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MAGNETIC STRUCTURE OF CUBIC $\text{Tb}_{0.3}\text{Y}_{0.7}\text{Ag}$

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Abstract. $\text{Tb}_{0.3}\text{Y}_{0.7}\text{Ag}$ undergoes a magnetic phase transition at $\sim 36$ K to an antiferromagnetic structure which neutron diffraction has shown to have two components. A commensurate antiferromagnetic component is similar to the $(\pi\pi0)$ structure found in $\text{TbAg}$, but with a correlation range of only 42 Å at 4 K, while an incommensurate modulated component is like that found in $\text{HoAg}$, but with a finite correlation range of 290 Å.

The CsCl-type compounds $\text{RAg}$ ($R = \text{rare earth}$) exhibit a fine balance between ferromagnetism and antiferromagnetism of various forms. The dilution of the rare earth by the chemically similar nonmagnetic yttrium should certainly lead to reductions in ordering temperatures, perhaps to modifications in the magnetic structures, and ultimately to spin glass behavior. Magnetization studies of the series $\text{Tb}_x\text{Y}_{1-x}\text{Ag}$ and $\text{Gd}_x\text{Y}_{1-x}\text{Ag}$ [1] have shown that for $x < 0.5$, thermoremanences appear along with associated time dependences which are indicative of spin glass behavior. We have carried out neutron diffraction measurements to clarify the nature of the magnetic state in these systems, starting with a polycrystalline sample of Tb concentration $x = 0.3$, which exhibited the largest remanence effects.

The neutron diffraction was performed on spectrometers at the National Bureau of Standards reactor, selecting 2.46 Å neutrons with a pyrolytic graphite (PG) monochromator and using a PG analyzer and filter to improve the signal to noise ratio of the data. A diffraction pattern taken at 4 K showed a set of additional peaks appearing at distinct positions from the nuclear peaks observed at 60 K. These could be associated with the set of indices $(h+1/2, k+1/2, \ell)$. This type of antiferromagnetic structure has been observed in other $\text{RAg}$ compounds, including $\text{TbAg}$ [2]. The $(\pi\pi0)$ structure [3] consists of moments ferromagnetically aligned in [110] planes, with neighboring planes antiferromagnetically coupled; the resulting magnetic lattice has tetragonal symmetry with a doubling of the cell axes in two directions. The structure observed here is a more complex variant of the $(\pi\pi0)$ structure.

Fig. 1 shows the first peak in the diffraction pattern, in which two reasonably sharp peaks are superimposed on a broad peak, approximately centered on the $(1/2 1/2 0)$ position. The broad central peak corresponds to the $(\pi\pi0)$ spin structure and the pair of satellites represent an incommensurate modulation of the basic antiferromagnetic structure. Such a modulated structure has been observed in $\text{HoAg}$, $\text{TmAg}$, $\text{ErAg}$ and $\text{DyAg}$. On cooling, $\text{ErAg}$ [4] and $\text{DyAg}$ [5] order first into an incommensurate structure, then transform at a lower temperature into a $(\pi\pi0)$ structure. In $\text{HoAg}$ [6, 8] and $\text{TmAg}$ [7, 8], arc-melted samples showed a mixed structure as found here, but annealing for 6-24 hours stabilized the modulated variant. As our sample was annealed for a total of six days, it is unlikely that further annealing would stabilize one of the two magnetic structures.

The magnetic peaks are not resolution limited, indicating that the correlation lengths are finite even at 4 K. The central $(\pi\pi0)$ peak is very broad, indicating a correlation range of only $\sim 42$ Å, which is approximately 12 chemical unit cells. The satellite peaks, while considerably sharper, still possess an intrinsic width corresponding to a correlation length of $\sim 290$ Å. Assuming that the structures are similar to those found in the related $\text{RAg}$ compounds, the diffraction pattern is consistent with the coexistence of a short-range ordered $(\pi\pi0)$-type structure and an incommensurate modulated structure of the type found in $\text{HoAg}$. In this structure, the individual moments are parallel to the unique c-axis; the propagation vector for the modulated state is directed along the cube edges, allowing for a set of domains $(h \pm 6, k, \ell), (h,
$k \pm \delta, \ell$, etc. In TbAg, magnetostriction measurements as well as crystal field analyses have indicated that the Tb moments are oriented along the c-axis [9]. The separation of the satellites from the $(1/2, 1/2, 0)$ position indicates that modulation wave vector has a magnitude of $0.059 (2\pi/a)$, corresponding to about 17 chemical unit cells.

Figure 2 shows the temperature dependence of the integrated intensity of the central peak as well as the sum of the integrated intensities of the satellites. As indicated in the figure, there is still measurable intensity at 37.5 K, persisting above the nominal transition derived from magnetization measurements. As the peaks have broadened still further, it is difficult to distinguish the satellite positions and the integrated intensities; some scattering remains up to 45 K. Clearly most of the magnetic order develops below approximately $\sim 36$ K, in agreement with the bulk measurements. Although the breadth of the peaks makes the precise determination of the peak positions difficult, the data are consistent with a temperature dependent modulation wavelength, as is found in HoAg and TmAg [8].

The coexistence of two antiferromagnetic structures with finite correlations clearly points out the importance of frustration in this system, with competition certainly between the $(\pi,0)$ and incommensurate modulated structure. It is also possible that some of the Tb moments remain essentially fully disordered in zero field, participating in neither of the antiferromagnetic structures. Preliminary measurements in an applied magnetic field suggest that the correlation ranges of the coexisting structures become even shorter when the sample is cooled in a field, but otherwise no dramatic effects occur. This suggests that the spin glass properties may arise from disordered moments remaining in the system, perhaps in competition with the antiferromagnetic moments. Further measurements as a function of applied field and Tb concentration should help to clarify this complicated situation.

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