Letter to the Editor

MAGNETIC PROPERTIES AND PRESSURE EFFECTS IN URANIUM COMPOUNDS BASED ON UFe_2[1])

МАГНИТНЫЕ СВОЙСТВА И ЭФФЕКТЫ ДАВЛЕНИЯ В УРАНОВЫХ СОЕДИНЕНИЯХ UFe_2

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The temperature and pressure dependence of the magnetic susceptibility of $U(Fe_{1-x}Mn_x)_2$ as well as the isoelectronic analogues $UFe_2 - U(Fe_{1-x}(Mn_{0.5}Co_{0.5})_x)_2$ were studied in the paramagnetic state. The discussion of the results is based on the band model. The significant role of the electron scattering in the alloys magnetism was shown. The volume derivative of the Stoner factor has been estimated.

The itinerant nature of magnetism in UFe_2 — based alloys [1—4] permits one to assume that the conduction electron exchange-enhanced spin susceptibility is dominant in their paramagnetic state

$$\chi_S = S\chi_P, \tag{1}$$

where $\chi_P = \mu_B^2\omega(E_F)$, $\omega(E_F)$ is the density of states at the Fermi level E_F, the Stoner factor $S = (1 - J\chi_P)^{-1}$, J is the parameter of the exchange-correlation interaction. The magnetic susceptibility can be used to study the specific features of the band structure and the electron interaction in the investigated alloys.

Below considered are the data on the magnetic susceptibility of the quasi-binary alloys UFe_2-UMn_2 with a varying electron concentration and that of quasi-ternary isoelectronic ones $U[Fe_{1-x}(Co_{0.5}Mn_{0.5})_x]_2$ $(0 \leq x \leq 1)$ in the temperature range of 78 to 300 K for the pressure of up to 4 kbar. The alloys were prepared by a crucible-less, semi levitation, induction melting in an argon protective atmosphere. The sample cubic Laves phase structure was confirmed by X-ray analyses. The temperature dependence of the susceptibility was measured in field of up to 1 T by the Faraday method with a parasitic ferromagnetism correction. The effect of the pressure was measured by a levitation method (300 K) [5], the data for 78 K were obtained with a pendulum magnetometer.

The isovalent alloys (analogues to UFe_2) permit the role of electron scattering in magnetism to

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be evaluated. The temperature dependence of their susceptibility can be well described by the modified Curie–Weiss law:

$$\chi(T) = \chi_0 + C/(T - \Theta), \qquad (2)$$

the parameters of which are shown in Figs. 1 and 2. These parameters are similar to those in quasi-binary UFe_2 — based alloys.

The susceptibility χ_S (1) can display the relation of type (2) if the curve $\omega(E)$ near E_F has a peak typical for the compounds under consideration [4]. The UFe_2 smoothing of this peak due to electron scattering under alloying is equivalent to an increase of the effective temperature in (2). This is responsible for the observed behaviour of $\Theta(x)$ in the isovalent alloys (Fig. 2): $d\Theta/dx = dT^+/dx \simeq \simeq 4$ K per at% of (Mn + Co). The data concerning dependencies on $\Theta(x)$ in Fig. 2 indicate that also

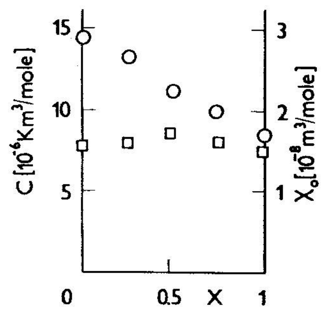

Fig. 1. χ_0 (□) and C(○) vs X in $U(Fe_{1-x}(Mn_{0.5}Co_{0.5})_x)_2$.

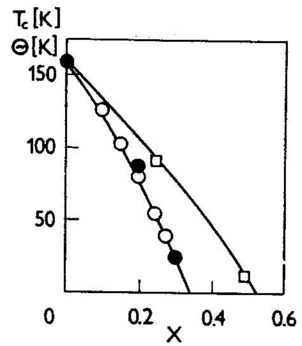

Fig. 2. Θ(□) vs X in $U(Fe_{1-x}(Mn_{0.5}Co_{0.5})_x)_2$ and Curie temperature T_c (close to Θ): ○ — $U(Fe_{1-x}Mn_x)_2$ [6], ● — $U(Fe_{1-x}Co_x)_2$ [1].

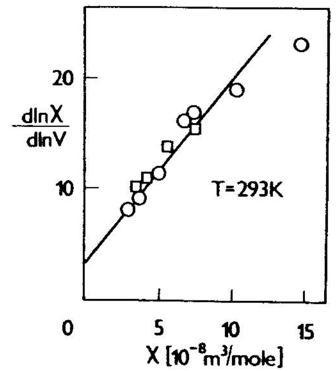

Fig. 3. $\frac{d\ln\chi}{d\ln V}$ vs χ in □ — $U(Fe_{1-x}(Mn_{0.5}Co_{0.5})_x)_2$; ○ — $U(Fe_{1-x}Mn_x)_2$.

in the quasi-binary alloys $U(Fe_{1-x}Mn_x)_2$, the scattering is a dominant factor in ferromagnetism suppression and should be included in calculations of magnetic phase diagrams for systems with the itinerant ferromagnetism.

According to (1), the magnetovolume effect is of the form

$$d\ln\chi/d\ln V = d\ln\chi_P/d\ln V + J\chi(d\ln\chi_P/d\ln V + d\ln J/d\ln V). \qquad (3)$$

If we neglect the electron transition between bands under pressure, which is low in UFe_2 [4], and the efect of thermal excitations, then $d\ln\chi_P/d\ln V \simeq d\ln\omega(E_F)/d\ln V \simeq -d\ln\Delta/d\ln V$ (where Δ is the band width). For a weak concentration dependence of J [4], the value of the magnetovolume effect in the systems studied must be a unified linear function of χ. Indeed, all the experimental values of $d\ln\chi/d\ln V$, except the points near the magnetic ordering temperatures, give a straight line as a function of χ (Fig. 3). According to (3), its intersection with the axis J gives $d\ln\Delta/d\ln V \leq -3 \pm 1$, which is somewhat larger than that known for the d-band (−1.7). This may be due to a considerable contribution of the f-states to $\omega(E_F)$ [4].

Using the averaged value $d\ln\Delta/d\ln V = -2$ and $J = 1.4 \times 10^6$ g/emu for UFe_2 [4] we obtain by the straight line slope (7.5×10^5 g/emu) the value $d\ln J/d\ln V = -1.5 \pm 1$. This value is close to those for V and Pd [8] and much like the latter is appreciably different from the calculated data based on the local density approximation ($d\ln J/d\ln V \simeq 0$). It is unlikely that a further involvement of the band structure details, the Van Vleck paramagnetism and the role of spin fluctuations eliminates these conspicuous discrepancies.

To sum up: Our measurements on quasi-binary $U(Fe_{1-x}Mn_x)_2$ and isoelectronic quasi-ternary alloys $U[Fe_{1-x}(Co_{0.5}Mn_{0.5})_x]_2$ demonstrate that the role of efectron scattering is significant in the explanation of the magnetic state of these alloys.

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