Critical magnetic fields of superconducting palladium hydride

N. E. Alakseevskiĭ, Yu. A. Samarskii, H. Wolf,[1] V. I. Tsebro, and V. M. Zakosarenko

Institute of Physics Problems, USSR Academy of Sciences
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We measured the critical magnetic fields of palladium hydrides with different values of T_c and calculated the coefficient of electronic specific heat γ. It turned out that $\gamma=0.28\pm0.02$ mcal/mole(°K)^2 regardless of the hydrogen concentration. It appears that the growth of T_c with increasing H concentration is due to the increase of the electron-phonon interaction constant.

The superconductivity of palladium hydride, recently observed by Skoskiewicz[1] was investigated in a number of studies.[2–5] The superconducting hydrides were obtained in these investigations by different methods: electrochemical, ion implantation, hydration under pressure, and joint condensation of palladium and hydrogen on a liquid-helium-cooled substrate. Principal attention was paid to the production of hydrides with maximal superconducting-transition temperatures T_c. The obtained values of T_c ranged from 2 to 9°K, depending on the hydrogen concentration.

It was of interest to measure the critical magnetic fields for Pd hydrides having different values of T_c and to estimate their coefficient of electronic specific heat γ. To this end we prepared samples of pure Pd, with a resistance ratio $R_{300°}/R_{4.2°K}\approx 3000$, in the form of coils measuring 30×3×0.08 mm.

The hydration was carried out in a solution of sulfuric acid at a temperature below 0°C and a current density ~150 mA/cm^2. Different values of T_c were obtained by varying the hydration time. After hydration, the samples were rapidly cooled with liquid nitrogen and placed in a helium cryostat. A magnetic field of intensity up to 3000 Oe was produced with a copper solenoid cooled with liquid nitrogen. The superconducting-transition curves were obtained by measuring the resistance with a four-contact method. The critical temperature was taken to be the midpoint of the transition curve.

Figure 1 shows transition curves in a zero magnetic field for several samples with different hydrogen contents.[1)]

Figure 2 shows plots of the critical magnetic field H_{c2} against the temperature. It is seen from the figure that with increasing T_c, i.e., the value of dH_{c2}/dT decreases, with increasing concentration of the hydrogen in the Pd-H, so that $H_{c2}(0)$ remains approximately constant for all the investigated samples.

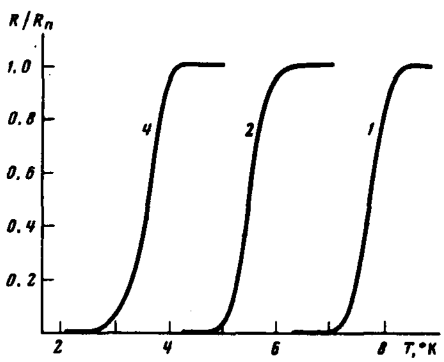

FIG. 1. Normalized superconducting-transition curves for certain samples with different hydrogen contents in the absence of a magnetic field. The numbers on the curves correspond to the numbers of the samples in the table.

Attention is called to the fact that for samples with small values of T_c the width of the transition decreases with increasing magnetic field (see Fig. 2). [$\Delta T(H)$ for samples with large T_c remains practically unchanged]. The principal results of the measurements are shown in the table.

From the obtained values of dH_{c2}/dT and from the residual resistance ρ_n we can calculate the electronic specific-heat coefficient γ.

$$\gamma = 2.2\cdot 10^{-5}\,\frac{1}{\rho_n}\,\frac{dH_{c2}}{dT}$$

in a manner similar to that used in[6,7]. For samples with different T_c, γ is constant within the limits of the measurement accuracy and equals (0.28±0.02) mcal/mole(°K)^2.

From the measurements of the magnetic susceptibility χ in the Pd-H system[8] it is known that when the hydrogen concentration is increased, up to H/Pd≈0.66, the value of χ decreases, possibly as a result of suppression of the fluctuations of the spin density in the Pd and the decrease of the density $N(0)$. The onset of superconductivity in Pd-H is attributed in[9] to suppression of the spin-density fluctuations. The increase of T_c with

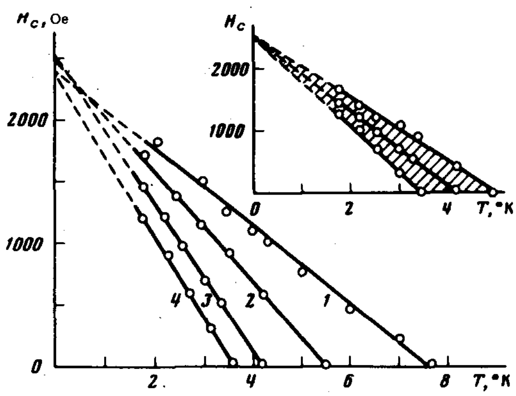

FIG. 2. Plot of $H_{c2}(T)$ for samples with different T_c. The numbers of the curves correspond to the numbers of the samples in the table. All the curves were plotted for the center of the transition. In the upper right corner are shown the plots of $H_{c2}(T)$ for sample 3, obtained for the start, midpoint, and end of the transition; it shows that the width of the transition decreases with increasing field.

Sample	T_c, °K	ΔT, °K	dH_{c2}/dT Oe/°K	H_{c2} (0) Oe	ρ_n 10^{-5} Ω-cm	γ mcal/mole(°K^2)
1	7.7	0.9	315	2430	0.60	0.28
2	5.5	0.7	455	2500	0.85	0.28
3	4.2	1.1	600	2520	1.04	0.30
4	3.6	0.9	660	2380	1.27	0.27
5	3.4	1.7	645	2190	1.23	0.26
6	6.2	1.1	350	2180	0.61	0.29

Note. Samples 1—5 were obtained by introducing different amounts of hydrogen into one and the same foil (Pd with $R_{300°}/R_{4.2°K} \approx 3000$). Sample 6 was made of palladium of lower purity ($R_{300°}/R_{4.2°K} \approx 300$).

hydrogen concentration at H/Pd ≈ 0.7 is regarded as a consequence of further decrease of the effective spin coupling constant μ_{spin} and of the Coulomb pseudopotential μ as a result of the decrease of the density of states $N(0)$, which is accompanied also by a decrease of the electron-phonon interaction constant λ.

It should be noted, however, that the simultaneous decrease of $N(0)$ and λ in the H/Pd concentration interval from 0.7 to unity, proposed in[9], does not agree with the constant γ obtained in this concentration region by us and also in measurements[10] of the specific heat of Pd-H samples. From the specific-heat data,[10] and also from preliminary results obtained by us on the Mossbauer effect in Sn^{119} impurity nuclei in superconducting palladium hydride, it follows that the Debye temperature of the Pd-H system at helium temperatures does not differ in practice from θ_D of pure Pd.

Thus, to explain the concentration dependence of T_c of the Pd-H system at H/Pd ≈ 0.7 it remains to propose that the electron-phonon interaction constant λ increases when the hydrogen concentration is increased. The mechanisms proposed in[9] are probably of secondary significance.

1)Chemistry Section, Bergakademie, Freiburg, E. Germany.

2)It should be noted that the widths T of the transition are smaller for the investigated samples than the widths given by others.[1,2]

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