Resonant X-ray Scattering Study of Gadolinium Cobalt Germanide

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Introduction

We report the preliminary results of a x-ray resonant exchange scattering (XRES)[1] study of a ternary intermetallic compound, $GdCo_2Ge_2$. This material crystallizes in the tetragonal $ThCr_2Si_2$-type structure (I4/mmm). This complex material is of general interest with regard to 4*f*-magnetism in metals, magnetic resonance phenomena, and its close electronic and isostructural relationship to the rare-earth nickel germanides where a robust Fermi-surface nesting has been found to be responsible for the magnetic wavevector.[2] All the known $Gd(TM)_2X_2$ (*TM* = transition-metal element, *X* = Ge or Si) order antiferromagnetically.[3] However, a few of their magnetic structures are known due primarily to the fact that Gd has the largest neutron absorption cross section among the elements. On the other hand, in all the members of the gadolinium cobalt germanides that have been studied, the ordering vector is of the form **q**=(0, 0, q_z).[3] This behavior is similar to that of the Ni germanides, suggesting the possibility of Fermi-surface nesting in these materials as well. The high-quality single crystal of $GdCo_2Ge_2$ used in this work was grown by a high-temperature solution-growth technique at Ames Laboratory.[4] According to magnetic susceptibility measurements with a field applied along the **c** axis, this material orders antiferromagnetically at $T_N \sim 33$K. No additional transitions at temperatures above 2K were observed.

Experimental Details

The XRES studies were performed on the bending magnet beamline in sector 1 of SRI CAT.[5] A Si (111) reflection was used to monochromatize the beam, which was then focused both vertically and horizontally down to a spot size of 600 µm-700 µm, respectively, at the sample. Higher harmonic contaminations in the beam were eliminated by using two Pd-coated mirrors.

A small single crystal of this material in the morphology of a rectangular tablet with dimensions 400X400X300 μm^3 was aligned with the [H 0 L] zone in the vertical scattering plane. Since the as-grown (0 0 1) surface showed no sign of residual flux, no preparation, such as mechanical polishing, of the sample surface was necessary. Initially, the incident photon energy (E_i) was tuned to the L_{III} edge (7.243 keV) of Gd in order to use the resonant enhancement.[3] Intensity was measured using a Ge solid-state detector. The sample was cooled in a closed-cycle He refrigerator.

Results

At 8.0K, with E_i fixed at 7.243 keV, two fundamental superlattice peaks associated with the (0 0 4) and (0 0 6) charge peaks, marked $(0\ 0\ 4)^+$ and $(0\ 0\ 6)^-$, respectively, appeared symmetrically on either side of the Brillouin-zone boundary (Fig. 1). Using this set of two superlattice reflections, the wavevector is found to be **q** = (0, 0, 0.93±0.006).

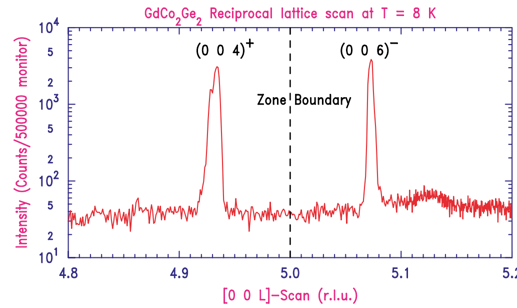

FIG. 1. Reciprocal lattice scan showing the superlattice peaks.

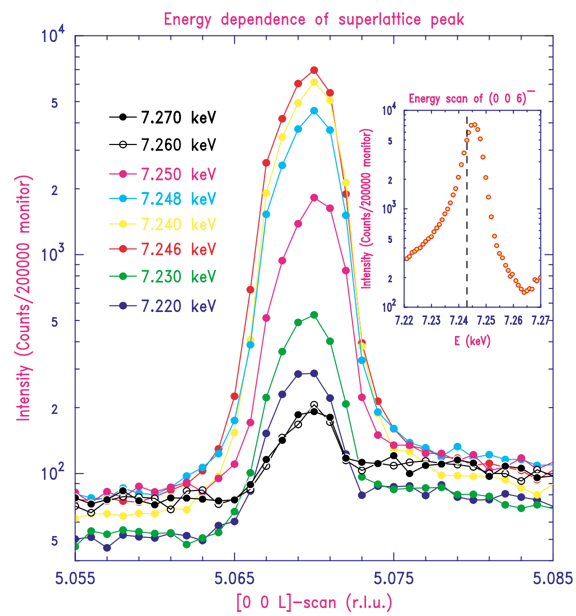

FIG. 2. Resonance properties of the $(0, 0, 6)^-$ satellite.

Figure 2 shows the reciprocal lattice scan through the $(0\ 0\ 6)^-$ peak as E_i was varied across the Gd L_{III} edge. As E_i was gradually changed from 7.220 to 7.270 keV, the $(0\ 0\ 6)^-$ grew stronger, reaching a maximum for E_{res} = 7.246 keV with a count rate of ~8000/sec. Upon further increasing the energy, the intensity of the peak decreased. However, significant intensity is observed far below (at 7.220 keV) and above (at 7.270 keV) E_{res} indicating the presence of strong nonresonant scattering in this compound. The inset (Fig. 2) shows an energy scan through the satellite peak at $(0\ 0\ 6)^+$. There is a strong resonance that occurs a few eV above the absorption edge (dashed line), which is consistent with the dipolar (E_1) nature ($2p_{1/2} \rightarrow 5d$) and the magnetic origin of the reflection. Note that there is strong asymmetry of the resonant line profile that most likely results from interference with the nonresonant scattering.

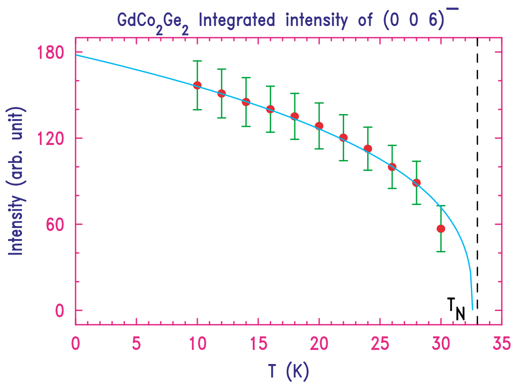

FIG. 3. Temperature dependence of the (0, 0, 6)⁻ magnetic peak.

Figure 3 shows the order parameter collected up to 30K. The integrated intensity of the $(0\ 0\ 6)^+$ magnetic peak decreases monotonically as the temperature is raised. The temperature dependence can be modeled reasonably well with a power law $(I(T) \approx 1 - T/T_N)^{2\beta}$ with $\beta \approx 0.18$ yielding a T_N of 32.6±0.5K.

Concluding Remarks

$GdCo_2Ge_2$ orders antiferromagnetically with seemingly an incommensurate propagation vector **q** = (0, 0, 0.93) at 8.0K. Additional experiments are needed to determine the moment direction, complete the *T* dependence, and study resonance and polarization properties. The observation of a strong nonresonant scattering is intriguing and can be exploited to refine the magnetic structure.

Acknowledgment

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