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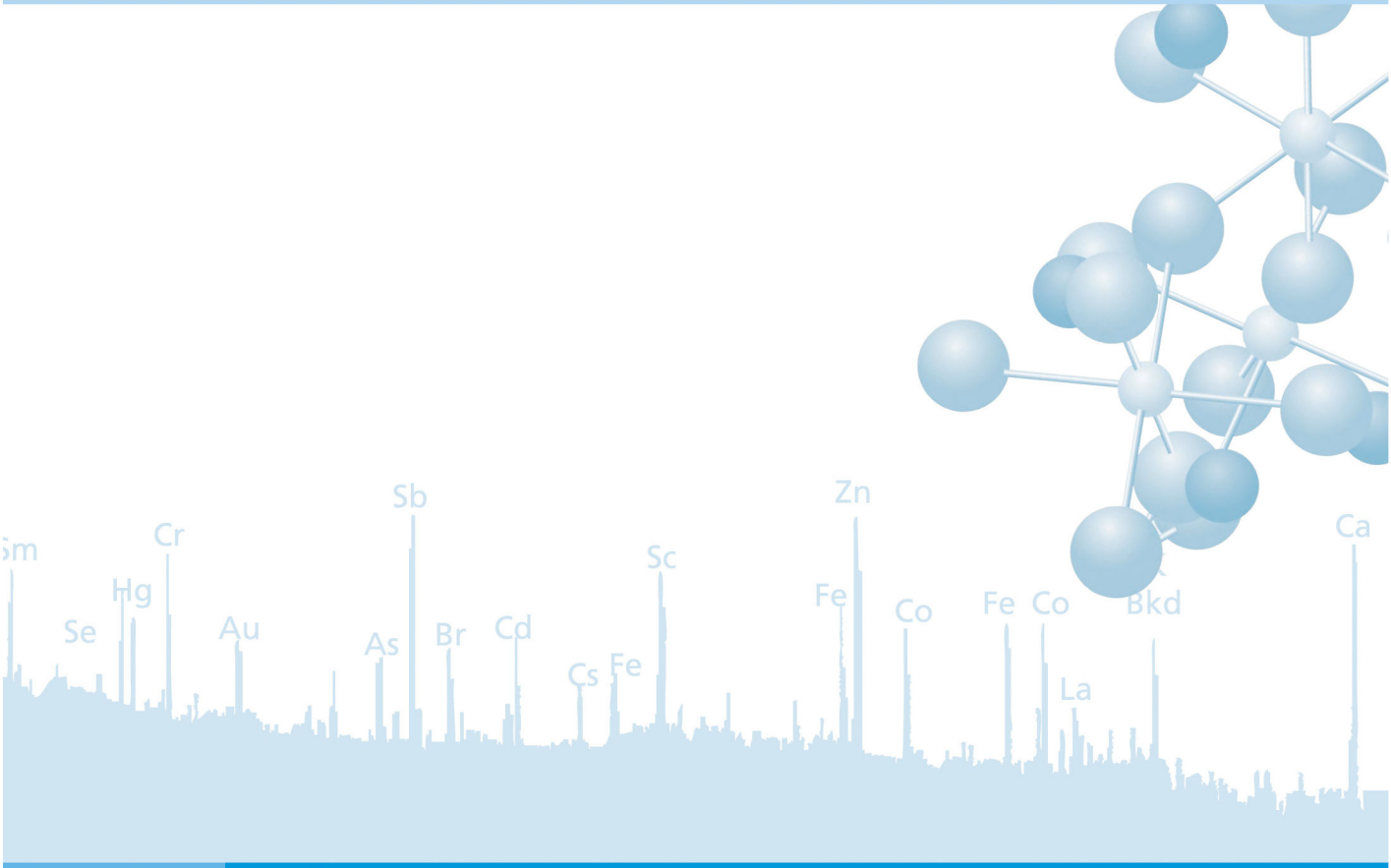

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Mössbauer spectroscopy and neutron diffraction studies of the In-substituted $FeIn_{0.1}Cr_{1.9}S_4$

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1. Introduction

The chromium chalcogenide spinel MCr_2X_4 (M = Fe, Co, Cu, Cd; X = S, Se) shows various magnetic property with M ions [1-4]. $CuCr_2Se_4$ and $CdCr_2Se_4$ are known to show metallic conduction and large magneto-optical effect [5]. In addition to colossal magnetoresistane (CMR) effect, metal-insulator transition and structural phase transition appear in $FeCr_2S_4$ [6-7], spin-frustration effects reveal in $FeSc_2S_4$ and $MnSc_2S_4$ [8]. These systems have been revisited relaxor ferroelectricity and colossal magnetocapactive effect [9]. These features were attributed to competition of isomorphic ions with the topological frustration, Jahn-Teller distortion, and geometric frustration of magnetic moment. Therefore, it is necessary to examine the interaction mechanism of the various compounds in the sulphur spinel.

We investigated the charge structure and interaction mechanism on In-doped sulphur spinel by using x-ray diffractometer (XRD), neutron diffractometer and Mössbauer spectroscopy.

2. Experiments

Syntheses of the sample was accomplished by the solid state reaction of the high-purity elements Fe, Cr, In and S in an evacuated quartz tube. The structure of the sample was examined using x-ray diffractometer (XRD) with Cu-K_α radiation and neutron diffractiometer at Korea atomic energy research institute reactor HANARO HRPD. The Mössbauer spectra were recorded using a conventional spectrometer of electromechanical type with a ^{57}Co source in a rhodium matrix.

