2nd Conference on Nanoscale Devices and System Integration

DIGEST

NDSI 2005

April 4-6, 2005
Warwick Hotel
Houston, Texas

NDSI'05

Magnetic Properties of Ni-Zn Spinel Ferrite Nanoparticles for Applications in Biomedicine

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Introduction

In recent years a lot of work has been done on nanocrystalline materials because of their unusual properties compared to the properties of bulk materials.[1] Very recently, attention has been drawn towards nanocrystalline ferrites because of their wide applications in industry and technology.[2] In particular, superparamagnetic nanoparticles have been used in biomedicine and biotechnology as contrast agents in magnetic resonance imaging (MRI) and as drug carriers for magnetically guided drug delivery. Superparamagnetism has been extensively studied in the nanoparticles of pure metals such as Fe, Co, and Ni. However, the size of such superparamagnetic metal nanoparticles is confined within a few nanometers. In addition, these metal nanoparticles are chemically unstable. On the other hand, abundant and diverse magnetic metal oxides offer great opportunities for developing superparamagnetic nanoparticles with desirable properties[3]. The nanoparticles of metal oxides such as spinel ferrites possess great potentials for applications.

In this study, a sol-gel procedure was used for the preparation of superparamagnetic nanoparticles $Ni_{0.9}Zn_{0.1}Fe_2O_4$ powders and their magnetic and structural properties as a function of annealing temperature were characterized by using an XRD, TG-DTA, Mössbauer spectroscopy, VSM and FE-SEM.

Experimental Procedures

Nanoparticles $Ni_{0.9}Zn_{0.1}Fe_2O_4$ was synthesized by a sol-gel method. The ferrite powders were annealed in the 200 – 500 °C temperature ranges, respectively. These were characterized by using the XRD. TGA-DTA was performed on the dried powders obtained from the Ni-Zn ferrite precursor solution. The size of nanoparticles Ni-Zn ferrite was controlled through controlling the annealing temperature. The mean particle size was confirmed by SEM. Mössbauer spectra were recorded using a 40 mCi Co source in a Rh matrix with the spectrometer working at constant acceleration mode. The saturation magnetization of the powders was measured with a VSM at a maximum applied field of 15 kOe from 60 to 480 K.

Results and Discussion

TGA analyses indicated a major weight loss above 272 °C. It can be seen that the gel exhibited approximately 58 % weight loss up to 500 °C. The x-ray diffraction measurement shows that all peaks of of Ni-Zn ferrite powders annealed at and above 300 °C are consistent with those of a standard pattern of a Ni–Zn ferrite. The grain size were obtained by the SEM estimated to be 10 - 19 nm for the powder annealed in 300 - 500 °C. Also, the SEM micrographs indicate the distribution of grains with uniform size and have the spherical shape.

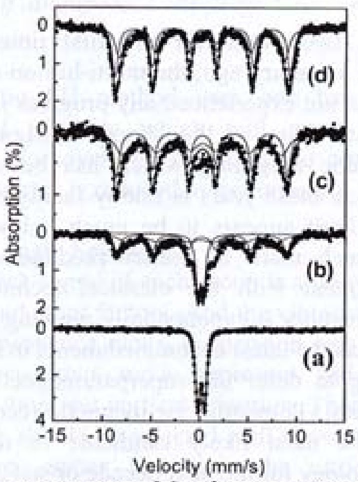

Fig. 1 Room temperature Mössbauer spectra of Ni –Zn ferrite powders annealed at (a) 200 °C, (b) 300 °C, (c) 400°C, (d) 500 °C.

Figure 1 shows some of the Mössbauer spectra of Ni-Zn ferrite samples measured at room temperature. The Mössbauer spectrum of sample annealed 200°C at room temperature show paramagnetic phase, but that of sample annealed 300 °C show superpamagnetic phase. Also, sample annealed 400, 500°C shows two-six line sub-patterns *A* and *B* of typical ferimagnetic Ni-Zn ferrite. The quadrupole shifts for both *A* and *B* patterns vanish in accord with the cubic crystal structure of Ni-Zn ferrite. The isomer shifts at room temperature for the *A* and *B* patterns were found to be (0.12-0.18) ± 0.01 and (0.17-0.18) ± 0.01 mm/s relative to the Fe metal, respectively, which are consistent with high-spin Fe^{3+} charge states. Magnetic properties of the superparamagnetic nanoparticle Ni-Zn ferrite annealed 300 °C were investigated with VSM. The Ni-Zn ferrite annealed 300 °C showed superparamagnetic behaviors. Figure 2(a) shows the magnetization versus magneticfield curves of the annealed 300 °C, measured at 60 K (solid line) and 300 K(dotted line). At low temperatures, the sample annealed 300 °C exhibits a hysteretic behavior, indicating that it has ferrimagnetic phase. However, at room temperature, the ferrimagnetic hysteresis seems to have disappeared.

References

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