Magnetic phase diagram of $GdGa_{1.75}Al_{0.25}$

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Abstract

DC and AC magnetization of $GdGa_{1.75}Al_{0.25}$ have been measured in the magnetic field up to 5 T on polycrystalline material. A specific heat measurement has shown an antiferromagnetic transition at T_N=24.0 K and a second transition at 22.9 K, immediately below T_N. A third transition has been observed at 7.7 K, which may be due to the change of the easy axis. Every temperature below T_N we have observed metamagnetic transitions and obtained complex H-T phase diagram. The magnetic structure of $GdGa_{1.75}Al_{0.25}$ is similar to that of $GdGa_2$.

Key words: Gd intermetallics; magnetic phase diagram; magnetization; specific heat

$GdGa_2$ crystallizes in the hexagonal AlB_2-type crystal structure [1]. It is reported that $GdGa_2$ orders antiferromagnetically at 23.6 K [2],[3], but the specific heat measurement points out the existence of two successive phase transition near Néel temperature T_N [4]. Another transition below T_N is observed at T_t=5 K [3]. Neutron diffraction measurements on powder sample at 2 K [2] showed $GdGa_2$ exhibits an incommensurate magnetic structure with a propagation vector $\boldsymbol{Q}$=(0.39, 0.39, 0). $GdGa_{2-x}Al_x$ keeps the same crystal structure as that of $GdGa_2$ within $x = 1.5$ [5]. The lattice constants ratio c/a is about 0.97 for $x < 0.6$ and about 0.84 for $x > 0.75$. The magnetic structure changes from a complex structure to a simple antiferromagnetical one with the change of this ratio [6]. Contrary to the other rare earth, Gd^{3+} is in an S state leading to negligible magnetocrystalline anisotropy. Therefore we have a plan to obtain a phase diagram on a polycrystalline sample of $GdGa_{1.75}Al_{0.25}$ in order to clarify the magnetic structure of $GdGa_2$ or $GdGa_{2-x}Al_x$.

Polycrystalline samples were prepared by the same method as reported previously [5]. A small sample was cut from the ingot and used for DC magnetization measurement. A relatively large sample was cut for AC magnetization measurement. DC and AC magnetization and specific heat were measured by use of Quantum Design SQUID magnetometer and PPMS.

Figure 1 shows the temperature dependence of DC susceptibility which is measured in a field of 0.1 T and the magnetic specific heat in zero field. Clearly two transitions are observed near Néel temperature by specific heat measurement. We can not distinguish these two transitions by the susceptibility measurement. Below Néel temperature another transition is observed at 7.7 K by susceptibility measurement but is not clear in the specific heat. This transition temperature T_t is higher than 5 K of $GdGa_2$. Figure 2 shows the typical DC magnetization process up to the magnetic field of 5 T. Very weak jumps of magnetization are observed. The field derivatives are also shown in the figure. The magnetization is not saturated within the magnetic field of 5 T. Figure 3 shows the field dependence of AC magnetization. Relatively clearly metamagnetic transitions are observed.

Final magnetic phase diagrams are shown in figure 4, which are obtained from DC and AC magnetization measurements, respectively. In the figure the results of the specific heat measured in the field of 0, 1 and 5T are included. The phase diagram (a) is simpler than (b). The critical fields in (a) are lower than (b). In Fig. 4 (b), we have added the critical fields with slight jumps of DC magnetization and connected these

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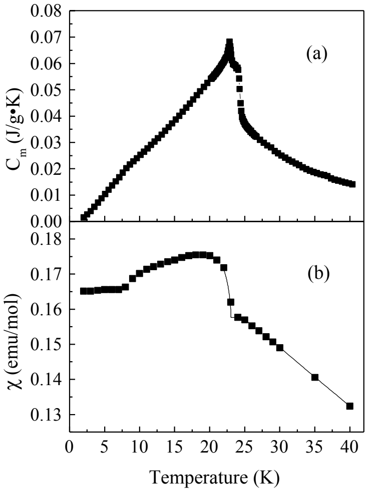

Fig. 1. Temperature dependence of magnetic specific heat (a) and DC susceptibility (b) of $GdGa_{1.75}Al_{0.25}$.

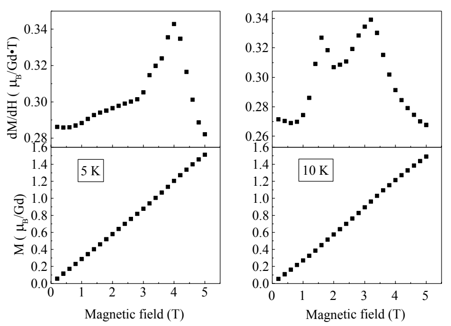

Fig. 2. Typical DC magnetization curves and field derivatives of $GdGa_{1.75}Al_{0.25}$ at 5 and 10 K.

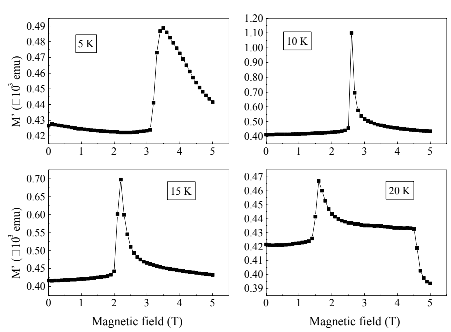

Fig. 3. Field dependence of AC magnetization of $GdGa_{1.75}Al_{0.25}$ at several temperatures.

by dotted lines. Dotted lines seem to reflect the phase diagram (a). The difference between these phase diagrams may be attributed to axial tendency of crystal growing in polycrystalline sample. In the phase diagram (a), there is a horizontal borderline which distinguishes the lower temperature phase and the interme-

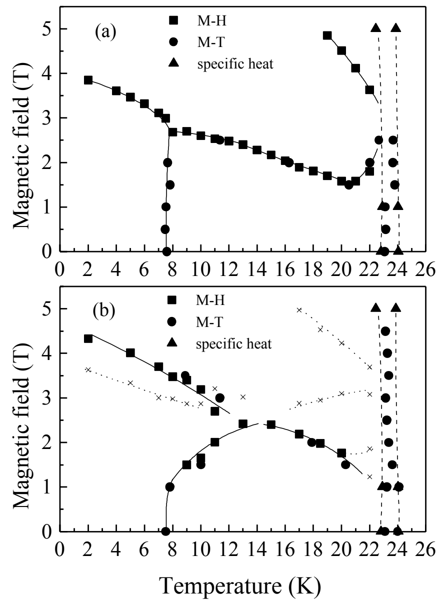

Fig. 4. Magnetic phase diagram (a) determined form AC magnetization measurements and (b) from DC magnetization measurements of $GdGa_{1.75}Al_{0.25}$. The results of specific heat are included in the figures. Lines are guides for eyes.

diate temperature phase. In account of the results of single crystal $GdGa_2$ [3], in lower temperature phase the easy axis is [100] and in intermediate temperature phase it changes its direction into [001]. In higher temperature phase the spin structure is unknown still. Magnetic field causes a metamagnetic transition and forces lower temperature phase and intermediate phase into the same phase. This field-induced spin structure is not known, too. In conclusion, we have a complex phase diagram of $GdGa_{1.75}Al_{0.25}$ with negligible magnetocrystalline anisotropy. The magnetic structure of $GdGa_{1.75}Al_{0.25}$ is similar to that of $GdGa_2$. Neutron diffraction study on single crystal is desirable to determine the precise spin structures in a magnetic field.

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