MAGNETIC PROPERTIES OF Pd-Co-Sn ALLOYS

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As is well known, a small amount of cobalt in palladium leads to the occurrence of impurity ferromagnetism, i.e., ferromagnetism of systems in which the magnetic centers are far from one another. There have been many investigations of Pd-Co alloys [1-6]. In particular, the effective magnetic fields at the Co^{60} nuclei were measured in [2] by an oriented-nuclei procedure, and the dependence of H_{eff} on the cobalt concentration in Pd was obtained. It was of interest to continue the investigation of the properties of ferromagnetic Pd alloys, and particularly to measure the effective magnetic fields at paramagnetic nuclei of tin added to the Pd-Co alloy, by determining the splitting of the lines of recoilless resonant absorption of γ radiation, and to ascertain the influence of the tin on the Curie temperature of these alloys.

We prepared for the measurements Pd-Co samples with Co contents (at.%) 0.1, 0.4, 1.5, 2.0, 2.4, 3.5, 5.0, 7.0, 8.3, 8.6, and 10.4, as well as Pd-Co-Sn samples with the following cobalt and tin contents:

Co, at.%	Sn, at.%
0.4	0.15, 0.6, 0.9, 1.7, 3.0, 5.0
1.5	0.7, 1.9, 3.8, 6.0
2.4	3.0
4.0 , 5.0 , 7.0, 8.6	5.0

The initial materials were palladium with a resistance ratio $\rho_{300}/\rho_{4.2} = 3000$, similar to that used in [7], and spectrally pure cobalt and tin. The samples were melted in a high-frequency furnace and rolled into a foil ~65 μ thick. The composition of the samples was monitored by a quantitative chemical analysis. The discrepancy between the charge composition and the sample composition did not exceed 10% with respect to cobalt.

The Curie points were measured by a ballistic method. In the region of intermediate temperatures (4.2 - 30°K), the temperatures were measured with the instrument described in [11]. At higher temperatures (30 - 300°K) we used a slow-heating bulky copper block of large heat capacity, to which the sample was fastened. The temperature of the sample was measured with a setup described in [8].

The measurements on the binary Pd-Co alloys have shown that the dependence of the Curie points on the Co concentration in Pd agrees well with the data of Dunlap and Dash [4],

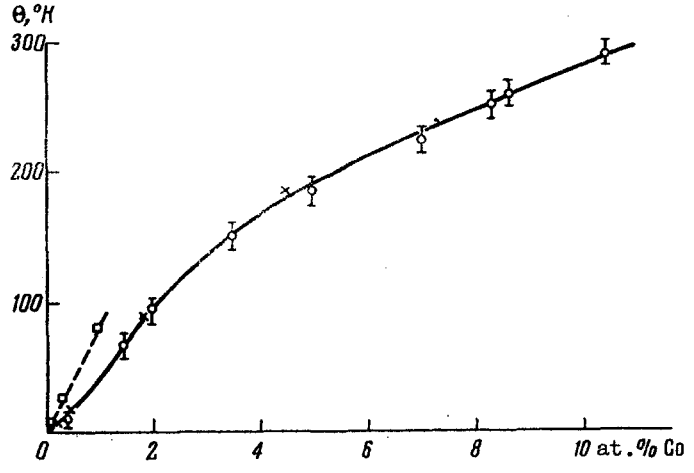

Fig. 1. Dependence of the Curie points on the Co concentration in Pd. × - data of [4], □ - data of [5], ⊻ - present data.

