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THERMOELECTRIC POWER AND RESISTIVITY OF UPS*

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Single crystals of uranium phosphorosulfide, UPS, have been obtained by the chemical transport method. Their thermoelectric power, $S(T)$, and electrical resistivity, $\rho(T)$, have been measured from ~ 2 K to room temperature. The transport properties of UPS show some anomalies, which could be ascribed to the Kondo-like scattering of the conduction electrons.

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UPS is a member of uranium pnictochalcogenides family — UXY, where X = P, As, Sb or Bi, and Y = S, Se or Te. All of these compounds crystallize into tetragonal crystal structures (space group P4/nmm or I4/mmm) formally isotypic with the PbFCl structure type. The most important feature of these tetragonal structures are layers stacked along the c-axis in the sequence $\cdots-\mathrm{X}-\mathrm{U}-\mathrm{Y}-\mathrm{Y}-\mathrm{U}-\cdots$. Ternary uranium compounds UXY are strongly anisotropic uniaxial ferromagnets with magnetic moment aligned along the c-axis and relatively high Curie temperatures (between about 40 and 120 K). Uranium arsenoselenide, UAsSe, is the member of this family of compounds for which the physicochemical properties were studied most intensively. All uranium pnictochalcogenides, examined so far, have a negative temperature coefficient of resistivity in the paramagnetic state. Below the ferromagnetic transition the resistivity decreases down to liquid helium temperature for all members of the family examined up till now with the exception of uranium arsenoselenide. The latter compound shows a well pronounced and strongly sample dependent unusual upturn of resistivity below $\sim 0.5\,T_{\mathrm{C}}$. An increase of this low temperature resistivity upturn is accompanied by a decrease of the Curie temperature. It seems that a disorder

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in the anionic sublattices may be at the origin of the observed transport properties. As a consequence, the non magnetic two level Kondo system is considered as the model that might describe the mechanism of the conduction electron scattering in uranium arsenoselenide (and in isostructural diamagnetic ThAsSe as well) [1–4]. In general, the uranium pnictochalcogenides crystallize in the well ordered structure with two different positions occupied by the X and Y anions, respectively. However, if the anions are neighbours in the periodic Table, like As and Se or P and S, (similar electronic structure and ionic radii) one can expect an increase of possibility of an interchage of lattice sites of the anions. This fact motivated our attempt to prepare uranium phosphorosulfide with slightly disordered anionic sublattices to show that its transport properties would behave similarly to that observed for uranium arsenoselenide. The recent paper of Kaczorowski *et al.* [5] does not report low temperature upturn in the resistivity of UPS. The authors found T^2 dependence of resistivity below ~ 20 K. Single crystals of uranium phosphorosulphide UPS were grown in sealed silica tube by the chemical transport method. The bromine in amount of $\sim 2 \div 3$ mg of Br_2 per cm^3 was used as the transporting agent. The crystals grew due to temperature gradient $950 \rightarrow 900°$C. The grown single crystals were thin plates with dimensions up to $\sim 6 \times 4 \times 0.5$ mm^3 (c-axis always perpendicular to the plate). The X-ray diffraction examination confirms a tetragonal structure of the PbFCl-type (space group P4/nmm) with lattice parameters in accordance with the literature data [5] (see Fig. 1).

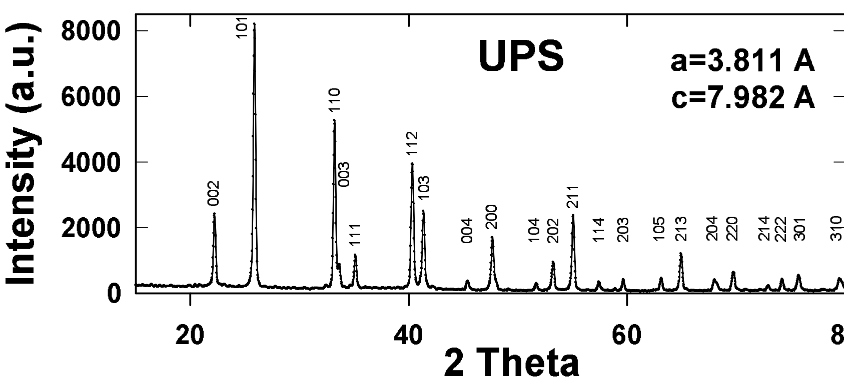

Fig. 1. X-ray powder diffraction pattern of UPS. The powder was prepared by grinding of single crystals.

