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Magnetic properties of Ga substituted $\text{NiCr}_{1.9-x}\text{Ga}_x\text{Fe}_{0.1}\text{O}_4$

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I. INTRODUCTION

The ferrimagnet chromites (ACr_2O_4 ; $A=\text{Co}, \text{Zn}, \text{Ni}$, etc) are cubic normal spinel, in which A ions occupy the tetrahedral sites and Cr ions occupy the octahedral sites. Recently, many researchers have been interested in the properties of chromite material with multiferroic effects[1,2]. The $\text{NiCr}_{2-x}\text{Fe}_x\text{O}_4$ system, there is a cubic to tetragonal ($c/a < 1$) transition for the Fe concentration $x \leq 0.2$ under room temperature.

In this work, we have studied the $\text{NiCr}_{1.9}\text{Fe}_{0.1}\text{O}_4$ with Ga doping, and evaluated the impact on magnetic properties by x-ray diffraction, neutron powder diffraction, magnetization, and Mössbauer spectroscopy measurements.

II. EXPERIMENT

Polycrystalline samples of the $\text{NiCr}_{1.9-x}\text{Ga}_x\text{Fe}_{0.1}\text{O}_4$ ($x=0.0, 0.45, 0.95$) were prepared with the solid state reaction method. The ultimate single phase samples were obtained by annealing for 12 h in atmosphere at 1200 °C. The crystalline structure was analyzed using a Philips x-ray diffractometer with $\text{Cu K}\alpha$ radiation and neutron diffraction at Korea Atomic Energy Research Institute Reactor HANARO HRPD (High Resolution Powder Diffractometer, $\lambda = 1.8348 \text{ \AA}$). The temperature dependence of magnetization curves were also obtained with a vibrating sample magnetometer (VSM). The hyperfine magnetic property of samples was measured by using Mössbauer spectroscopy.

III. RESULT AND DISCUSSION

The crystalline structure of $\text{NiCr}_{1.9-x}\text{Ga}_x\text{Fe}_{0.1}\text{O}_4$ ($x=0.0, 0.45, 0.95$) were found to be a cubic spinel with space group of $Fd-3m$ at room temperature. Figure 1 shows some of the neutron diffraction patterns for $\text{NiCr}_{1.45}\text{Ga}_{0.45}\text{Fe}_{0.1}\text{O}_4$ at various temperature ranges. The neutron diffraction patterns for $\text{NiCr}_{1.45}\text{Ga}_{0.45}\text{Fe}_{0.1}\text{O}_4$ above 4 K showed that the magnetic peaks were overlapping on the nucleus peaks. The magnetic peaks decreases when temperature increases and it disappears at Néel temperature.

The temperature dependence of zero field cooled (ZFC) curves for the $\text{NiCr}_{1.9-x}\text{Ga}_x\text{Fe}_{0.1}\text{O}_4$ ($x=0.0, 0.45, 0.95$) were taken under low external field of 100 Oe. The ferromagnetic transition of $\text{NiCr}_{1.9-x}\text{Ga}_x\text{Fe}_{0.1}\text{O}_4$ ($x=0.0, 0.45, 0.95$) were observed at 150 K, 125 K, and 90 K, respectively.

Figure 2 shows the Mössbauer spectra of $\text{NiCr}_{1.9-x}\text{Ga}_x\text{Fe}_{0.1}\text{O}_4$ ($x=0.45, 0.95$) at 4.2 K. Mössbauer spectra of the Ga substituted $\text{NiCr}_{1.9-x}\text{Ga}_x\text{Fe}_{0.1}\text{O}_4$ ($x=0.45, 0.95$) were measured at various temperatures ranging from 4.2 to 295 K. The Mössbauer spectrum of $\text{NiCr}_{1.45}\text{Ga}_{0.45}\text{Fe}_{0.1}\text{O}_4$ indicates that there are two magnetic phases, which are due to the two different sites of the Cr^{3+} state.[1] However, in case of the Mössbauer spectrum of $\text{NiCr}_{0.95}\text{Ga}_{0.95}\text{Fe}_{0.1}\text{O}_4$ indicates that there are three magnetic phases. As well-known, NiGa_2O_4 has an inverse spinel structure at room temperature. Therefore, the increasing of the Ga substitution, Ga ions enter into both octahedral (B) and tetrahedral (A) sites; simultaneously the same amounts ratio of Fe ions occupied to the B and the A sites.

[1] K. Tomiyasu, J. Fukunga, and H. Suzuki, Phys. Rev. B **70**, 214434, 2004.

[2] L. G. Antoshina, A. N. Goryaga, and D. A. Chursin, Phys. Solid State **44**, 747, 2002.

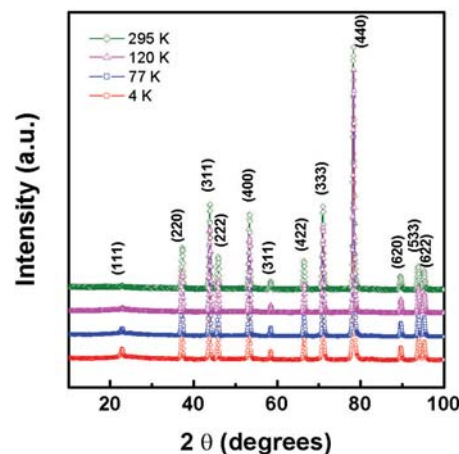


Fig. 1. The neutron diffraction patterns for $\text{NiCr}_{1.45}\text{Ga}_{0.45}\text{Fe}_{0.1}\text{O}_4$ at various temperature ranges.

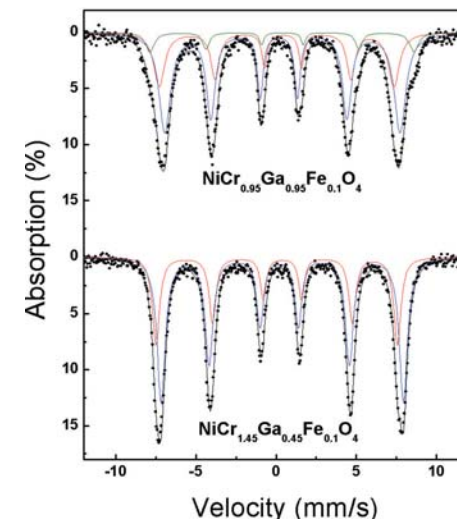


Fig. 2. The Mössbauer spectra of $\text{NiCr}_{1.9-x}\text{Ga}_x\text{Fe}_{0.1}\text{O}_4$ ($x=0.45, 0.95$) at 4.2 K.