Thermal expansion measurement under pressure of UGe_2

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Abstract

Volume expansion measurements of single crystalline UGe_2 samples have been made under pressure. The linear coefficient $\alpha_V(T)$ at ambient pressure shows a broad hump at around $T_x \sim 25$ K and a sharp transition at $T_C = 52$ K. We have observed that the anomaly in $\Delta\alpha_V$ at T_x becomes prominent and increases in magnitude with increasing pressure.

Key words: thermal expansion; high pressure; UGe_2; superconductivity

The ferromagnet UGe_2 has a Curie temperature $T_C \simeq 52$ K at ambient pressure, and T_C decreases with increasing pressure[1]. Recently, superconductivity was observed in the pressure range between 1.0 and 1.6 GPa, with a maximum superconducting transition temperature of $\sim$ 0.8 K at about 1.2 GPa[2]. The interesting is that UGe_2 is still in the ferromagnetic phase in this pressure range. In addition to these phase transions, an anomaly was observe at $T_x \sim 25$ K at ambient pressure, and it was argued that "fluctuations" relevant to this anomaly may play an essential role in the mechanism of the superconductivity[3-6]. In our previous paper[7], we have found that the temperature dependence of dc magnetization shows an upturn around T_x under pressure, which becomes prominent with increasing pressure. In this paper, we present results of the thermal expansion measurement, particularly concentrating on a temperature region around T_x .

Single crystalline samples of UGe_2 were grown by the Czochralski method using a tetra-arc furnace. The thermal expansion measurements were made with a Be-Cu clamp cell. A mixture of Flourinert FC70 and FC77 was used as pressure-transmitting medium. A

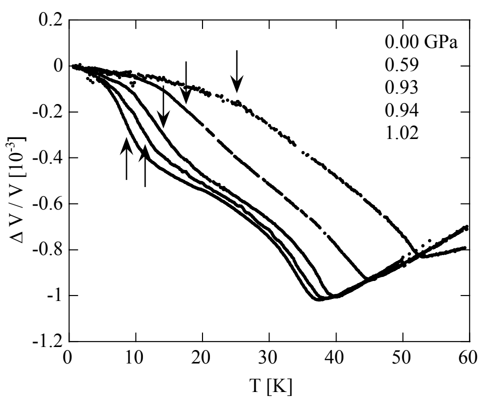

Fig. 1. Volume thermal expansion $\Delta V/V$ as a function of temperature. T_x denoted by an arrow shifts to the lower temperature side and the hump at T_x becomes prominent with increasing pressure.

pressure at low temperatures was determined from the pressure dependence of superconducting transition temperatures of In and Pb with an estimated accuracy of ±0.03 GPa by measuring the ac magnetic susceptibility. Thermal expansion $(\Delta l/l)_i$ $(i = a, b, c)$ was measured in the temperature range between 1.0 and 60 K by means of strain gauge method. Copper was used as a reference material. We calculate the volume expansion $\Delta V/V$ as a function of temperature via the

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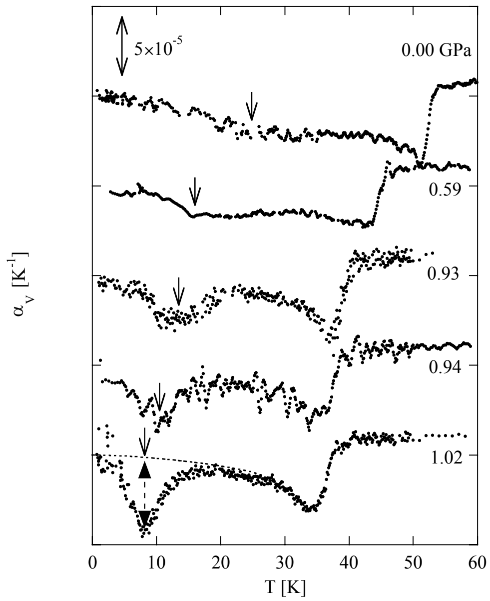

