ABSTRACT CODE

Phonon, electronic and magnetic contributions to the specific heat of UGe_2

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UGe_2 is the first known material, where both the superconducting (SC) and ferromagnetic (FM) state are generated by the 5f electrons [1]. The wide-spread undertaken studies of this phenomenon have proved that superconductivity is not associated with the ferromagnetic transition at T_C (=53 K), but the SC phase arises deeply in the FM phase. Usually for the unconventional superconductors, the superconductivity is indicated by the enhanced magnetic fluctuations (MF), and appears in close proximity to the boundary $T_C(p)$ around the second-order phase transition. In the case of UGe_2, the phase boundary is different and denoted as $T^*(p)$, where T^* is the so-called characteristic temperature. Thus at this temperature, being equal to about $T_C/2$, a giant negative magnetoresistivity (MR) of about 40 %, measured for j//b and H//a configuration (a is an easy magnetization axis) takes place [2]. Thus this observation clearly confirms the presence of strong fluctuations located deep in ferromagnetic phase. Very recently Watanabe and Miyake [3] have discussed the nature of superconductivity of UGe_2 as being caused by the coupled CDW and SDW fluctuations, which in their opinion just form the $T^*(p)$ new boundary [3].

The purpose of the present paper is to investigate first of all the phonon contribution to the total specific heat, which allows one to analize precisely the remaining (magnetic) part of C_p. In Watanabe and Miyake paper [3] the phonon specific heat has been determined from a sum of two contributions: the Debye C_D one due to acoustic phonon determined from coeficient β (Θ_D=182 K) and to optical phonon modes C_K being the subject to the Kohn effect due to the nesting of the majority-spin band, which in turn gives rise to considerable contribution to the total phonon specic heat C_{ph}.

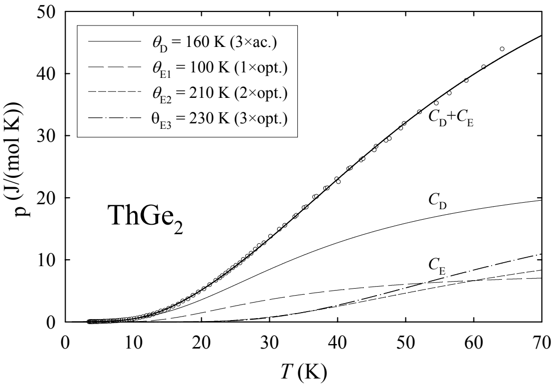

Fig. 1. C_p vs. T (open circles). Solid and dashed lines are defined in the inset.

In Fig. 1 we present the specific heat C_p vs. T for the nonmagnetic lattice reference to UGe_2, as is the case $ThGe_2$. This stoichiometric compound crystallizes in the orthorombic $ZrSi_2$-type structure (Cmcm) [4], being only slightly different from that of UGe_2, i.e. the $ZrGa_2$-type (Cmmm). The latter structure is considered as a stacking variant of the former type [5].

The electronic part of C_p of $ThGe_2$ was practically found to be zero while the low temperature lattice contribution, $C_D=\beta T^3$, yields $\Theta_D\approx160$ K. Such a temperature Θ_D is possible to obtain from the fitting of the Debye function to the ellectrical resistivity ρ vs. T (Fig.2).

As seen in Fig.1, this $C_D(T)$ approach is far to explain fully $C_{ph}(T)$ comprising only the three accoustic branches. To explain fully $C_{ph}(T)$ we have to consider the optical branches as well, the number of which n is 6. The latter are describing by the Einstein approximation by taking into account as many as three the Einstein temperatures Θ_{Ei} (see figure 1).

