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Magnetism in U_2T_2X compounds

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Abstract

Magnetic and other electronic properties are presented for the U_2T_2X compounds (T = late transition metal, X = Sn or In), that crystallize in the tetragonal U_3Si_2 -type structure. They show the formation of 5f magnetic moments and antiferromagnetic ordering in compounds where weak 5f–d hybridization is expected. Near the onset of magnetic ordering strongly enhanced γ -values are found. Neutron-diffraction experiments on U_2Pd_2Sn and U_2Pd_2In point to a connection between the mutual coordination of U atoms and the type of magnetic anisotropy.

We have studied systematically the magnetic and other electronic properties of U_2T_2X compounds (T = transition metal, X = Sn or In), which crystallize in the tetragonal U_3Si_2 structure [1,2]. Similar to other actinide compounds with transition metals, the character of the 5f electron states is strongly dependent on the strength of the 5–d hybridization. Here, we review basic magnetic data obtained on polycrystalline samples and the results of low-temperature specific-heat measurements. The magnetic structure of U_2Pd_2In and U_2Pd_2Sn was investigated by powder neutron diffraction.

Antiferromagnetic (AF) ordering is indicated by the peak in the temperature dependence of the magnetic susceptibility $\chi(T)$ and the specific heat $C(T)$ in U_2T_2Sn for T = Ni, Pd, Pt, Rh. The ordering temperatures are given in the Table 1. For In compounds, the range of stability of the AF ordering is restricted to U_2Ni_2In and U_2Pd_2In . In the paramagnetic range, $\chi(T)$ can be well accounted by the Modified Curie–Weiss law (MCW): $\chi = C/(T - \Theta_p) + \chi_0$, where χ_0 represents a temperature-independent susceptibility. Values of the paramagnetic Curie temperature Θ_p and the effective moments μ_{eff} obtained from C are also summarized in Table 1. Nevertheless, we are aware that

μ_{eff} -values can be severely affected by magnetic anisotropy in the paramagnetic range, which leads to values generally smaller than those obtained on a single crystal. The MCW type of behaviour was detected also for U_2Pt_2In and U_2Co_2Sn , which do not show magnetic ordering down to 1.6 K, but for which χ increases to rather large values, and the magnetic behaviour can be labelled as spin fluctuator. U_2Pt_2In also displays a very strong γ -enhancement. U_2Rh_2In was not yet subjected to susceptibility measurement, but the absence of any anomaly in $C(T)$ and a certain γ -enhancement found also in this case point to the presence of spin fluctuations, too. The MCW behaviour at high temperatures can be followed also in U_2Ir_2Sn , but the presence of a ferromagnetic impurity (UIr) does not allow to assess the low-temperature behaviour. The remaining compounds behave as more or less enhanced temperature-independent Pauli paramagnets.

Comparison of the values of the electronic specific-heat coefficient γ (Table 1) shows a strong enhancement tendency from the Pauli paramagnets U_2Ru_2Sn and U_2Co_2In towards spin fluctuators (largest γ = 850 mJ/mol K² in U_2Pt_2In – note that 1 mole contains 2 U atoms in this case), but high γ -values are found also in antiferromagnets. Some of them display very small magnetic entropy S (in U_2Rh_2Sn and U_2Pt_2Sn S does not exceed 0.4R ln 2).

Neutron powder diffraction experiments at LANSCE, Los Alamos, have indicated that in U_2Pd_2In and U_2Pd_2Sn the same non-collinear ordering exists with U moments

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lying within the basal plane along the directions of the [1 1 0] type [3]. The magnetic and crystallographic unit cells are identical. In $\text{U}_2\text{Pd}_2\text{Sn}$, which is presumably the

Table 1

Summary of bulk properties of $\text{U}_2\text{T}_2\text{In}$ (a) and $\text{U}_2\text{T}_2\text{Sn}$ (b) compounds. The type of ground state is displayed in the upper right corner of each rectangle (WP – weak paramagnet, SF – spin fluctuator, AF – antiferromagnet). The MCW parameters account for the high-temperature $\chi(T)$ behaviour (μ_{eff} related to 1 U-atom). In the case of WP, the χ -value at 4.2 K is given instead. In the lower part, the low-temperature γ -coefficient of the specific heat is given (the values are normalized to 1 f.u., 2 U-atoms). For some of the compounds, magnetic properties have not been studied yet ($\text{U}_2\text{Ru}_2\text{In}$). For $\text{U}_2\text{Ir}_2\text{In}$ the susceptibility data are contaminated by a considerable amount of ferromagnetic binary UIr

