measurements, sliver electrodes were applied to both sides of the disc samples. The resistances of disc samples were determined by using a LCR meter (Victor VC9018). The resistivities were computed out according to the measured resistances and the

geometry of discs. The power loss of sintered Ni-Zn ferrite toroids were determined by using two windings (both primary and secondary coils are 50 turns) and sample geometries by an ac magnetic property measuring equipment (TY-2000A). The testing flux density is 0.08T and the testing frequencies are 30 kHz and 50 kHz respectively. The microstructures of samples were examined by using a scanning electron microscope (JSM-6360LV) equipped with energy dispersive spectrometer (EDS).

Results

Sintered Density. Table 1 shows the comparison of sintered densities of samples at different sintering temperatures. It indicates that the samples prepared by nano-ZnO (N sample) could achieve higher densities at all sintering temperatures. Obviously, the high sintering temperature enhances the densification of Ni-Zn ferrites.

Table 1 The sintered densities of samples

Sintering Temperature（℃）	1150	1200	1250
Sintered Density for C Samples（g/cm^3）	3.57±0.01	4.21±0.02	4.35±0.02
Sintered Density for N Samples（g/cm^3）	3.62±0.01	4.22±0.01	4.42±0.02

Resistivity. Fig.1 shows the resistivities of Ni-Zn ferrite samples as a function of sintering temperatures. It is interesting to see that the resistivities of N samples decrease with the increase of sintering temperature, but the resistivities of general Ni-Zn ferrites have the maximum value obtained at the samples sintered at 1200°C. The trend of the resistivities indicates that the N samples can achieve the higher resistivities than those C samples, which could be due to the effect of using nano-ZnO.

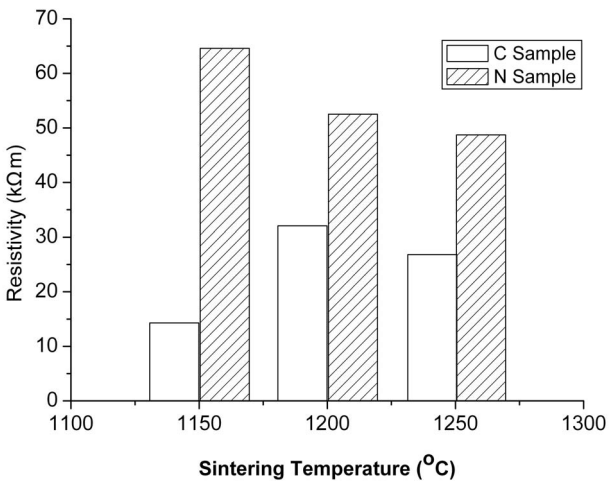


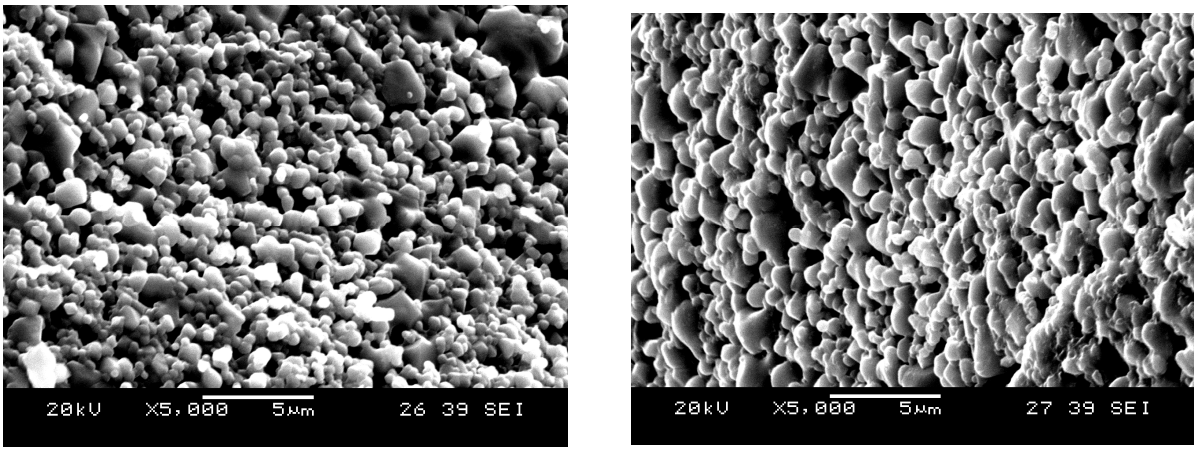
Fig. 1 The resistivity of samples

The permeability and power loss. The permeability and power loss are two of important magnetic properties for soft ferrites. The permeability and power loss of both Ni-Zn ferrite samples are shown in Table 2. It is obvious that the samples made by using nano-ZnO (N samples) have higher permeability's than those of general samples. The testing frequencies were 30 kHz and 50 kHz respectively. Furthermore, the samples sintered at higher temperature have higher values of permeability's. From Table 2, it can also be seen that the N samples have less power losses than those of C samples. The power losses of samples increased with higher sintering temperature.