Fig. 2. Volume expansion coefficient $\alpha_{\rm V}$ as a function of temperature. The "peak height" at T_x is shown as an broken arrow.

following relation:

$$\frac{\Delta V}{V} = (\frac{\Delta l}{l})_a + (\frac{\Delta l}{l})_b + (\frac{\Delta l}{l})_c.$$

Figure 1 shows the temperature dependence of $\Delta V/V$. In addition to a sharp transition at $T_{\rm C} \simeq 52$ K, corresponding to the Curie temperature, we observed a weak anomaly at $T_x \sim 29$ K at ambient pressure, although it is difficult to determine the temperature definitively from this figure (see Fig. 2). This anomaly at T_x becomes evident and moves to the lower temperature side with increasing pressure. This feature around T_x may resemble that of the dc magnetization[7].

Figure 2 shows the temperature dependence of the volume expansion coefficient $\alpha_{\rm V}$. Corresponding to the results given in Fig. 1, the anomaly at T_x shifts to the lower temperature side and sharpens with increasing pressure. We evaluated the "peak height" of $\Delta\alpha_{\rm V}$ at T_x as indicated by a broken arrow, and also estimated the "half width of the peak" ΔT_x.

Figure 3 shows the pressure dependence of (a) $T_{\rm C}$ and T_x, (b) $\Delta\alpha_V$ and ΔT_x and (c) $\Delta C/T_x$. Here a "jump" of the specific heat ΔC corresponding to $\Delta\alpha_{\rm V}$ was estimated via the following equation, assuming that the anomaly corresponds to a second-order transition,

$$\frac{{\rm d}T_x}{{\rm d}P} = \frac{\Delta\alpha_{\rm V}}{(\Delta C/T_x)}.$$

We clearly observe that $\Delta\alpha_{\rm V}$ increases but ΔT_x decreases with increasing pressure. We also note that $\Delta C/T_x$ seems to be independent of pressure. However,

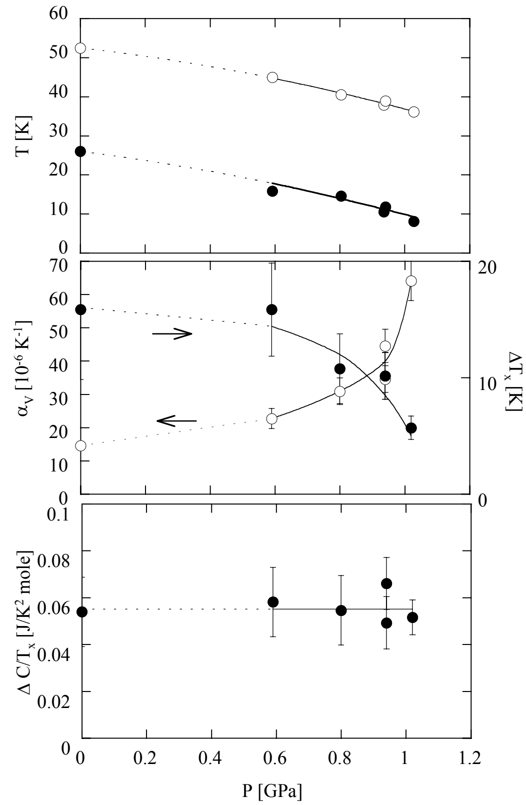

Fig. 3. Pressure dependence of (a) $T_{\rm C}(\circ)$ and $T_x(\bullet)$, (b) $\Delta\alpha_{\rm V}(\circ)$ and $\Delta T_x(\bullet)$, and (c) $\Delta C/T_x(\bullet)$.

any sharp anomaly has not been observed in the heat capacity at ambient pressure[3], and thus we conjecture that the observed hump in the heat capacity corresponds to this anomaly that is broadened by some effect.

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