Study of valence state of U ion in the quasi-two dimensional ternary uranium compounds

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A fairly large number of Ce, Eu and Yb intermetallics have been known from many years to exhibit an intermediate valence (IV) state while such a state has not been reported for a long time for the uranium-based intermetallic compounds despite the intensive studies of their magnetism and electronic structures for more than 50 years. The first such an example published recently turned out to be a tetragonal U_2Ru_2Sn [1] where the susceptibility was found to go through a maximum at about $T_{max} \sim 170$ K and resistivity revealed the formation of a hybridization gap (or so called pseudo-gap) at the Fermi level (E_F) [2], which classified this compound as a Kondo semiconductor with a narrow gap. The recent inelastic neutron scattering measurements have confirmed the spin gap in this compound [3]. As the second candidate exhibiting the IV state among the uranium based ternary intermetallics has been considered the layered compound $UCoGa_5$, which crystallizes in the tetragonal $HoCoGa_5$ type structure [4]. However, the susceptibility of this compound exhibits a maximum at as high temperature as 650 K. Very recently we have discovered the third candidate, namely U_2RuGa_8 which joins as yet a very short list of the uranium IV family. U_2RuGa_8 also has a layered structure with the stacking sequence of two layers of UGa_3 and one layer of $RuGa_2$ [5]. The $UCoGa_5$ and U_2RuGa_8 gallides were grown as single crystals by the so-called self flux method [4, 5]. For these two cases the susceptibility measured for both main directions of the tetragonal unit cell, *i.e.* parallel and perpendicular to the c axis, goes through a broad maximum at about 200 and 220 K, respectively with distinct anisotropy in its magnitudes. The susceptibilities in these two directions can be fairly well fitted to the interconfiguration model of Sales and Wohlleben [1]. This model results *e.g.* for U_2RuGa_8 in a characteristic spin fluctuation temperature $T_{sf} = 320$ and 460 K for the directions mentioned above, respectively. An energy difference between the corresponding two states (*i.e.* U^{4+} and U^{3+}) $\Delta E/k_B$ is for these two directions over 1000 K. The most important finding is that the susceptibility measured along both the directions follows the Curie-Weiss law at temperatures above ~ 500 K with the effective magnetic moments of uranium being close to the free ion values of U^{4+} ($5f^2$) or U^{3+} ($5f^3$). In similar way the temperature dependence of the susceptibility has been considered for U_2Ru_2Sn. For both U_2Ru_2Sn and U_2RuGa_8 a common scaling curve followed also by a number of the rare earth IV compounds is presented.

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