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Thermal Expansion and Magnetostriction of the Ising Antiferromagnet TbNi$_2$Ge$_2$

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Abstract. We have measured the linear thermal expansion and magnetostriction of the Ising antiferromagnet TbNi$_2$Ge$_2$ along its c-axis from room temperature to 2 K and in magnetic fields to 14 T. We find a magnetic phase diagram that agrees with earlier work and estimate aspects of its uniaxial pressure dependence. We also find a new high field feature near 10 T which may signal the onset of an additional field-induced phase.

Keywords: Thermal Expansion, Magnetostriction, Antiferromagnetism.

INTRODUCTION

The ternary rare-earth intermetallic compound TbNi$_2$Ge$_2$ crystallizes in a body-centered tetragonal ThCr$_2$Si$_2$ structure and exhibits Ising-like antiferromagnetism with phase transitions into incommensurate and commensurate states at $T_N = 16.7$ K and $T_I = 9.6$ K respectively; six additional metamagnetic phases have been observed in applied fields at 2 K. The magnetic properties of TbNi$_2$Ge$_2$ are driven by indirect exchange interactions (presumably of the RKKY variety) between the magnetic rare-earth ions via the conductions electrons. TbNi$_2$Ge$_2$ has been studied by Bud’ko et al. as part of a more general inquiry into the magnetic behavior of rare-earth-Ni$_2$Ge$_2$ compounds [1]; references to earlier work may also be found in Ref. [1].

We have measured the linear thermal expansion and magnetostriction along the c-axis of TbNi$_2$Ge$_2$ (the axis along which the spins align) using a capacitive dilatometer constructed of OFHC copper and designed to operate in a Physical Property Measurement System available from Quantum Design Inc. A detailed description of the dilatometer will appear elsewhere [2].

RESULTS AND DISCUSSION

The linear thermal expansion of TbNi$_2$Ge$_2$ along its c-axis ($\alpha = \frac{d\ln(L)}{dT}$ where L is the length of the sample, 0.85 mm here) is shown in Fig. 1. Features associated with the phase transitions at $T_N$ and $T_I$ are clearly visible. The broad maximum near 30 K is due to crystal field effects.

FIGURE 1. Linear thermal expansion of TbNi$_2$Ge$_2$ along its c-axis. The inset shows an expanded view of the low temperature phase transitions.

We first focus on the feature at $T_N$, the shape of which suggests that it is due to a 2$^{nd}$ order phase transition. Combining the jump in thermal expansion ($\Delta \alpha = 2.9\times10^{-5}$ K$^{-1}$) with the jump in molar specific heat from Ref. [1] ($\Delta C_p = -15$ J/mol K), we can use the Ehrenfest relation...
\[
\frac{dT_N}{dP_c} = V_M T_N \frac{\Delta \alpha_c}{\Delta C_p},
\]

where \(P_c\) is the uniaxial pressure along the c-axis and \(V_M\) is the molar volume, to estimate the uniaxial pressure dependence of \(T_N\) to be \(-0.16\) K/kbar.

The sharp feature at \(T_t\) suggests that this phase transition is 1\(^{st}\) order, a suggestion that is supported by the presence of magnetic hysteresis across this phase boundary in higher magnetic fields [1]. However, the feature observed in \(C_p\) at this temperature is relatively broad and therefore at odds with this suggestion. Should this be a 1\(^{st}\) order transition, a Clausius-Clapyeron equation would apply:

\[
\frac{dT_t}{dP_c} \approx V_M \frac{\Delta(\Delta L/L)}{\Delta S},
\]

where \(\Delta(\Delta L/L)\) is the jump in the expansivity \(\Delta L/L = L(T)-L(0)/L(0)\) at the phase transition (\(\Delta L/L\) is determined by integrating \(a(T)/T\) across the transition), and \(\Delta S\) is the jump in molar entropy at the phase transition (determined by integrating \(C_p(T)/T\) across the transition). Integrating our data shows that \(\Delta(\Delta L/L)\) is clearly finite at \(T_t\), but integrating the specific heat data suggests that \(\Delta S\) is very close to zero. If this transition is 1\(^{st}\) order, Eqn. (1) suggests that the uniaxial pressure dependence of \(T_t\) might be very large.

The magnetostriction of \(\text{TbNi}_2\text{Ge}_2\) at 2 K, measured along its c-axis with magnetic fields applied parallel to the c-axis, is shown in Fig. 2 where \(\Delta L/L = L(H)-L(0)/L(0)\). Magnetic hysteresis is observed in low fields along with a series of metamagnetic phase transitions consistent with the measurements of Bud’ko et al. [1] up to about 6 T.

We observe an abrupt change in the slope of \(\Delta L/L\) near 10 T at 2 K (marked by an arrow in Fig. 2, the derivative of the data with respect to magnetic field in the vicinity of 10 T is shown in the inset of Fig. 2). We suspect that this feature may signal a new field-induced phase transition although there is no corresponding signal of such a transition in high field magnetization measurements [1]. The feature was quite reproducible in our measurements and increased in field as the temperature increased (reaching 12.8 T at 30 K; the feature was not observed at 50 K up to our maximum field of 14 T). This temperature dependence suggests that the feature may be due to a spin-flop-like transition, though one would expect to see an associated metamagnetic-like feature in the field dependent magnetization, a feature that is not observed [1]. Understanding the origin and nature of this feature will require further study.

CONCLUSIONS

We have measured the thermal expansion and magnetostriction of \(\text{TbNi}_2\text{Ge}_2\) along its c-axis from room temperature to 2 K and in magnetic fields to 14 T. Our results on the magnetic phase diagram agree with earlier results except for the observation of what may be a new field-induced phase above 10 T at low temperature. Application of thermodynamic relations to our results allowed us to estimate the affect of uniaxial pressure on the magnetic phase transitions in zero field.

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REFERENCES

1. S.L. Bud’ko et al., J. Mag. Mag. Mater. 205, 53 (1999).
2. G.M. Schmiedeshoff et al. in preparation.