Magnetic and structural properties of ultrafine Ni–Zn–Cu ferrite grown by a sol–gel method

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Ultrafine $Ni_{0.65}Zn_{0.35}Cu_{0.2}Fe_{1.8}O_4$ particles were fabricated by a sol–gel method. The magnetic and structural properties of the powders were investigated with x-ray diffraction, vibrating sample magnetometer, and Mössbauer spectroscopy. Ni–Zn–Cu ferrite powders that were fired at and above 823 K have only a single phase spinel structure and behave ferrimagnetically. Powders annealed at 523, 623, and 723 K have a typical spinel structure and are simultaneously paramagnetic and ferrimagnetic in nature. The magnetic behavior of Ni–Zn–Cu ferrite powders fired at and above 623 K showed that an increase of the annealing temperature yielded a decrease of the coercivity and an increase of the saturation magnetization. The maximum coercivity and the saturation magnetization of Ni–Zn–Cu ferrite powders were $H_c = 96$ Oe and $M_s = 68$ emu/g. Mössbauer spectra of powder annealed at 1223 K were taken at various temperatures ranging from 12 to 675 K. As the temperature increased toward T_N, a systematic line broadening effect in the Mössbauer spectra was observed and was interpreted as originating from the different temperature dependencies of the magnetic hyperfine fields at various iron sites. The isomer shifts indicated that the iron ions were ferric at the tetrahedral $[A]$ and the octahedral site $[B]$. The Néel temperature was determined to be $T_N = 675 \pm 2$ K.
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