3. Results and Discussions

The x-ray diffraction (XRD) patterns for sample reveal spinel structure. The crystal structure at room temperature is determined by the Rietveld method. It is found that the space group is *Fd3m* and resulting lattice parameter are a_0=10.029 Å. Figure 1 shows the results of neutron diffraction patterns for $FeIn_{0.1}Cr_{1.9}S_4$ at various temperature. Neutron diffraction on $FeIn_{0.1}Cr_{1.9}S_4$ above 4 K shows that there is no crystallographic distortion and reveals antiferromagnetic ordering. Below Néel temperature (T_N=173 K), magnetic peaks exist on the crystal diffraction peaks in figure 1. It proves that spin structure of the same species are aligned parallel. Specifically, all magnetic peaks are overlapped on nuclear peaks. Therefore, it is concluded that the intersublattice superexchange interaction of Fe(A)-Cr(B) is antiferromagnetic, while intresublattice superexchange interaction of Fe(A)-Fe(A) and Cr(B)-Cr(B) is ferromagnetic, respectively.

In order to clarify and determine the state of Fe ions in the samples, the Mössbauer spectra were measured. Figure.2 shows the Mössbauer spectra at various temperatures. From the Mössbauer results, it is determined that charge state of the iron ions in the sample is ferrous. The iron and copper ion for the sample show the ferrous (Fe^{2+}) and tri valence (In^{3+}) characters, respectively. The large asymmetrical line broadening of Mössbauer absorption lines is shown for the sample at 4.2 K.

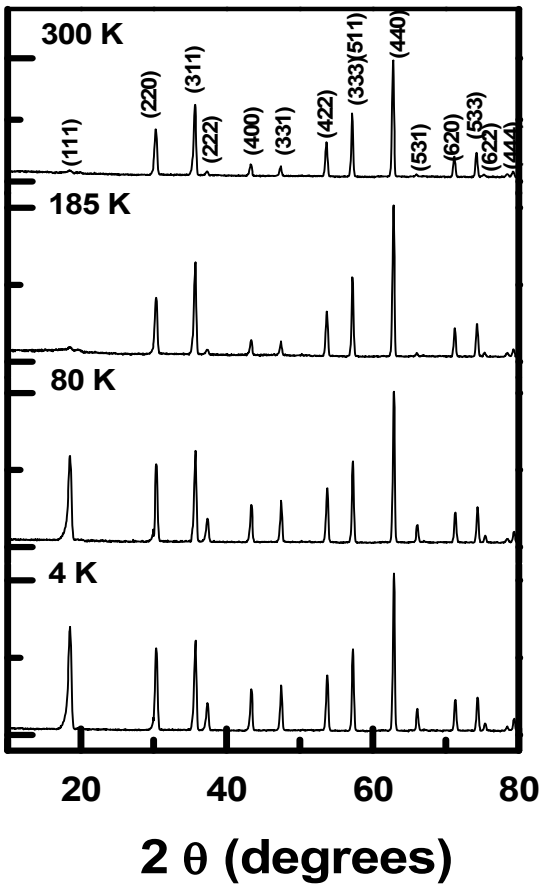

Figure 1. Neutron diffraction data for the $FeIn_{0.1}Cr_{1.9}S_4$ at various temperatures.

4. Conclusion

The crystal structure of $FeIn_{0.1}Cr_{1.9}S_4$ is found to be a cubic spinel by Rietveld refinement of x-ray diffractometer. The charge state of Fe ions is determined by Mössbauer spectra, which reveals that Fe ions are the ferrous. The intersublattice of A-B interaction is coupled to antiferromagnetic arrangement, while intrasublattice of A-A and B-B interaction are coupled to ferromagnetic arrangement by neutron diffraction results.

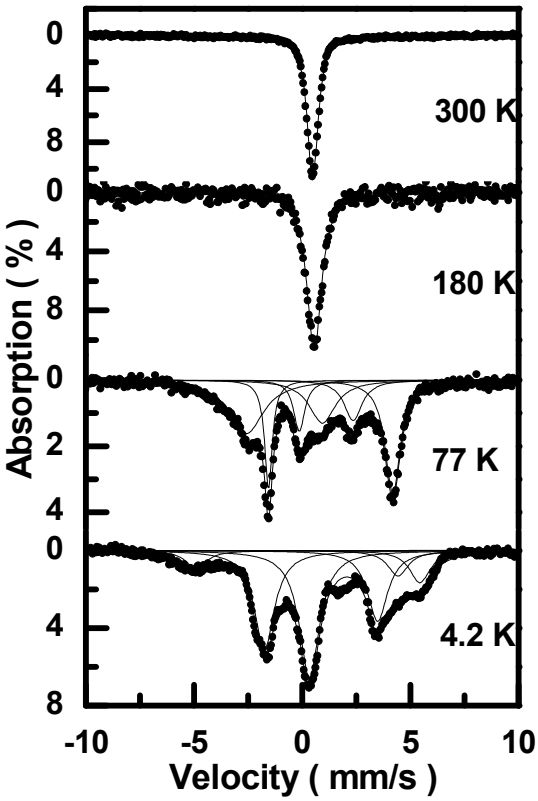

Figure 2. Mössbauer spectra of $FeIn_{0.1}Cr_{1.9}S_4$ at various temperatures.

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