Kondo effect in the presence of ferromagnetism in $U_{1-x}Th_xNiSi_2$

(ORAL)

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The compound $UNiSi_2$ crystallizes with an orthorhombic structure of the $CeNiSi_2$-type and exhibits a ferromagnetic ordering of localized magnetic moments of uranium (~ 1.2 μ_B) at the Curie temperature T_C = 95 K [1]. Our recent experiments carried out on high-quality single crystalline specimens revealed that the ferromagnetic ordering occurs in the system in the presence of the Kondo effect, which dominates the electrical resistivity of $UNiSi_2$ in the paramagnetic region [2]. In turn, investigation of a solid solution $UNi_{1-x}Co_xSi_2$ ($0 \le x \le 1$) indicated a very robust nature of the ferromagnetism observed in the parent compound, and its persistence up to the very vicinity of $x = 1$ [3]. Also partial substitution of silicon by germanium in $UCoSi_{2-x}Ge_x$ revealed immediate appearing of the ferromagnetic order to be observed already for $UCoSi_2$ doped with about 1% of germanium [4].

In order to shed more light on the origin of the strong ferromagnetism in $UNiSi_2$ we have undertaken comprehensive studies of another isostructural solid solution of that system, namely $U_{1-x}Th_xNiSi_2$. Here we present some preliminary results of X-ray powder diffraction, magnetic susceptibility, electrical resistivity and specific heat measurements carried out in wide temperature and magnetic field ranges using polycrystalline specimens of the latter system.

Since the partial substitution of uranium by 15%-larger thorium expands the unit cell of the parent compound (cf. Fig. 1), the Kondo effect in the system is supposed to become weaker than the RKKY interactions for a certain Th-content [5], and thus the ferromagnetic order might be promoted at temperatures higher than in pure $UNiSi_2$ (95 K). On the other hand, the U/Th substitution gradually dilutes the magnetic sublattice in the $U_{1-x}Th_xNiSi_2$ system and hence the long range magnetic order in the diluted limit should eventually be suppressed to absolute zero temperature. Indeed, as can be inferred from the temperature variations of magnetization (Fig. 2), electrical resistivity (Fig. 3) and specific heat (Fig. 4), the U/Th substitution results in systematic decrease of the Curie temperature from T_C = 95 K in pure $UNiSi_2$ down to about 30 K in $U_{0.2}Th_{0.8}NiSi_2$. Though in the Th-rich alloys the phase transition is no longer as sharp as in the parent compound $UNiSi_2$, the ferromagnetic order remarkably survives in the system down to very diluted limit, hence reflecting a very robust nature of the ferromagnetism in $U_{1-x}Th_xNiSi_2$.

In the paramagnetic region, the electrical resistivity of all the samples studied increases logarithmically with decreasing temperature, being characteristic of Kondo systems. The slope of the resistivity curves does not change significantly upon increasing x, hence indicating that the transport properties are governed by single Kondo impurity effects. Minor modification of the $\rho(T)$ curves in this region can be ascribed to the reduction of the Kondo temperature being a consequence of the change in the unit cell volume.

The presented results suggest that $UNiSi_2$ may be another clear example (together with e.g. isostructural $NpNiSi_2$ [6]) of a ternary system that shows coexistence of ferromagnetic ordering and Kondo interactions, as recently considered by Coqblin and co-workers in terms of underscreened Kondo lattice approach [7]. Further results (in particular for samples with lower uranium content) as well as their extended analysis will be updated at the time of the conference.

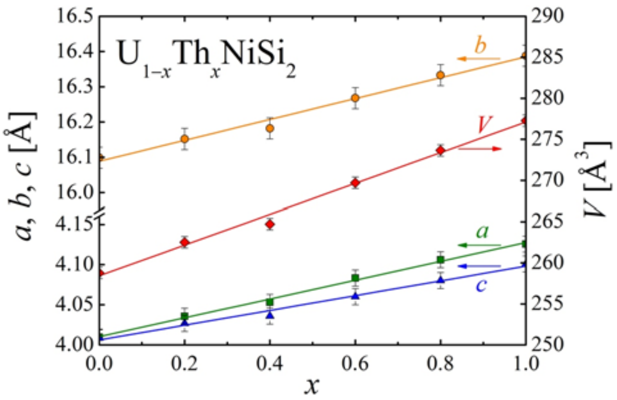

Fig.1. Lattice parameters *a*, *b* and *c* (left axis), and unit cell volume *V* (right axis) of $U_{1-x}Th_xNiSi_2$ as a function of Th content *x*.

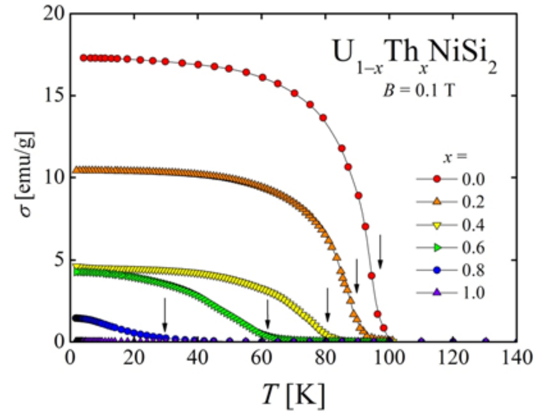

Fig.2. Temperature dependence of magnetization σ of $U_{1-x}Th_xNiSi_2$ measured in field cooling regime. The arrows mark the phase transition temperatures.

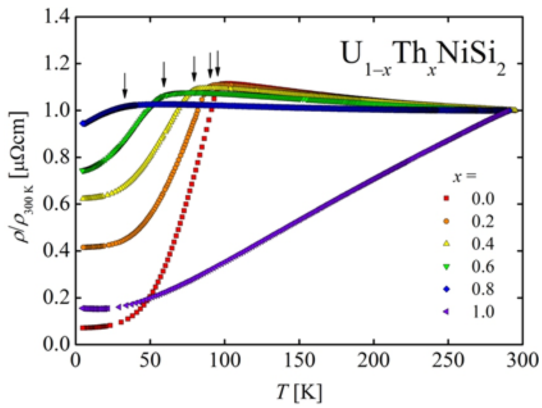

Fig.3. Temperature variation of the normalized electrical resistivity ρ/ρ_{300K} of $U_{1-x}Th_xNiSi_2$. The arrows mark the Curie temperatures.

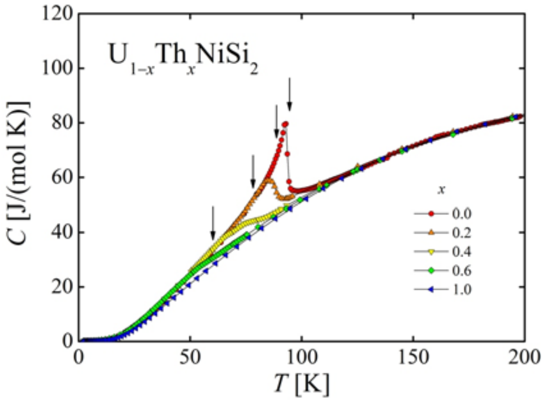

Fig.4. Specific heat of the compounds $U_{1-x}Th_xNiSi_2$ as a function of temperature. The arrows mark the phase transition temperatures.

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