Study of Magnetic Ordering in $AlFe_{2-x}Mn_xB_2$ by Mössbauer Spectroscopy

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Introduction

Magnetocaloric effect (MCE) [1], the reversible temperature change of a magnetic material upon the application or removal of a magnetic field, has attracted unprecedented attention because of its great prospect as magnetic refrigeration. The room temperature magnetic refrigeration is of special interest as environmentally friendly and energy efficient technology with great societal and economic benefits [2]. Our current research discovered large MCE in $AlFe_2B_2$ around room temperature [3]. Magnetic measurement revealed that $AlFe_2B_2$ exhibits an abrupt ferromagnetic transition at 285 K. Hole doping by substitution of Mn for Fe results in gradual suppression of the ferromagnetic ordering as the Mn content is increased. To understand the role of the Fe sublattice in the magnetic behavior of $AlFe_{2-x}Mn_xB_2$, the materials in questions were studied by Mössbauer spectroscopy.

Experimental

Mössbauer spectra were collected on a conventional constant acceleration spectrometer housed in the NHMFL EMR facility. A ^{57}Co gamma-ray source was used. Pulse height analysis was done using a Reuter-Stokes gas proportional counter. The spectrometer was calibrated using a natural abundance iron foil. The Mössbauer spectra were recorded for samples $AlFe_{2-x}Mn_xB_2$ (x=0.4, 1.2, 1.6) in zero magnetic field at variable temperatures.

Results and Discussion

We collected Mössbauer spectra of $AlFe_{2-x}Mn_xB_2$ samples with x = 0.4, 1.2, and 1.6. All of them exhibit two spectral components. At 4.2 K in zero applied magnetic field the spectra consist of a sextet and a quadrupole doublet (Fig. 1) assigned to a ferromagnetic (FM) and a paramagnetic (PM) species, respectively. The observed quadrupole doublet of the PM phase is essentially the same for all samples and is characterized by δ = 0.33(3) mm/s and ΔE_Q = 0.36(3) mm/s. The contribution of PM component increases with increasing x, from ~14(2)% for x = 0.4 to 23(3)% for x = 1.2 to 35(5)% for x = 1.6. Furthermore, the centroid of the sextet pattern, the isomer shift of the FM phase, δ = 53(1) mm/s, is nearly independent of x. This value, however, is distinctly different from that of the PM phase, suggesting that the two spectral components account for species with distinctly different chemical makeup.

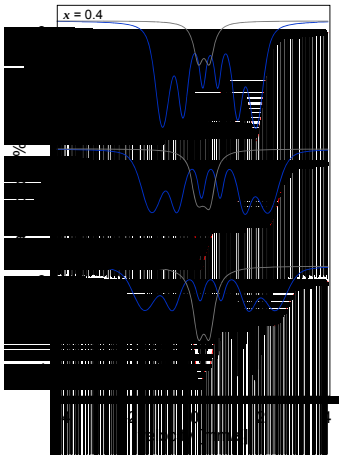

Fig. 1. Zero-field Mössbauer spectra of $AlFe_{2-x}Mn_xB_2$ at 4.2 K.

The quadrupole doublet of the PM phase is essentially conserved in the entire temperature range, but the FM phase shows a marked decrease of the observed hyperfine splitting as function. Among the three samples investigated only x = 0.4 exhibits a clear FM to PM transition such that for this sample the hyperfine splitting of the FM phase is fully collapsed above the Curie temperature, T_C ~ 220 K. For the samples with x = 1.2 and 1.6, the hyperfine splitting of the FM sextet is not collapsed even at RT suggesting that their Curie temperatures are higher than 300 K. This observation indicates the increase in T_C for the samples with higher Mn content.

Conclusions

Mössbauer spectroscopy on $AlFe_{2-x}Mn_xB_2$ revealed the FM transition temperature of 220 K for x = 0.4, which agrees with the results of magnetic measurements. The spectra of samples with x = 1.2 and 1.6, however, reveal higher magnetic ordering temperature, which suggests that magnetic measurements at higher temperatures are required for these sample, to corroborate the conclusions of Mössbauer experiments.

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