Table 2 The permeability and power loss of samples

	Permeability μ_m (mH/m)				Power Loss (W/Kg)			
	30kHz		50kHz		30kHz		50kHz	
Samples	C	N	C	N	C	N	C	N
1150℃ sintered	0.46±0.01	0.68±0.01	0.45±0.01	0.68±0.01	20.8±0.1	13.3±0.1	33.0±0.2	20.3±0.1
1250℃ sintered	0.52±0.01	0.75±0.01	0.51±0.01	0.74±0.01	60.8±0.3	51.8±0.2	103.9±0.3	88.3±0.2

Microstructure. The typical SEM micrographs of samples sintered at 1150°C are shown in Fig.2. It can be clearly seen that the grain size of N sample (Fig.2b) is more uniform and the sintered body looks denser, which may be due to the more chemical activity of nano-ZnO. This is why the sintered density of N sample is higher than that of C sample. The roughly estimated average grain size is 1.1±1.6μm for C sample and 1.0±0.8μm for N sample.



(a) (b)

Fig. 2 Typical SEM micrographs of Ni-Zn ferrites sintered at 1150°C, (a) C sample; (b) N sample

Discussion

The permeability and power loss are two of important magnetic properties for soft ferrites. Usually the influence factors for the permeability are formulation, staring materials, processing route and the resulting microstructure. If the formulation and processing route are same, the ferrites with larger and more uniform grain size have higher permeability.[4-7] In this experiment, the samples made by using nano-ZnO (N samples) have similar grain size and better uniformity, these may be attributed to the higher chemical activity of nano-ZnO powder. Therefore, they have higher permeability than those of general samples. At higher sintering temperature, the higher permeability can be attributed to the larger average grain size.

Generally the power loss P_L of ferrite materials consists of three components, i.e., the hysteresis loss P_h, eddy current loss P_e, and residual loss P_r. Since the residual loss P_r is only of importance at very low induction levels or at high frequency (>500kHz) [8-10], the power loss can be expressed as following:

$$P_L = P_h + P_e \quad (1)$$

For the materials operating at typical frequencies P_h and P_e can be given as [8, 9, 11]:

$$P_h = C_h B^3 f \quad (2)$$

$$P_e = C_e B^2 f D^2 / \rho \quad (3)$$

where C_h, and C_e, are the coefficients for hysteresis loss and eddy current loss, respectively, B is

flux density (Tesla), f is frequency (kHz), D is the average grain size (μ m) and ρ is resistivity(Ω m). Combining (2) and (3), the power loss can be expressed as:

$$P_L = P_h + P_e = C_h B^3 f + C B^2 f^2 D^2 / \rho \quad (4)$$

Since the testing flux density are fixed (B = 0.08T), according to Equation (4), it can be seen the influence factors to power loss are frequency f, average grain size D and resistivity ρ. The power loss is proportional to f, therefore the samples have higher power losses at higher frequency. Moreover, since the average grain sizes for both samples are similar, therefore, the resistivity plays important role in power loss. The samples made by using nano-ZnO (N samples) have much higher resistivities than those of C samples (refer Fig.1), hence N samples have less power losses are quite reasonable.

Conclusions

The sintered density, resistivity, permeability and power loss of $Ni_{0.5}Zn_{0.5}Fe_2O_4$ ferrite are strongly affected by sintering temperature.

The comparison of sintered samples made by using nano-ZnO (N samples) and general ZnO powder, the samples using nano-ZnO have higher sintered densities, resistivities and permeabilities, less power losses.

The use of nano-ZnO increased the chemical activity, improved the densification and homogeneity, and enhanced the electrical and magnetic properties of Ni-Zn ferrites.

Acknowledgements

The authors acknowledge the supports by the Natural Science Foundation of China (51072238).

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