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. Magnetic measurements 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 question 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, 1.2, 1.6) in zero magnetic field at variable temperatures.

Results and Discussion

The thermal evolution of the Mössbauer spectra of $AlFe_2B_2$ confirms the PM to FM ordering transition of Fe observed by temperature dependent susceptibility measurement. The spectrum at 295 K shows a doublet indicative of paramagnetic Fe (**Figure 1a**). The spectrum collected at 4 K exhibits hyperfine splitting, as expected for the ferromagnetically ordered Fe sublattice and consistent with the single unique crystallographic site of Fe atoms. When Mn is substituted for Fe, the Curie temperature (T_C) and the magnetization value gradually decrease at higher Mn content. The variable temperature Mössbauer spectra confirm that the ferromagnetism is gradually suppressed by substitution of Mn for Fe. For both $AlFe_{0.8}Mn_{1.2}B_2$ and $AlFe_{0.4}Mn_{1.6}B_2$, the Mössbauer spectra show only doublet above T_C, but a hyperfine-split component appears below T_C. For these two samples, all Mössbauer spectra recorded below T_C are composed of ferromagnetic and paramagnetic components, with the contribution from the former increasing at lower temperatures. A comparison of the Mössbauer spectra of $AlFe_{0.4}Mn_{1.6}B_2$ at 84 K and 4 K clearly demonstrates the increased contribution from the hyperfine-split component (sextet) at 4 K (**Figure 2**).

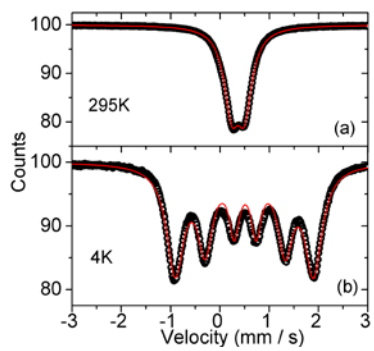

Figure 1. Mössbauer spectra of $AlFe_2B_2$ measured at 295 K and 4 K.

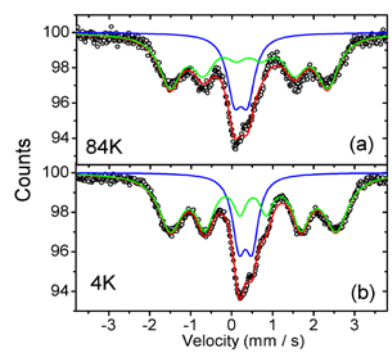

Figure 2. Mössbauer spectra of $AlFe_{0.4}Mn_{1.6}B_2$ measured at 84 K and 4 K.

Conclusions

Mössbauer spectroscopy proves that the substitution of Mn for Fe in $AlFe_2B_2$ leads to gradual suppression of ferromagnetic ordering. Nevertheless, Mössbauer spectra reveal that the weak ferromagnetic ordering is still present even at sufficiently high Mn content, i.e. in $AlFe_{0.4}Mn_{1.6}B_2$.

Acknowledgements

This research is supported by the National Science Foundation CAREER Award (NSF-DMR-0955353).

References

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[2] Gschneidner, Jr. K.A., *et al.*, Rep. Prog. Phys., **68**, 1479-1539 (2005).