



ABSTRACTS

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temperature to 238 K, and then increases linearly below 238 K. When the annealing time increases up to 6 h the spectroscopic splitting factor and the effective magnetization are almost constant, but the exchange stiffness constant decreases slightly with increasing annealing time.

**DP-11. Magnetic and structural properties of ultrafine  $\text{CoFe}_{1.9}\text{RE}_{0.1}\text{O}_4$  (RE = Gd, Nd) powders grown by using a sol-gel method.** W.C. Kim, S.J. Kim and C.S. Kim. *Department of Physics, Kookmin University 861-1 Chongnung-dong, Songbuk-gu, Seoul 136-702, South Korea*

Ultrafine  $\text{CoFe}_{1.9}\text{RE}_{0.1}\text{O}_4$  (RE = Gd, Nd) powders have been fabricated by a sol-gel method. Magnetic and structural properties of the powders were investigated by x-ray diffractometer, Mössbauer spectroscopy, and vibrating sample magnetometer. The  $\text{CoFe}_{1.9}\text{Gd}_{0.1}\text{O}_4$  powders that were fired at and above 923 K contained only a single spinel phase and behaved ferrimagnetically. The grain diameters were estimated to be 11 ~ 30 nm for the Co-Gd ferrite powders fired in 773 ~ 1123 K. Mössbauer spectra measurements showed that the  $\text{CoFe}_{1.9}\text{Gd}_{0.1}\text{O}_4$  powders fired at 723 ~ 823 K and the  $\text{CoFe}_{1.9}\text{Nd}_{0.1}\text{O}_4$  powders fired at 523 ~ 1023 K had a spinel structure and were mixed paramagnetic and ferrimagnetic in nature. Mössbauer spectra of the Co-Gd ferrite powder fired at 923 K were taken at various temperatures ranging from 14 to 875 K. The iron ions at both A (tetrahedral) and B (octahedral) sites were found to be in ferric high-spin states. The Néel temperature  $T_N$  was found to be  $875 \text{ Å} \pm 2 \text{ K}$ . Debye temperatures for A and B sites were found to be  $\Theta_A = 675 \text{ Å} \pm 5 \text{ K}$  and  $\Theta_B = 286 \text{ Å} \pm 5 \text{ K}$ , respectively. The magnetic behaviors of the  $\text{CoFe}_{1.9}\text{Gd}_{0.1}\text{O}_4$  powders fired at and above 723 K and  $\text{CoFe}_{1.9}\text{Nd}_{0.1}\text{O}_4$  powders fired at and above 923 K, respectively, showed that an increase of the firing temperature yielded a decrease in the coercivity and an increase in the saturation magnetization. The maximum coercivity and the saturation magnetization were  $H_c = 1,149 \text{ Oe}$  and  $M_s = 72 \text{ emu/g}$  in the  $\text{CoFe}_{1.9}\text{Gd}_{0.1}\text{O}_4$  samples and  $H_c = 959 \text{ Oe}$  and  $M_s = 63 \text{ emu/g}$  in the  $\text{CoFe}_{1.9}\text{Nd}_{0.1}\text{O}_4$  samples.

**DP-12. Magnetic properties of  $\text{Zn}^{2+}$  Substituted ultrafine Co-ferrite grown by a sol-gel method.** S.H. Lee<sup>1</sup>, Y.G. Ryu<sup>1</sup>, K.J. Yang<sup>1</sup>, C.S. Lee<sup>2</sup>, S.Y. An<sup>3</sup> and C.S. Kim<sup>3</sup>. 1. *Dept. of Electronic Engineering, Chungju National University, Chungju 380-702, South Korea*; 2. *Dept. of Physics, Pukyong National University, Busan 611-735, South Korea*; 3. *Dept. of Physics, Kookmin University, Seoul 136-702, South Korea*