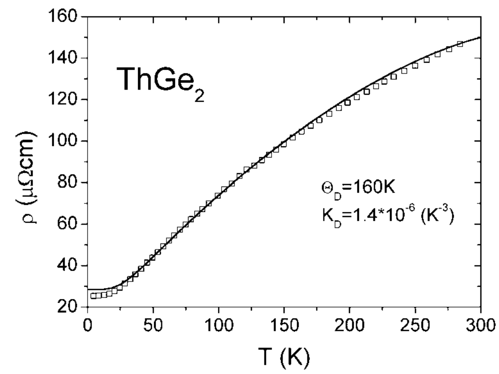

Fig. 2. ρ vs. T (open squares) and the Debye function (solid line).

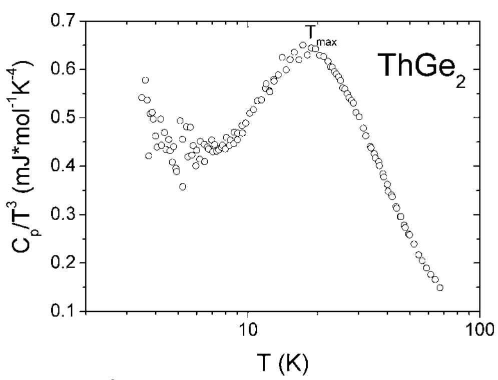

Fig. 3. C_p/T^3 vs. logT.

The necessity to consider also the optical branches in $C_{ph}(T)$ arises from the plot C_p/T^3 vs. logT [6], where the temperature of the maximum, T_{max}, is related to the Einstein temperature as about $5\times T_{max}$ yielding ~100 K in accordance with the fitting shown in Fig.1.

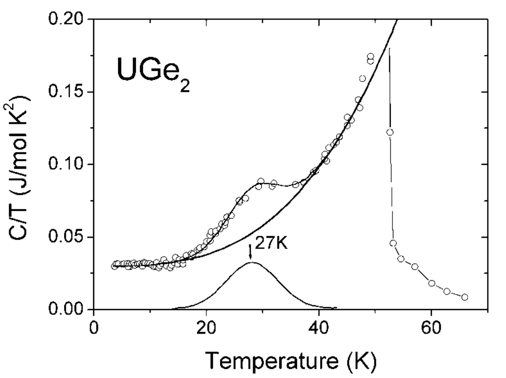

Fig. 4. $\Delta C/T$ vs. T (open circles) and C_{magn} vs T (solid line).

In Fig.4 the difference $\Delta C/T=(C_p-C_{ph})/T$ is plotted against the temperature for UGe_2. The specific heat of UGe_2 has been measured on single-crystalline sample. As seen from this figure the above difference may be presented as a sum of three contributions:

$\Delta C=C_e+C_{magn}+C_{hump}$.

Where $C_e=\gamma T$ (γ=32.5 mJ/K^{2}mol), $C_{magn}=AT^2\exp(-\Delta/kT)$ and C_{hump} is a bell shaped new contribution to the global specific heat propably corresponding to the presence of the strong magnetic fluctuations located deep in the ferromagnetic state with a maximum nearT^*. This together with the MR data [2] strongly indicates on the heterogenious nature of the ordered state in UGe_2, i.e. local ferromagnetic behaviour with its characteristic λ-type anomaly at T_C and with the additional hump-type contribution originated from some kind of strong fluctuations or eventually short range magnetic order, having probably their origin in two different kinds of 5f electron states, recently associated in the literature with the so-called 5felectron-dualism [7].

Some confirmation of more localized character of 5f electrons in UGe_2 than itinerant is a high value of magnetic entropy S_m shown in Fig. 5 as a function of temperature.

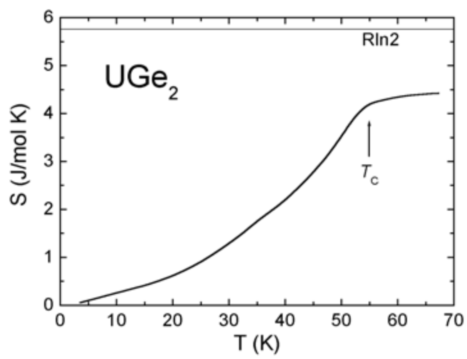

Fig. 5. Magnetic entropy S_m as a function of temperature.

References

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