TRANSPORT PROPERTIES OF $UX_{1-x}Y_{1+x}$ (X=P, As, Sb; Y=S, Se, Te) FERROMAGNET: IS THERE AN ANALOGY BETWEEN THE NONMAGNETIC KONDO-LIKE SYSTEM AND THE CLASSICAL HEAVY FERMION ONE?*

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(Received July 10, 2002)

The a-axis thermoelectric power, $S(T)$ of the two-level-system Kondo ferromagnets UPS, $UAs_{1-x}Se_{1+x}$ and USbTe have been examined. Two peaks of $S(T)$ dependence, related to two characteristic temperatures of electronic scattering, T_1^* and T_2^*, are observed below the Curie temperature. The temperature T_1^*, which we specify as the Kondo temperature is independent of x and equals 29.9 ± 1.7 K. An overall similarity of $S(T,x)$ behaviour for $UAs_{1-x}Se_{1+x}$ and that for $Ce_xY_{1-x}Cu_{2.05}Si_2$ heavy-fermion alloy system is observed and its origin is discussed.

PACS numbers: 75.50.Cc, 72.15.Jf, 72.15.Qm

Cox and Zawadowski [1] predicted that assistance of the conduction electrons to the tunnelling of an atom or group of atoms of the two level system (TLS) may lead to effects similar to those observed for single-ion Kondo system. This nonmagnetic analog of the ordinary Kondo problem is called the TLS Kondo effect. How far does the analogy go? This problem can be studied in uranium and thorium pnictochalcogenides. Their crystals show the TLS Kondo effect [2], that is especially strong in UPS and UAsSe ferromagnets ($T_C \approx 100 \div 120$ K). This is presumably due to the inclination to a disorder in their anionic sublattices [2,3]. The low-T resistivity, $\rho(T)$ upturn and a peak of the thermoelectric power, $S(T)$ at Kondo

* Presented at the International Conference on Strongly Correlated Electron Systems, (SCES 02), Cracow, Poland, July 10–13, 2002.

temperature $T_K \approx 20 \div 50\,K$, are signs of the incoherent Kondo scattering from the TLS centres in these compounds [3–5]. We extended our study to USbTe and some $UAs_{1-x}Se_{1+x}$ solid solutions and found that the $S(T)$ data for UPS, $UAs_{1-x}Se_{1+x}$ and USbTe form quite complete picture which we analyse quantitatively below.

The examined crystals were grown by the chemical vapour transport method [2]. We have determined $S(T)$, $\rho(T)$, while x was estimated from $x(T_C)$ graduation curve [2]. The $S(T)$ was found to be strongly anisotropic. The previous analysis of $S(T)$ behaviour of some dipnictides and pnictochalcogenides showed that the Kondo-like features are the most clearly shown by the a-axis $S(T)$.

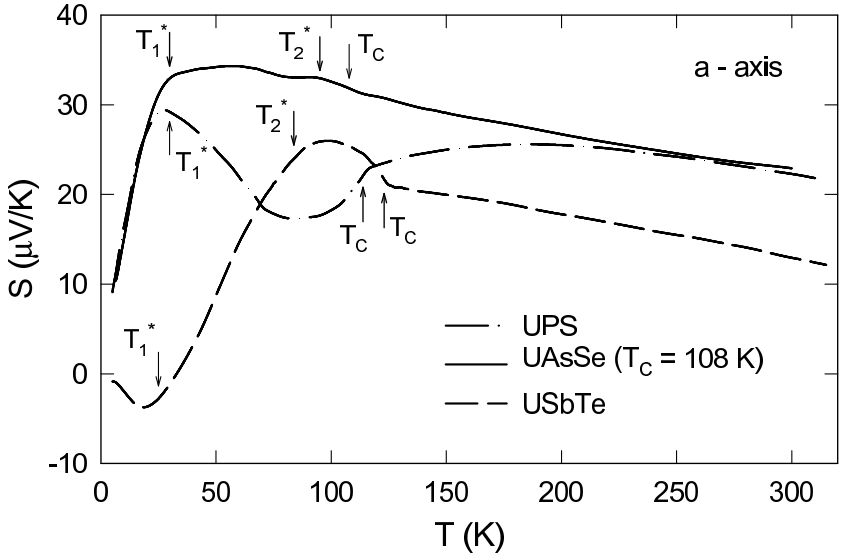

Fig. 1. The $S(T)$ for UPS, USbTe and UAsSe ($T_C = 108\,K$). Arrows denote in turn the characteristic temperatures $T_1^* = T_K$, T_2^* and T_C.

The a-axis $S(T)$ data for UPS, USbTe and UAsSe (T_C = 108 K) are shown in Fig. 1. The low-T resistivity upturn [3] and the peak of the positive contribution to $S(T)$ for UPS at a characteristic temperature T_1^* (Fig. 1)are the clear sign of the TLS Kondo effect in UPS. The $\rho(T)$ for USbTe shows no sign of the low-T resistivity upturn. However, we think that the low-T peak of the negative contribution to $S(T)$ shown for USbTe in Fig. 1, can be also related to the temperature T_1^*. Another distinct phenomenon observed for USbTe is the high-T peak of the positive contribution at T_2^* of an unknown origin. A shape of $S(T)$ curve for UAsSe (T_C = 108 K) in Fig. 1 reflects simultaneous presence of phenomena related to temperatures T_1^* and T_2^*, respectively.