(a)	$\text{U}_2\text{Co}_2\text{In}$ WP	$\text{U}_2\text{Ni}_2\text{In}$ AF $T_N = 14$ K MCW: $\mu = 2.0 \mu_B$ $\Theta_p = -81$ K $\chi_0 = 2.5 \cdot 10^{-8} \text{ m}^3/\text{mol}$ $\gamma = 200 \text{ mJ/mol K}^2$ (350 mJ/mol K ² above T_N)
	$\text{U}_2\text{Ru}_2\text{In}$	$\text{U}_2\text{Rh}_2\text{In}$ SF
	$\text{U}_2\text{Ir}_2\text{In}$ WP?	$\text{U}_2\text{Pt}_2\text{In}$ SF MCW: $\mu = 2.4 \mu_B$ $\Theta_p = -106$ K $\chi_0 = 1.0 \cdot 10^{-8} \text{ m}^3/\text{mol}$ $\gamma = 850 \text{ mJ/mol K}^2$
(b)	$\text{U}_2\text{Fe}_2\text{Sn}$ WP	$\text{U}_2\text{Co}_2\text{Sn}$ SF MCW: $\mu = 1.5 \mu_B$ $\Theta_p = -51$ K $\chi_0 = 2.3 \cdot 10^{-8} \text{ m}^3/\text{mol}$ $\gamma = 250 \text{ mJ/mol K}^2$
	$\text{U}_2\text{Ru}_2\text{Sn}$ WP	$\text{U}_2\text{Rh}_2\text{Sn}$ AF $T_N = 24$ K MCW: $\mu = 2.41 \mu_B$ $\Theta_p = -106$ K $\chi_0 = 1.0 \cdot 10^{-8} \text{ m}^3/\text{mol}$ $\gamma = 131 \text{ mJ/mol K}^2$
		$\text{U}_2\text{Pd}_2\text{Sn}$ AF $T_N = 41$ K MCW: $\mu = 2.50 \mu_B$ $\Theta_p = -30$ K $\chi_0 = 1.4 \cdot 10^{-8} \text{ m}^3/\text{mol}$ $\gamma = 203 \text{ mJ/mol K}^2$
		$\text{U}_2\text{Ir}_2\text{Sn}$ SF MCW: $\mu = 1.73 \mu_B$ $\Theta_p = -100$ K $\chi_0 = 1.6 \cdot 10^{-8} \text{ m}^3/\text{mol}$ $\gamma = 130 \text{ mJ/mol K}^2$
		$\text{U}_2\text{Pt}_2\text{Sn}$ AF $T_N = 15.5$ K MCW: $\mu = 2.03 \mu_B$ $\Theta_p = -34$ K $\chi_0 = 2.5 \cdot 10^{-8} \text{ m}^3/\text{mol}$ $\gamma = 334 \text{ mJ/mol K}^2$ (390 mJ/mol K ² above T_N)

Fig. 1. Temperature dependence of the magnetic susceptibility of selected $\text{U}_2\text{T}_2\text{In}$ (a) and $\text{U}_2\text{T}_2\text{Sn}$ (b) compounds. The dotted lines shown in some cases represent the MCW fits with parameters shown in Table 1.

compound with the most apparent local-moment behaviour in the 2:2:1 family, moments of $1.89 \mu_B$ on U atoms (at 10 K) have been obtained by the refinement procedure. In $\text{U}_2\text{Pd}_2\text{In}$ the moments are reduced to $1.40 \mu_B$. The stronger tendency to magnetism in Sn compounds seems to be a general feature compared to the $\text{U}_2\text{T}_2\text{In}$ group. As the U moments are perpendicular to the nearest U–U link (which is along c), we may speculate about the hybridization-induced anisotropy mechanism in the $\text{U}_2\text{T}_2\text{X}$ compounds.

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References

- [1] M.N. Peron et al., J. Alloys Comp. 201 (1993) 203.
- [2] F. Mirambet, P. Gravereau, B. Chevalier, L. Trut and J. Etourneau, J. Alloys Comp. 191 (1993) L1.
- [3] A. Purwanto et al., Phys. Rev. B 50 (1994) 6792.