Ultrafine  $\text{Co}_{1-x}\text{Zn}_x\text{Fe}_2\text{O}_4$  ( $0 \leq x \leq 1.0$ ) particles are fabricated by a sol-gel method. The magnetic and structural properties of powders were investigated with x-ray diffraction, vibrating samples magnetometer and Mössbauer spectroscopy. The lattice parameter ( $a_0$ ) increases linearly with increasing Zn concentration ( $x$ ) and follows Vegard's law approximately.  $\text{Co}_{0.9}\text{Zn}_{0.1}\text{Fe}_2\text{O}_4$  powders that were fired at and above 673 K have only a single phase spinel structure and behave ferrimagnetically. Powders annealed at 523 K, and 573 K has a typical spinel structure and are simultaneously paramagnetic and ferrimagnetic in nature. The magnetic behavior of  $\text{Co}_{0.9}\text{Zn}_{0.1}\text{Fe}_2\text{O}_4$  powders fired at and above 573 K shows that an increase of the annealing temperature yields a decrease of the coercivity and an increase of the saturation magnetization. The maximum coercivity and the saturation magnetization of  $\text{Co}_{0.9}\text{Zn}_{0.1}\text{Fe}_2\text{O}_4$  ferrite powders are 1328 Oe and 81.1 emu/g, respectively. Mössbauer spectra of Co-Zn ferrite have been taken at various temperatures from 20 to 800 K. The isomer shifts indicate that the iron ions were ferric at the tetrahedral[A] and the octahedral[B]. The Néel temperature of  $\text{Co}_{0.9}\text{Zn}_{0.1}\text{Fe}_2\text{O}_4$  was determined to be  $T_N = 790 \text{ K}$  and it is found that Debye temperature for the A and B sites of the sample fired at 1,123 K is found to be  $\Theta_A = 756 \pm 5 \text{ K}$  and  $\Theta_B = 199 \pm 5 \text{ K}$ , respectively. The Néel temperature dramatically decreased with increasing  $x$  from about  $T_N = 870 \text{ K}$  for  $x = 0.0$  to  $T_N = 35 \text{ K}$  for  $x = 1.0$ .

**DP-13. Mössbauer studies of superexchange interactions in  $\text{CoFe}_2\text{In}_x\text{O}_4$**  S.Y. An<sup>1</sup>, S.H. Lee<sup>2</sup> and C.S. Kim<sup>1</sup>. 1. *Dept. of Physics, Kookmin University, Seoul 136-702, South Korea*; 2. *Dept. of Electronic Engineering, Chungju National University, Chungju 380-702, South Korea*

$\text{CoFe}_{2-x}\text{In}_x\text{O}_4$  ( $0 \leq x \leq 0.5$ ) ferrite has been studied with Mössbauer spectroscopy, x-ray diffraction and vibrating samples magnetometer. The crystal structure for this system is spinel structure. The lattice parameter ( $a_0$ ) increases linearly with increasing In concentration ( $x$ ) and follows Vegard's law approximately. The Mössbauer spectra of  $\text{CoFe}_{2-x}\text{In}_x\text{O}_4$  were measured at various temperatures from 17 to 825 K. The isomer shifts indicate that the valence states of the irons at both tetrahedral(A) and octahedral(B) sites are in ferric high-spin states. The Néel temperature of  $\text{CoFe}_{1.9}\text{In}_{0.1}\text{O}_4$  was  $T_N = 765 \pm 3 \text{ K}$ . Debye temperature for the A and B sites of  $\text{CoFe}_{1.9}\text{In}_{0.1}\text{O}_4$  is found to be  $\Theta_A = 664 \pm 5 \text{ K}$  and  $\Theta_B = 207 \pm 5 \text{ K}$ , respectively. The temperature dependence of the magnetic hyperfine fields at  $^{57}\text{Fe}$  nuclei at the tetrahedral(A) and octahedral(B) sites is analyzed by the Néel theory of ferrimagnetism. The intersublattice A-O-B and intersublattice A-O-A superexchange interactions of  $\text{CoFe}_{1.9}\text{In}_{0.1}\text{O}_4$  are found to be antiferromagnetic with their strength of  $J_{A-B} = -14.7 \text{ k}_B$  and  $J_{A-A} = -3.6 \text{ k}_B$ , respectively, while intrasublattice B-O-B superexchange interaction is ferromagnetic with its strength  $J_{B-B} = 7.4 \text{ k}_B$ . The VSM data showed that the saturation magnetization decreased with increasing  $x$  from about 83.7 emu/g for  $x = 0.1$  to 63.6 emu/g for  $x = 0.5$ .

