Scaling of the magnetic susceptibility and electrical resistivity in CeRhAl

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In this communication we report a discovery of a Fermi-liquid breakdown in CeRhAl that can be understood as complex effect of disorder. Our studies of polycrystalline CeRhAl sample suggest a weak magnetic ground state which could be related to the existence of a ferromagnetic clusters (ferromagnetic islands) in the paramagnetic sample. It has been reported [1] that CeRhAl adopts a different structure type than remaining compounds of the series RERhAl (RE is rare earth). While the other ReRhAl compounds crystallize in the orthorombic TiNiSi-type structure [1], CeRhAl has the orthorombic $Pd_2(MnPd)Ge_2$-type structure, which is a combination of orthorombic TiNiSi-type and hexagonal ZrNiAl-type structure, with the *c*-lattice parameter almost double of that in the TiNiSi-type RERhAl series. A comparison of the unit cell volume per formula unit in the RERhAl series shows a volume of CeRhAl smaller than the volume expected on the basis of lanthanide contraction [1], what suggests the mixed valence of Ce.

From the Ce 3d XPS spectra obtained for CeRhAl we estimated an occupation number of the *f*-shell (valence of Ce in CeRhAl) and the hybridization energy Δ basing on the Gunnarsson-Schönhammer theoretical model [2]. The separation of the overlapping peaks was made on the basis of the Doniach- Šunjić theory [3]. Three final state contributions $3d^9f^0$, $3d^9f^1$, and $3d^9f^2$ are observed, which exhibit a spin-orbit splitting Δ_{SO} = 18.6 eV. The appearance of the $3d^9f^0$ component in the 3d XPS spectrum of CeRhAl is clear evidence of the intermediate valence behavior of Ce. Based on the Gunnarsson-Schönhammer (GS) theoretical model, the intensity ratio $I(f^0)/(I(f^0)+I(f^1)+I(f^2))$, which should be directly related to the *f*-occupation probability in the final states, indicates an *f*-occupation number n_f=0.92. On the base of the GS model it is also possible to obtain the hybridization energy $\Delta = \pi V_{fs}^2 \rho_{max}$, which describes the hybridization part of the Anderson impurity Hamiltonian [4]. Here ρ_{max} is the maximum in the DOS and V_{fs} is the hybridization matrix element. It is possible to estimate Δ from the ratio $r=I(f^2)/(I(f^1)+I(f^2))$, calculated as a function of Δ in Ref. [2], when the peaks of the Ce 3*d* XPS spectra that overlap are separated. The intensity ratio r = 0.14 gives for CeRhAl a crude estimate of a hybridization width ~70 meV, which is twice smaller than Δ value of CeRhSb or CeNiSn Kondo insulators [5]. The decreasing number of the conduction electrons (*n*-number) could be a reason which removes a hybridization gap in CeRhSb when Sb is replaced by Al (considering the fractional valence of Ce in CeRhAl, which is compared with that of CeRhSb).

The valence v>3 of Ce in CeRhAl can not be, however, a main reason of existence of its curious structural properties in the RERhAl series. Ce usually exhibits a mixed valence behavior in the series of ternary intermetallic alloys, having the hexagonal (ZrNiAl-type) or orthorombic (TiNiSi-type) structure. CeRhSb is an example of a mixed valent Ce-based compound having a hybridization Kondo gap [6]. We therefore have investigated an electronic structure of CeRhAl, which usually decides about the structural properties of the compound. We also report an unusual temperature dependenceies of the magnetic susceptibility χ(T) and electrical resistivity ρ(T) below 20 K. In CeRhAl the electrical resistivity ρ and magnetic susceptibility χ have following scaling forms for T<20 K: $\rho(T) = \rho_0 + bT^{1.5}$ and $\chi = \chi_0 + aT^{-1.6}$, where a and b are positive. At the low temperatures χ is strongly dependent on magnetic

field what is indicative of atomic disorder effect which can correspond to these power-law divergences in the T-dependencies of the physical properties at low temperatures.

In view of this observation we try to understand the power-law behavior in resistivity and susceptibility of CeRhAl. The temperature power-law exponents of ρ (ε =1.5) and χ (n = 1.6) obtained for CeRhAl are equal or close to the value 3/2 predicted by the spin-fluctuation theory for AFM-QCP in 3D (D being the spatial dimension) [7,8]. The influence of the weak magnetic phase on the measured properties as well as its significance for a correct theoretical explanation is, however, unclear.

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