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Magnetization of Co-H Solid Solutions

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Since a considerable number of hydrogen-containing phases on the basis of transition metals of the groups VI to VIII of the periodic table was obtained only in recent years (see review papers /1, 2/), works dealing with their physical properties are still rare. As to the magnetic properties, it was found that the hydride of antiferromagnetic chromium is paramagnetic down to low temperatures /3/; the hydride of antiferromagnetic manganese is ferromagnetic /4/; the dissolving of hydrogen in ferromagnetic nickel lowers its Curie temperature /5, 6/, and at room temperature nickel hydride is paramagnetic /7/; hydrogenation of strong paramagnetic palladium beyond H to the metal atomic ratio $n \approx 0.8$ leads to the appearance of superconductivity /8/.

The solubility of hydrogen in the low-temperature h.c.p. allotropic modification of cobalt was shown to increase steadily with pressure of molecular hydrogen, reaching $n \approx 0.5$ at $P_{H_2} = 65$ kbar and $T \approx 500$ K /9/. In the present paper the magnetization of Co-H solid solutions was measured at P = 1 at in a pulsed magnetic field up to 50 kOe in the temperature range (80 to 220)K, the pulse duration being 0.01 s. The specimens were prepared by quenching down to 260 K after the hydrogenation of electrolytically pure cobalt plates ≈ 0.2 mm thick at $P_{H_2} \leqq 60$ kbar and T = 520 K for some hours. Note, that at normal pressure Co-H samples thus obtained are kinetically unstable in regard to the desintegration into the metal and molecular hydrogen at temperatures above 260 K /9/. The methods of Co-H sample preparation and their chemical analysis (with an accuracy of about 3%) are described in /9/, and the magnetic measurement techniques in /10, 11/.

The temperature dependence $\sigma(T)$ of the spontaneous magnetization of our Co and Co-H specimens is weak in the temperature range investigated, and the changings in $\sigma(T)$ are within the limits of the experimental error $\delta\sigma/\sigma \approx 0.05$. The value of

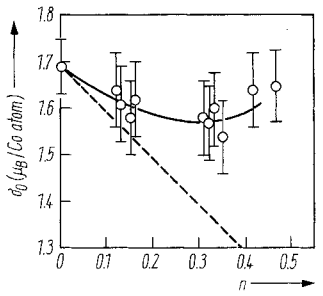

Fig. 1. Spontaneous magnetization σ_0 at T = 0 K of Co-H solid solutions as a function of the H to metal atomic ratio n. The broken line shows the $\sigma_0(n)$ dependence in the rigid band approximation

$|\partial\sigma/\partial T|$ is known to decrease with decreasing temperature. So, we assumed the mean value of σ at $80 \leqq T \leqq 220$ K to be equal to the spontaneous magnetization σ_0 at absolute zero.

Experimental results are presented in Fig. 1. The broken line shows the linear dependence $\sigma_0(n)$ with a slope $\partial\sigma_0^r/\partial n = -1\ \mu_B$/Co atom ($\mu_B$ is the Bohr magneton). This dependence is given by a rigid band approximation under the assumptions that (i) cobalt is a strong itinerant ferromagnet, and (ii) hydrogen, on dissolving into cobalt, transfers its electron to the conduction band of the metal /12/. As one can see from Fig. 1, the slope of the experimental curve $\sigma_0(n)$ differs noticeably from the value predicted by the rigid band model even at low hydrogen content in cobalt: $\partial\sigma_0/\partial n\Big|_{n=0} \approx 0.6\ \mu_B$/Co atom. Thus a study of the $\sigma_0(n)$ dependence shows that hydrogen being dissolved in cobalt strongly deforms its band structure. It is worth pointing out that direct quantum mechanical calculations of the band structures of hydrides of several 3d- and 4d-elements /13 to 15/ also show that the rigid band approximation and, in particular, the "protonic" and "anionic" models are unsatisfactory for describing of physical properties of these compounds.

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