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Neutron diffraction and magnetic structure studies on Co-Al ferrite

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Al substituted $CoAl_xFe_{1-x}O_4 (x = 0.1, 0.3, 0.5)$ samples were fabricated using the sol-gel method, and their magnetic and structural properties have been studied with x-ray and neutron diffraction, Mössbauer spectroscopy and magnetization measurements. The crystals of the samples x = 0.1, 0.3, and 0.5, fired at 1000 °C, were found to have a cubic spinel structure with lattice constants of a_0 =8.3864, 8.3670, and 8.3392 Å, respectively.

Mössbauer data were collected in the temperature range of 14-850 K. The temperature dependence of the magnetic hyperfine field in ^{57}Fe nuclei at the tetrahedral (A) and octahedral (B) sites was analyzed based on the Néel theory of magnetism. For the sample $CoAl_{0.1}Fe_{1.9}O_4$, the intersublattice A-B interaction and intrasublattice A-A superexchange interaction were antiferromagnetic with strengths of J_{A-B} = -23.3 k_B and J_{A-A} = -18.0 k_B, respectively, while the intrasublattice B-B superexchange interaction was found to be ferromagnetic with a strength of J_{B-B} = 5.6 k_B. While for the sample $CoAl_{0.5}Fe_{1.5}O_4$, the strengths of the A-B, A-A and B-B interaction were J_{A-B} = -21.4, J_{A-A} = -13.6, and J_{B-B} = 4.1 k_B, respectively.

Neutron diffraction patterns on $CoAl_{0.1}Fe_{1.9}O_4$ and $CoAl_{0.5}Fe_{1.5}O_4$ were obtained at various temperature ranges from 10 K to Néel temperature, and all cation distributions and atomic distances were determined by Rietveld refinements. Neutron diffraction at 10 K for $CoAl_{0.1}Fe_{1.9}O_4$ revealed a cubic spinel structure of ferrimagnetic long range ordering, with magnetic moments of Fe^{3+}(A)(-4.18 μ_B), Fe^{3+}(B)(4.81 μ_B), Co^{2+}(B)(2.98 μ_B), respectively. The changes of exchange interactions with Al substitution are interpreted on the basis of cation distributions and bond lengths. It is interpreted that a noticeable strength of the A-A interaction and the unusual reduction of magnetic moment are closely related to the covalency effects.