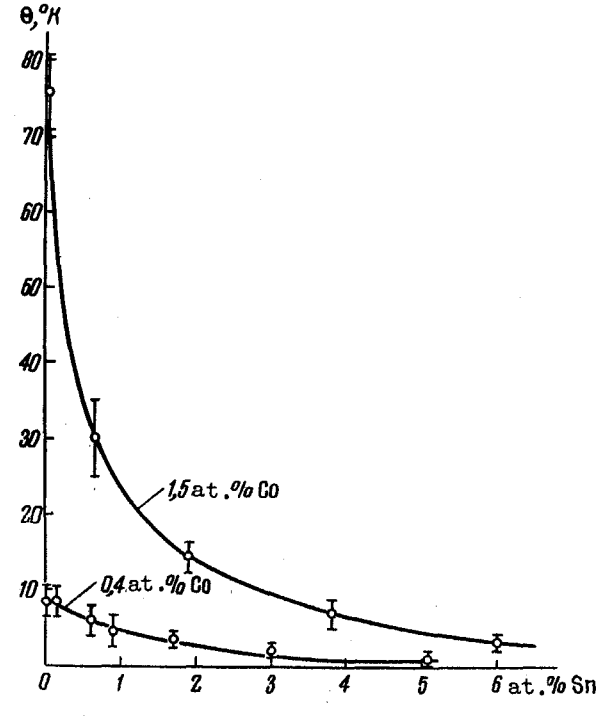

Fig. 2. Dependence of Curie points on the tin concentration in the Pd-Co-Sn system at fixed Co concentrations equal to 0.4 and 1.5 at.%.

whereas the points obtained by Bozorth et al. [5] lie above the presented curve (Fig. 1) [1].

We also obtained the dependence of the Curie points in the Pd-Co-Sn system on the tin content at two Co concentrations, 1.5 and 0.4 at.% (Fig. 2). The character of the curves recalls the dependence obtained by Bozorth et al. [5] for the Pd-Co-Rh system. However, the decrease of the Curie temperature Θ with increasing tin concentration is sharper than with increasing rhodium concentration.

Measurement of the resonant absorption of 23.8-keV γ rays at temperatures above and below the Curie points were made for Pb-Co-Sn alloys containing a constant concentration of natural tin (approximately 5 at.%), while the cobalt concentration varied from 0.4 to 7.6 at.%. Figure 3 shows typical curves of resonant absorption at 4.2, 77, and 300°K and at Co concentrations equal to 4.0 and 8.6 at.%. It is seen from these curves that the magnetic field at the tin nucleus is not strong enough to obtain resolved hyperfine-structure lines. This structure is manifest only in a noticeable broadening of the resonance-absorption line.

From the data obtained at T = 4.2°K, where all the investigated alloys were ferromagnetic, we plotted the dependence of the half-width of the absorption line as a function of the cobalt concentration (Fig. 4). We note that the thickness of the employed resonant absorbers was chosen to be constant at 65 ± 5 μ so that, within the limits of

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[1] It should be noted that annealing in vacuum reduced the smearing of the temperature dependence of the magnetic moment, and increased slightly the values of the Curie points. This increase, however, did not exceed the error limits indicated on the curve.

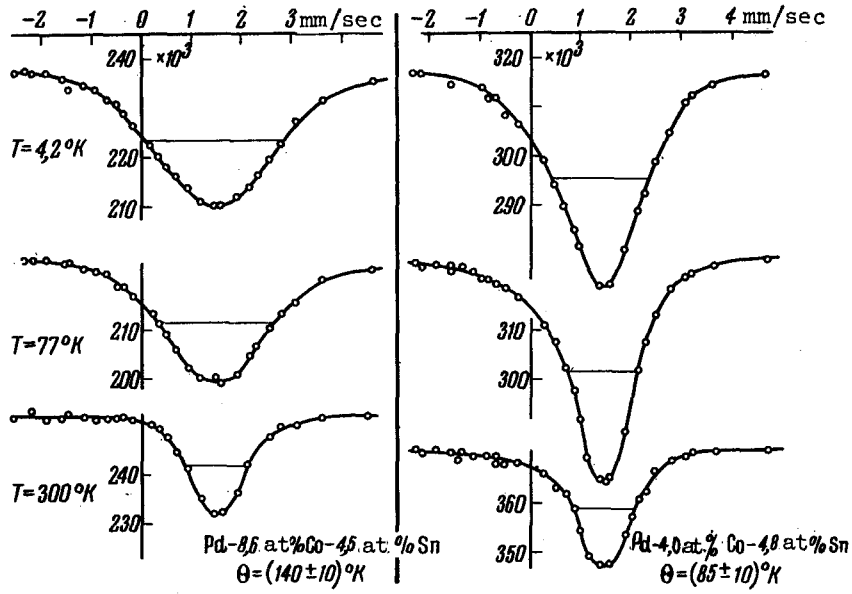

Fig. 3. Typical curves of resonant absorption by Sn^{119} at 4.2, 77, and 300°K and at two cobalt concentrations.

measurement accuracy, the change of Γ_{obs} was due only to the magnetic broadening. If we regard the line shape as an unresolved doublet, then we can estimate the value of the effective field at the tin nuclei [9,10]. In the case of the maximum considered concentration, 8.6 at.%, the estimate yielded a value H = 12 ± 2 kOe.