**DP-14. Mössbauer studies on superexchange interactions in  $\text{Y}_3\text{Fe}_5\text{Al}_x\text{O}_{12}$  ( $x = 0.25, 0.75$ ).** B.K. Min, S.J. Kim and C.S. Kim. *Physics, Kookmin Univ., Seoul, 136-702, South Korea*

$\text{Al}^{3+}$  substituted garnet  $\text{Y}_3\text{Fe}_{5-x}\text{Al}_x\text{O}_{12}$  ( $x = 0.25, 0.75$ ) was fabricated by a sol-gel method. The crystallographic and magnetic properties of  $\text{Y}_3\text{Fe}_{5-x}\text{Al}_x\text{O}_{12}$  have been studied with Mössbauer spectroscopy, X-ray diffraction (XRD), thermogravimetry analysis (TGA), differential thermal analysis (DTA), and vibrating samples magnetometer (VSM). The crystal structures were found to have a single phase of garnet cubic spinel structure with the lattice constants of the  $\text{Y}_3\text{Fe}_{4.75}\text{Al}_{0.25}\text{O}_{12}$  being  $a_0 = 12.361 \text{ Å}$  and the  $\text{Y}_3\text{Fe}_{4.25}\text{Al}_{0.75}\text{O}_{12}$  being  $a_0 = 12.328 \text{ Å}$ , respectively. The Mössbauer spectra of the  $\text{Y}_3\text{Fe}_{5-x}\text{Al}_x\text{O}_{12}$  have been taken at various temperatures ranging from 15 to 600 K. The temperature dependence of the magnetic hyperfine fields at the tetrahedral (24d) and octahedral (16a) sites was analyzed based on the Néel theory of ferrimagnetism. The Néel temperature was decreased from 555 ( $x = 0.25$ ) to 495 K ( $x = 0.75$ ). As the temperature increased toward  $T_N$ , a systematic line broadening effect in the Mössbauer spectra was observed and interpreted to originate from different temperature dependencies of the magnetic hyperfine fields at various iron sites. It results from the probability distribution ( ${}_6C_n$ ) of  $\text{Fe}^{3+}$  and  $\text{Al}^{3+}$  at tetrahedral sites. Mössbauer spectra can be analyzed using 3 ( $x = 0.25$ ) or 5 sets ( $x = 0.75$ ) of six Lorentzians. The isomer shifts indicated that the iron ions were ferric at the octahedral 16a-site and the tetrahedral 24d-sites, respectively. For  $\text{Y}_3\text{Fe}_{4.75}\text{Al}_{0.25}\text{O}_{12}$ , the intersublattice  $a-d$  superexchange interaction, intrasublattice  $a-a$ ,  $d-d$  superexchange interaction were antiferromagnetic with a strength of  $J_{a-d} = -12.6$ ,  $J_{a-a} = 6.8$ , and  $J_{d-d} = -11.2 \text{ k}_B$ , respectively.

**DP-15. Z Type Ba Hexagonal Ferrites with Tailored Microwave Properties.** P. Lubitz and F.J. Rachford. *Naval Research Laboratory, Washington, DC*

The microwave properties of Z type Ba hexagonal ferrites can be controlled over a wide range by choice of an appropriate mixture of Zn, Ni and Co as divalent species. Z type hexagonal ferrites were made by conventional sintering methods. Using unmagnetized powders, the permeability spectra were taken in a swept frequency mode. From this data, the magnetization and the product  $g\text{Ha}$  were derived in the temperature range 200 to 550 K. Here  $g = g_e/mc$ , where  $g$  is the effective  $g$ -value for the ferrimagnet and  $\text{Ha}$  is the uniaxial anisotropy field. The pure Zn or Co ferrites were found to have temperature dependences of  $g\text{Ha}$  similar to those of Zn or Co Z, W or Y type hexagonal ferrites as described in the literature, i.e. nearly flat for Zn and strongly increasing with T for Co. Ni-Z ferrite is strikingly different and differs from any reported results in this system: the combination  $g\text{Ha}$ , which determines the frequency of maximum absorption, is found to decrease rapidly with increasing temperature. The