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Mössbauer Studies on Superexchange Interactions in $Y_3Fe_{5-x}Al_xO_{12}$

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The crystallographic and the magnetic properties of $Y_3Fe_{5-x}Al_xO_{12}$ (x = 0.25, 0.50, and 0.75) have been studied with Mössbauer spectroscopy, X-ray diffraction (XRD), and vibrating sample magnetometry (VSM). The lattice parameter (a_0) decreased linearly with increasing Al concentration (x) and followed Vegard's law approximately. The Mössbauer spectra of the $Y_3Fe_{5-x}Al_xO_{12}$ were taken at various temperatures ranging from 15 to 600 K. As the temperature increased toward the Neel temperature (T_N), a systematic line broadening effect in the Mössbauer spectra was observed and interpreted as originating from the different temperature dependencies of the magnetic hyperfine fields at various iron sites. The results from the probability distribution ($_6C_n$) of Fe^{3+} and Al^{3+} at the tetrahedral sites. The isomer shifts indicated that the iron ions were ferric at the octahedral a-sites and the tetrahedral d-sites. The temperature dependence of the magnetic hyperfine fields at the tetrahedral (d) and the octahedral (a) sites was analyzed based on the Néel theory of ferrimagnetism. For $Y_3Fe_{4.75}Al_{0.25}O_{12}$, the intersublattice $a-d$ superexchange interaction was antiferromagnetic with a strength of J_{a-d} = –20.1 ± 0.2 k_B while the intrasublattice $a-a$ and $d-d$ superexchange interactions were ferromagnetic with strengths of J_{a-a} = 1.1 ± 0.2 and J_{a-d} = 2.9 ± 0.2 k_B, respectively.

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