AQ-09. EEG Characteristics under Magnetic Stimulation at Acupuncture Point and at Mock Point. H. Yu1, G. Xu1, Q. Zhou1, S. Yang1, Y. Geng1 and X. Xie1. Province-Ministry Joint Key Laboratory of Electromagnetic Field and Electrical Apparatus Reliability, Hebei University of Technology, Tianjin, China

AQ-10. Detection of radiation-induced effect on the protein tagged by magnetic nano particle by cyclic voltammeter measurement. D. Park1, H. Song1 and C. Angani1. Korea Atomic Energy Research Institute, Daejeon, Republic of Korea

AQ-11. Stochastic resonance in evoked magnetoencephalogram investigated by analysis of coherences. K. Tanaka1, I. Nemoto2, M. Kawakatsu3 and Y. Uchikawa1. Science and Engineering, Tokyo Denki University, Higun, Saitama, Japan; 2. Information Environment, Tokyo Denki University, Inzai, Chiba, Japan

AQ-12. Frequency Dependence of P300 Latency by Low-Frequency Repetitive Transcranial Magnetic Stimulation. T. Torii1, A. Sato1, M. Iwahashi1 and K. Irimina2. Department of Medical Engineering, Junshin Gakuen University, Fukuoka, Japan; 2. Graduate School of Systems Life Sciences, Kyushu University, Fukuoka, Japan

AQ-13. Effect of ELF magnetic fields on anticancer drugs potency. M. Kakikawa1 and S. Yamada1. Institute of Nature and Environmental Technology, Kanazawa University, Kanazawa, Japan

AQ-14. Transition of after Effect on P300 by Short-Term rTMS to Prefrontal Cortex. T. Torii1, A. Sato1, M. Iwahashi1 and K. Irimina2. Department of Medical Engineering, Junshin Gakuen University, Fukuoka, Japan; 2. Graduate School of Systems Life Sciences, Kyushu University, Fukuoka, Japan

AQ-15. Size and anisotropic effects on (Mn, Ni)-Zn ferrites for hyperthermia applications. S. Hyun1, W. Kwon1, K. Joo1 and C. Kim1. Physics, Kookmin University, Seoul, Republic of Korea; 2. Physics, Myongji University, Yongin, Kyungki, Republic of Korea

AQ-16. Direct detection of magnetic resonance signals in ultra-low field MRI using optically pumped atomic magnetometer with ferrite shields: A simulation study. T. Oida1, M. Tsuchida1 and T. Kobayashi1. Graduate School of Engineering, Kyoto University, Kyoto, Japan
Size and anisotropic effects on (Mn, Ni)-Zn ferrites for hyperthermia applications.

S. Hyun\(^1\), W. Kwon\(^1\), K. Joo\(^2\), C. Kim\(^1\)
\(^1\) Physics, Kookmin University, Seoul, Republic of Korea; \(^2\) Physics, Myongji University, Yongin, Kyungki, Republic of Korea

<Introduction>

The ferrite magnetic nanoparticles (NPs) have long been studied with scientific and technological interests, especially, for catalysts, high density magnetic storage and biosensors [1-3]. Recently, these NPs have shown the novel magnetic properties due to their small sizes [3]. Specially, spinel ferrites, MFe\(_2\)O\(_4\) (M=Mn, Co, Ni, Cu, Zn, etc.) are interesting not only in recording and microwave applications but also in the fields of hyperthermia, target drug delivery, and the magnetic resonance imaging (MRI) [4,5].

In this study, we have prepared the M\(_{1-x}\)Zn\(_x\)Fe\(_2\)O\(_4\) (M=Mn, Ni; x=0.5, 0.8) NPs using high temperature thermal decomposition. We have also measured and analyzed the magnetic and hyperthermic properties of synthesized NPs.

<Experiment>

The transition metal doped M\(_{1-x}\)Zn\(_x\)Fe\(_2\)O\(_4\) (M=Mn, Ni; x=0.5, 0.8) NPs were prepared by a high temperature thermal decomposition process [2]. Manganese(III) acetylacetonate, nickel acetylacetone, zinc(II) acetylacetonate, and iron(III) acetylacetonate were used as starting materials to fabricate uniform NPs. The starting materials with 1,2-hexadecanediol were mixed in benzyl ether and the mixture was heated up to 298 °C to dissolve and form the M\(_{1-x}\)Zn\(_x\)Fe\(_2\)O\(_4\) (M=Mn, Ni; x=0.5, 0.8) NPs, and maintained for 30 min. Then, the temperature was downed to 200 °C and maintained for 1h to uniformly disperse the NPs. Then, it was cooled down to room temperature (RT). The crystal structures of the samples were examined by x-ray diffraction (XRD) with Cu-K\(_\alpha\) radiation (\(\lambda=1.5406\) Å). Also, field emission scanning electron microscope (FESEM) was measured to confirm the XRD measurement on the particle size. Magnetic measurements were performed with vibrating sample magnetometer (VSM). The hyperfine interaction between the Fe and its environment in the crystal lattice was characterized by field induced Mössbauer spectroscopy with external field of 5 T, which used conventional spectrometer with a 57Co source in a rhodium matrix. Hyperthermia properties were performed by magneTherm device with 50 kHz frequency and 25 mT external magnetic field.

<Results and Discussion>

The crystal structure of synthesized NPs was cubic spinel with space group of Fd\(_3\)m by x-ray diffraction (XRD). From FESEM measurements and Scherrer equation, we have obtained the average diameter of particles to be 19 ± 1 nm for Mn\(_{1-x}\)Zn\(_x\)Fe\(_2\)O\(_4\) (x=0.5, 0.8), and 11 ± 1 nm for Ni\(_{1-x}\)Zn\(_x\)Fe\(_2\)O\(_4\) (x=0.5, 0.8) as shown in Fig. 1. The hysteresis loops were measured using VSM with maximum applied field of 1.5 T at RT. The values of magnetization (\(M\)) are 81.0 and 83.2 ± 0.1 emu/g for Mn\(_{1-x}\)Zn\(_x\)Fe\(_2\)O\(_4\) (x=0.5, 0.8), and 61.3 and 70.8 ± 0.1 emu/g for Ni\(_{1-x}\)Zn\(_x\)Fe\(_2\)O\(_4\) (x=0.5, 0.8), respectively.

The hyperfine interaction between the Fe and its environment in the crystal lattice was characterized by field induced Mössbauer spectroscopy. Mössbauer spectra were taken at 4.2 K and RT. The canting angle between hyperfine field and external field direction, which calculated from 5 T external magnetic field induced spectrum, was increased with increasing Zn concentration. The hyperthermia properties of synthesized NPs were measured with pure powder and in the agar solution. The temperature versus time measurements with pure powder and the agar solution under 50 kHz and 25 mT showed that the temperature increases up to about 120 °C and 43 °C for Mn\(_{1-x}\)Zn\(_x\)Fe\(_2\)O\(_4\) (x=0.5, 0.8), respectively, while the temperature maintains almost room temperature for Ni\(_{1-x}\)Zn\(_x\)Fe\(_2\)O\(_4\) (x=0.5, 0.8). It can be explained that Mn-Zn ferrites were preferable for hyperthermia applications due to its magnetic anisotropy energy, which leads to increasing of the thermal energy. However, synthesized Ni-Zn ferrites showed non-increasing property for hyperthermia, although the changes on anisotropic energy, due to its small sizes as shown in Fig. 2.