Transport and thermodynamic properties of UFe_2Zn_{20}

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Ternary rare-earth-based intermetallic compounds RT_2M_{20} (R = Ce, Gd, Yb; T = d-electron transition metal; M = Zn, Al) crystallize with a cubic structure of the $CeCr_2Al_{20}$-type (space group Fd3m, No. 227) [1-5]. The characteristic feature of the unit cell is that the R atom has only one unique crystallographic site surrounded by as many as sixteen M atoms, which constitute a Frank-Kasper-type nearly spherical polyhedron of cubic symmetry. The shortest R-R spacing is about 6 Å, thus the R atoms may be considered as mutually isolated. In contrast, all the T and M atoms occupy positions (one for T and three for M) with trigonal point symmetry.

Similar compounds with uranium and zinc were reported to form with T = Fe, Co, Ru, Rh, Ir [6-9]. They exhibit a variety of anomalous physical properties governed by different strength of f-d hybridization. The phases UCo_2Zn_{20} and URh_2Zn_{20} were described as paramagnetic heavy-fermion systems with well localized 5f electrons [8,9], while UIr_2Zn_{20} was found to be a heavy-fermion itinerant ferromagnet [7,8]. Very limited information is available for UFe_2Zn_{20}. The compound was reported by Goncalves at al. in their pioneering study on polycrystals [6] to be paramagnetic down to 5 K, yet no other than the magnetization and ^{57}Fe Mössbauer data was communicated in the literature up to date.

Single crystals of UFe_2Zn_{20} were grown in Zn flux. The obtained crystals were well-developed cubes with the dimensions up to 60 mm^3. Heat capacity and electrical resistivity measurements were performed in the temperature range 0.35 K – 300 K using a Quantum Design PPMS platform. The resistivity was measured with the AC current flowing along the [110] direction.

The temperature variation of the specific heat of UFe_2Zn_{20} is shown in Fig. 1. In agreement with the magnetic data [6], no hint at any phase transition is seen down to 350 mK. The electronic contribution to the specific heat, determined from the region below 7 K (see the inset), is about 180 mJ/(mol K^2). This enhanced value of the Sommerfeld coefficient may indicate heavy-fermion character of the compound studied.

Fig. 2 displays the temperature dependence of the electrical resistivity of UFe_2Zn_{20}. At room temperature the resistivity is about 160 μΩcm. The resistivity at the terminal temperature of 0.35 K amounts to about 13 μΩcm, yielding the residual resistivity ratio of about 12. These values are similar to those reported for the other UT_2Zn_{20} compounds [7,8]. On decreasing temperature from 300 K down to ca. 130 K, the resistivity increases in a logarithmic manner [$\rho(T) = 243.2 - 14.2\ln T$], hence suggesting significant Kondo contribution to the scattering of conduction electrons. Consequently, the maximum in $\rho(T)$ near 100 K should associated with a crossover from single-ion to coherent Kondo regime. In the latter state, the resistivity decreases rapidly with decreasing temperature, and below 10 K it is proportional to T^2 [$\rho(T) = 12.8 + 0.143T^2$], as expected for a Fermi liquid. Combining the specific heat and electrical resistivity data of UFe_2Zn_{20} one obtains the Kadowaki-Woods

ratio of $0.43 \cdot 10^{-5}$ μΩcm/(mol K^2/mJ)^2 that is fairly close to the universal value for nonmagnetic Fermi liquid systems (with the orbital degeneracy N = 2).

To summarize hitherto findings, UFe_2Zn_{20} seems to be a novel paramagnetic moderately-enhanced heavy-fermion system, quite similar to the isostructural compounds UCo_2Zn_{20} and URh_2Zn_{20}. Further experimental studies aimed at verifying this hypothesis are presently underway and the results will be reported at the conference.

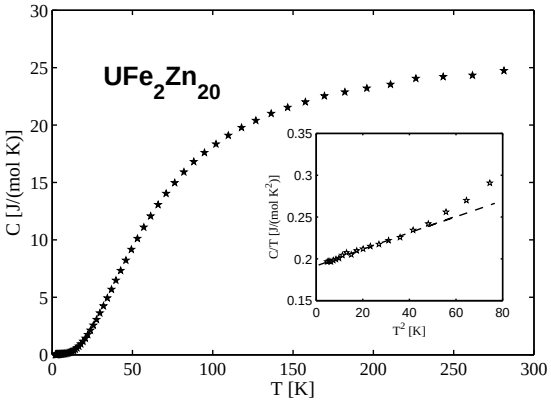

Fig. 1. Temperature dependence of the specific heat of single-crystalline UFe_2Zn_{20}. The inset shows the heat capacity data in the form C/T vs. T^2. The dashed line emphasizes the linear dependence.

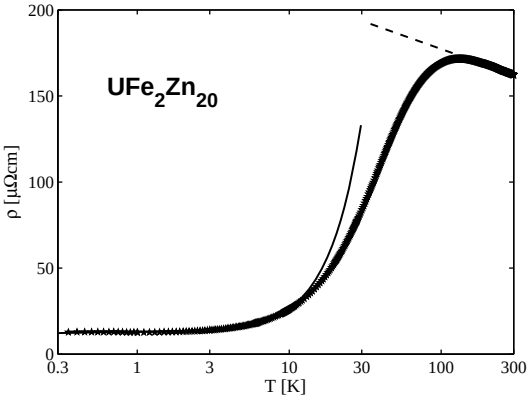

Fig. 2. Temperature variation of the electrical resistivity of single-crystalline UFe_2Zn_{20} (note semilogarithmic scale). The solid and dashed curves mark the Fermi-liquid- and Kondo-like behaviors at low and ambient temperatures, respectively.

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