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A study on anisotropic changes of MFe_2O_4 (M=Mn, Gd) for bio-applications.

S. Hyun, C. Kim
Physics, Kookmin University, SEOUL, Republic of Korea

Introduction

The ferrite nanoparticles have long been studied due to its scientific and technological interests with the novel magnetic properties caused by its small sizes, hyperthermia, target drug delivery, and the magnetic resonance imaging (MRI) [1-2]. Q. Song et al. were reported to have enhanced properties of $MnFe_2O_4$ for MRI reagents, when their sizes reach in nanometer scale [3].

In this study, we have characterized with the magnetic properties, hyperfine structure and indirectly measurements for hyperthermia of MFe_2O_4 (M=Mn, Gd).

Experiment

MFe_2O_4 (M=Mn, Gd) was synthesized by a thermal decomposition method. Manganese (II) acetylacetonate (acac), gadolinium acetylacetonate and Iron(III) acetylacetonate were used as starting materials to prepare MFe_2O_4 (M=Mn, Gd) nanoparticles. Manganese acac, gadolinium acac and Iron(III) acac were mixed and stired with phenyl ether with 1, 2-hexadecanediol for mono dispersed nanoparticles. The mixture was heated up to 200 ^oC to dissolve and uniformly disperse the particles, and maintained for 30 min under Ar atmosphere. It was reheated up to 256 ^oC and maintained for 30 min to form the $MnFe_2O_4$. Then, it was cooled down to room temperature (RT) and the black $MnFe_2O_4$. powder was obtained. The reaction with surfactants at high temperature successfully leads to form the ferrite nanoparticles, because the reaction allows ferrite nanoparticles to be easily isolated during the chemical reaction between byproducts and the ether solvent.

Results and Discussion

The crystal structure of MFe_2O_4 (M=Mn, Gd) was cubic spinel with space group of Fd3m by x-ray diffraction (XRD). The high resolution transmission electron microscopy (HRTEM) was measured to confirm the XRD measurement on the average particle sizes. The magnetization measurement was performed with vibrating sample magnetometer (VSM). The hyperfine interaction between the Fe and its environment in the crystal lattice was characterized by Mö ssbauer spectroscopy. Mö ssbauer spectrometer of the electromechanical type with a 50 mCi ^{57}Co source in Rh matrix was used in the constant-acceleration mode. Mö ssbauer spectra were taken at various temperatures ranging from 4.2 K to RT. The drastic line broadening for the temperature dependence was observed in the temperature dependent Mö ssbauer spectra. The temperature versus time of synthesized nanoparticles was measured in the agar solution.

Here, we have investigated MFe_2O_4 (M=Mn, Gd) nanoparticles prepared in order to characterize the magnetic properties and hyperthermia applications. We have observed the superparamagnetic behaviour at room temperature and rapidly increasing relaxation frequencies with increasing temperature. Also, the temperature versus time measurements in agar solution under 112 kHz and 25 mT showed that the temperature increases up to 45 ^oC for $GdFe_2O_4$ while temperature increases up to 38 ^oC for $MnFe_2O_4$. It suggests that the gadolinium ferrite was preferable for hyperthermia better than manganese ferrite. Also, the relaxation frequencies at RT rapidly increased with increasing temperature due to its small sizes and thermal energy, which leads to increasing of the magnetic anisotropy energy.

[1] Y. Piao, et al Nature Mater. 7, 242-247 (2008).

[2] Q. Song, et al Chem. Mater. 19, 4633-4638 (2007).

[3] U. I. Tromsdorf, et al Nano Lett. 7, 2422-2427 (2007).

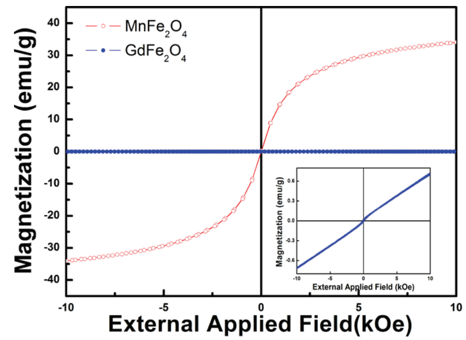

Fig. 1 Magnetization curves for MFe_2O_4 (M=Mn, Gd) with applied field of 1 T at room temperature. The inset shows $GdFe_2O_4$ curve.

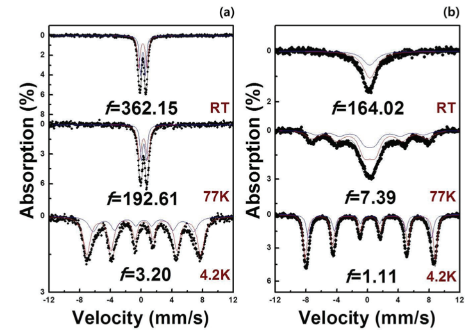

Fig. 2 Mössbauer spectra of MFe_2O_4 (M=Mn, Gd) at various temperatures.