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Superexchange Interactions of In^{3+}- Substituted $CoFe_2O_4$

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Polycrystalline samples of $CoFe_{2-x}In_xO_4$ ($0 \leq x \leq 0.5$) ferrite were prepared by slow cooling and studied using Mössbauer spectroscopy, X-ray diffraction and vibrating sample magnetometry(VSM). The crystals were found to have a cubic spinel structure. The lattice parameter (a_0) increased linearly with increasing In concentration x. The Mössbauer spectra of $CoFe_{2-x}In_xO_4$ were measured at various temperatures from 17 to 825 K. The isomer shifts indicated that the valence states of the irons at both tetrahedral (A) and octahedral (B) sites were in ferric high-spin states. The Néel temperature of $CoFe_{1.9}In_{0.1}O_4$ was $T_N = 765 \pm 3$ K. The Debye temperatures for the A and the B sites of $CoFe_{1.9}In_{0.1}O_4$ were found to be $\Theta_A = 664 \pm 5$ K and $\Theta_B = 207 \pm 5$ K, respectively. The temperature dependences of the magnetic hyperfine fields at ^{57}Fe nuclei at the tetrahedral (A) and the octahedral (B) sites were analyzed by using the Néel theory of ferrimagnetism. The intrasublattice A-O-B and the intersublattice A-O-A superexchange interactions of $CoFe_{1.9}In_{0.1}O_4$ were found to be antiferromagnetic with strengths of $J_{A-B} = -14.7$ k_B and $J_{A-A} = -3.6$ k_B, respectively, while intrasublattice B-O-B superexchange interaction was ferromagnetic with a strength of $J_{B-B} = 7.4$ 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 $x = 0.5$.

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