Variation of the shape of $S(T)$ curves with x is shown in Fig. 2(a) for samples of $UAs_{1-x}Se_{1+x}$ system in the range $-0.006 \leq x \leq 0.074$. The increase of x transforms non-monotonously the low-T peak from positive to negative contribution while the high-T peak contribution remains always positive. The low-T behaviour is shown more clearly in Fig. 2(b), where $S(27\,\mathrm{K})$ data for particular crystals are plotted *vs* x. This non-monotonous variation of the low temperature $S(T)$ is accompanied by the monotonous increase of $r = \rho(4.2\,\mathrm{K})/\rho(300\,\mathrm{K})$ ratio where r ratio is a rough measure of the Kondo resistivity.

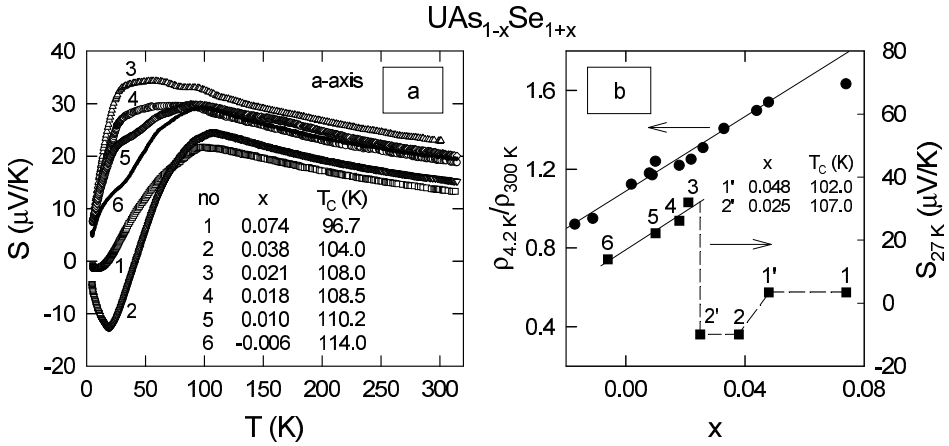

Fig. 2. (a) The a-axis $S(T)$ for selected $UAs_{1-x}Se_{1+x}$ crystals with different x and corresponding T_C. (b) The S (27 K) *vs* x for $UAs_{1-x}Se_{1+x}$ crystals, the same as in Fig. 2(a) plus two additional, full squares. Full circles present the $\rho_{4.2K}/\rho_{300K}$ ratio *vs* x for another set of $UAs_{1-x}Se_{1+x}$ crystals.

Overall behaviour of $S(T)$ for $UAs_{1-x}Se_{1+x}$ ferromagnetic system is strikingly similar to that observed for $Ce_xY_{1-x}Cu_{2.05}Si_2$ paramagnetic heavy-fermion alloy system when x varies from 0.1 to 1 [6]. In the latter case, the low temperature transport properties reflect the electronic scattering from the ground state doublet of the Ce^{+3} ion whereas the high temperature transport properties are determined by the lattice contribution and by the electronic scattering from the whole sextet of the Ce^{+3} ion CEF levels. The high temperature $S(T)$ is characterised by an extended positive peak weakly depending on x.

The same mechanism of electronic scattering is predicted either for the ground state doublet or the TLS [1]. This is the most probable origin of the qualitative similarity of the low-T $S(T,x)$ behaviour observed for the discussed systems. On the other hand several scattering mechanisms in the uranium system (electronic scattering from lattice, magnetic moment and

unknown phenomena related to T_2^*), produce all together an extended peak of the positive contribution to $S(T)$ depending weakly on x. This leads to the overall similarity of the $S(T,x)$ behaviour of both systems. To reduce an influence of these additional contributions on the determination of T_1^* we followed the procedure proposed in Ref. [6].

T_1^* is assumed to be equal to the temperature at which an abrupt change of dS/dT *vs* $\log T$ dependence is observed. This procedure gives $T_1^* = 30.5\,\mathrm{K}$ for UPS and $T_1^* = 25.5\,\mathrm{K}$ for USbTe. For $UAs_{1-x}Se_{1+x}$ system we obtain T_1^* randomly scattered between values 31.6 K for samples 3 and 2' and 28.5 K for samples 1 and 2 with a mean value of T_1^* of 8 crystals equal to 29.9 K and inaccuracy limit $\pm 1.7\,\mathrm{K}$ assumed as half of the scattering range.

In conclusion, it has been found that the characteristic temperature T_1^* of the $UAs_{1-x}Se_{1+x}$ system does not depend on x, Kondo-like resistivity and hybridisation [7], unlike that observed for the $Ce_xY_{1-x}Cu_{2.05}Si_2$ reference system. Transformation of the low-T peak of $S(T)$ from positive to negative contribution is accompanied by the increase of the Kondo resistivity in the case of $UAs_{1-x}Se_{1+x}$ system, unlike that observed for the $Ce_xY_{1-x}Cu_{2.05}Si_2$, and with the disappearance of the low-T incoherent Kondo resistivity when we pass from UPS to USbTe, like it is in the reference system [6].

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