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Magnetic properties of the Ga substituted $FeGa_{0.1}Cr_{1.9}S_4$ with the inverse spinel structure

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The spinel magnetic semiconductor compound $FeCr_2S_4$ has recently attracted much interest due to its colossal magnetoresistance (CMR), and its half-metallic behavior. The presence of CMR in perovskite structure is ascribed to the double exchange (DE) interaction and Jahn-Teller polarons. CMR effect in $FeCr_2S_4$ was suggested that the conduction mechanism in these materials may not be caused by the DE of the carriers. The ferrimagnetic semiconductor material $FeGa_{0.1}Cr_{1.9}S_4$ has been studied by x-ray diffraction, Mössbauer spectroscopy, vibrating sample magnetometer (VSM), and magnetoresistance (MR) measurements.

The crystal structure is found to be a cubic spinel by Rietveld refinement of x-ray diffraction. The MR measurement of the sample shows that the metal-semiconductor transition occur in the temperature range from 77 to 300 K. The saturation magnetization is 36.39 emu/g under 5 kOe external field at 30 K. It proves that $FeGa_{0.1}Cr_{1.9}S_4$ is ferrimagnetic and this result is in agreement with the Mössbauer analysis. Mössbauer spectra of $FeGa_{0.1}Cr_{1.9}S_4$ consist of the two doublets at room temperature. The one corresponds to the iron ions at the tetrahedral (A) sites, the other corresponds to the iron ions at the octahedral (B) sites. The cation distribution is determined by Mössbauer spectra, which reveals that the Ga ion occupy to the tetrahedral site and $FeGa_{0.1}Cr_{1.9}S_4$ belongs to an inverse spinel type. The electric quadrupole splitting of the A and B sites are 0.26 and 2.93 mm/s for the sample $FeGa_{0.1}Cr_{1.9}S_4$, respectively. Reminding that $FeCr_2S_4$ has a single line at room temperature, it is abnormal that it has large quadrupole splittings.

We notice that, the quadrupole splitting of A site largely increases, compared to that of the B site with substitution of non magnetic Ga ions. It gives a direct evidence that Ga ion cause a large quadrupole interaction and leads the conclusion that orbital angular contribution plays an important role in $FeGa_{0.1}Cr_{1.9}S_4$.