The thermoelectric power, $S(T)$, of UPS along the a-axis has been measured by the method described in [6]. The examination was done for temperatures ranging from liquid helium to room temperature. Samples for the thermoelectric power measurements were cut into bars of $\sim 0.5 \times 1 \times 5$ mm^3.

The temperature difference at the ends of sample was equal to ~2 K. Our results of $S(T)$ measurements are the first in the literature and are presented in Fig. 2. The a-axis thermoelectric power of UPS is positive and is about one order of magnitude larger than that of normal metals. The $S(T)$ curves have a well pronounced change of slope at the Curie temperature ($T_{\rm C}$), as indicated by the arrow on Fig. 2, and a broad maximum in paramagnetic state. The temperature dependence of the thermoelectric power of UPS below $T_{\rm C}$ exhibits two anomalies: a peak at $\sim$ 25 K and a valley at $\sim$ 80 K. The observed peak of $S(T)$ at 25 K originates possibly from the Kondo effect. Further examinations are necessary for a better understanding of its origin.

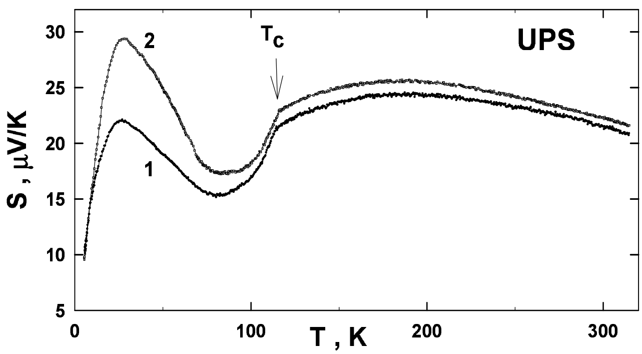

Fig. 2. Thermoelectric power, $S(T)$, for two samples of UPS (labelled 1 and 2) in the basal plane perpendicular to the c-axis.

Electrical resistivity of UPS has been measured along the a-axis by *dc* method from about 2 K to room temperature. Contrary to the previous results [5] our single crystals show low temperature upturn of the resistivity (see Fig. 3). The room temperature value of the electrical resistivity does not change much from sample to sample and is close to 240 $\mu\Omega$cm. When the low temperature upturn in the ferromagnetic state increases, a smooth decrease of the Curie temperature and a distinct decrease of the thermoelectric power 25 K peak is observed.

If we assume that the mechanism of conduction electron scattering in UPS and UAsSe is the same, *i.e.* that we observe the non magnetic Kondo like behaviour, then the total measured resistivity of UPS can be resolved into four terms. They are due to scattering of electrons on static impurities ($\rho_{\rm o}$), on phonons ($\rho_{\rm ph}(T)$), on spin disorder of the ferromagnetic matrix ($\rho_{\rm s}(T)$) and on dynamic centres (Kondo component $\rho_{\rm K}(T)$):

$$\rho(T) = \rho_{\rm o} + \rho_{\rm ph}(T) + \rho_{\rm s}(T) + \rho_{\rm K}(T)\,,$$

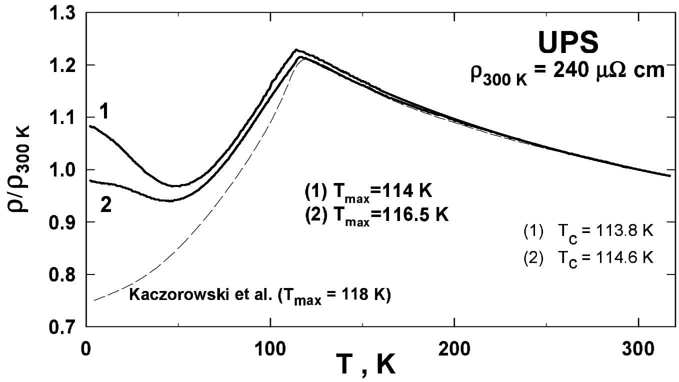

Fig. 3. Resistivity, $\rho(T)$, for two samples of UPS (labelled 1 and 2) in the direction of a-axis. Our results are compared to the data taken from the paper [5] (dashed line). Curie temperature T_{C} is taken as a maximum of $d\rho/dT$.

as it was shown for UAsSe [1]. It seems that uranium phosphorosulphide is another good example of magnetic uranium compound in which nonmagnetic Kondo-like behaviour is distinctly observed.

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