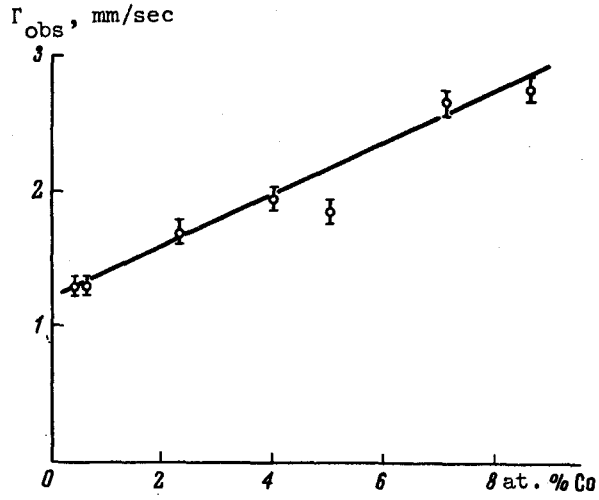

Fig. 4. Half-width of resonant absorption line in the Pd-Co-Sn system at T = 4.2°K as a function of the cobalt concentration. Tin concentration 5 at.%

The results obtained with binary Pd-Co alloys agree well with the data by others, and can apparently be attributed to long-range polarization of the Ruderman-Kitell-Ioshida type. The indirect interaction, according to Low and Holden [3], proceeds in this case via the hole part of the Fermi surface of palladium, which constitutes a grid of open corrugated cylinders [7]. Introduction of small amounts of tin should apparently weaken such an indirect interaction, decreasing the spin free path of the carriers. The fields produced at the tin nuclei can be due to polarization of the Pd atoms, the polarization encompassing up to 200 matrix atoms [3]. It is likewise not excluded that the field at the tin nuclei may be due to scattering of the polarized carriers, which implement the indirect exchange, by the tin atoms.

In conclusion, the authors thank G. E. Karstens and A. A. Grigor'ev for help with the work, and all the laboratory members who helped with the numerous measurements.

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INVESTIGATION OF THE THERMAL CONDUCTIVITY OF FERROMAGNETIC $CrBr_3$

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This paper is devoted to a study of the thermal conductivity of the ferromagnetic dielectric $CrBr_3$ at helium temperatures.

The $CrBr_3$ crystal has an hexagonal structure. It becomes ferromagnetic below a temperature T_c = 37°K [1], and the hexagonal axis is the easiest-magnetization axis.

The method of preparing the single crystals used in the investigation is similar in

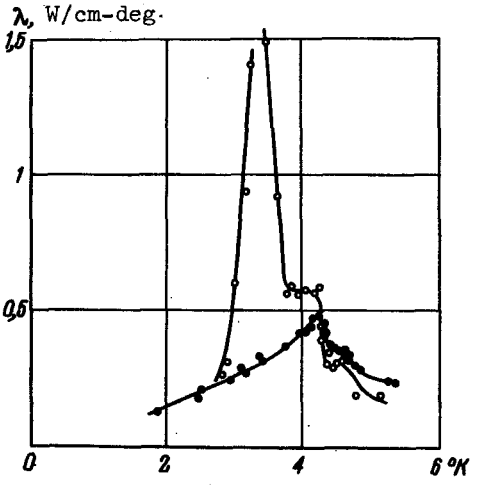

Fig. 1. Thermal conductivity vs. temperature for samples I and III: o - sample I (80 μ thick), • - sample III (50 μ thick).

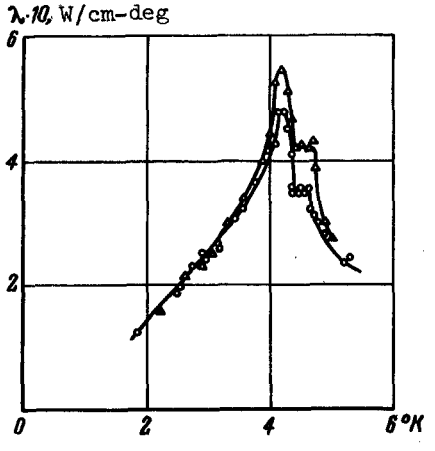

Fig. 2. Thermal conductivity vs. temperature for samples II and III: Δ - sample II (55 μ thick), o - sample III (50 μ thick).