Pd-H system as a possible room temperature superconductor

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Abstract

Some experimental data on PdH(D) at 300K, shows resistivity (ρ) less than the pure Pd. Moreover T_c greater than 9K reported in literature has been measured, hence a phenomenological description of the ρ for highly loaded PdH(D) system at 300K has been developed. This approach uses a parallel model of two concurrent electrical transport processes: i) ρ has a linear raise with the concentration x = H/Pd, due to the increase of Pd relative lattice volume ii) ρ has an exponential decrease versus x due to superconducting fluctuations at very high x in PdH(D). Superconducting state appears at x_c(300K). Inverse isotopic effect for 0.6$\leq$ x $\leq$0.96 changes to normal isotopic effect at x $\approx$ 1.

Key words:
PdH(D); HTSC; room temperature superconductor

1. Introduction

Relative resistance R/R_0 of the PdH_x versus stoichiometry x, where R_0 is the resistance of pure Pd, is usually interpreted with the Mott and the modified Mott model for metals and metal-alloys [1]. This model considers two phases: α-phase (0$\leq$ x $\leq$0.02) , β-phase (x$\geq$0.6) and their coexistence [$\alpha + \beta$]-phase (0.02$\leq$ x $\leq$0.6) in Pd, but it is not able to explain the experimental R/R_0 values less than unit at 300K [2][3], at 100K [4] and T_c in stable PdH_x (x$\geq$1) samples [5] much higher than 9K previously measured [6], therefore a new phenomenological approach to explain the Pd-H(D) electrical resistance behaviors for x$\geq$1 at 300K will be proposed. The Pd-H(D) resistance consists of two different electric transport mechanisms. Increasing x, the first correlates the R/R_0 increasing with the lattice structure change during the Octahedral (O) sites filling up and the second describes the exponential decreasing of R/R_0.

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2. Discussion

In the first mechanism the increasing of x affects the interaction between the H and Pd lattice with consequent increasing of the electron-phonon scattering. Moreover the slow motion (acustic phonon) of Pd lattice is very sensitive to the H^+ fast hopping motion between O-sities [7]. The increasing of R/R_0 vs x can be correlated with the linear lattice expansion in Pd-H(D) for 0$\leq$ x $\leq x_0$ where x_0 is the stoichiometric value when R/R_0 has the maximum value. We describe R/R_0 linear change in the first eq.1 where the parameter m is directly correlated with the increasing of Pd relative volume. For the second mechanism the following evidences must be considered.

The electronic configuration changes due to the filling up of the d-band vacancies, hence a reduction of s-d scattering and R/R_0 would be expected [3][8]. H vibration around their O-sities at very high frequencies (optical phonon) probably affect the normal resistance [9]. Because of the diffusion of H, these optical modes are local and independent from the Pd lattice vibrations [7]. Increasing x, the density of H in the O-

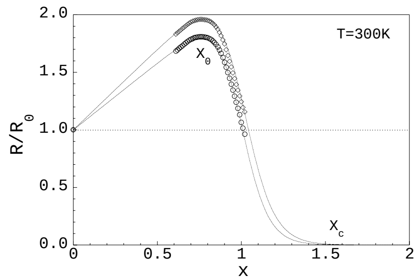

Fig. 1. R/R_0 fit of experimental data for PdH and PdD vs x

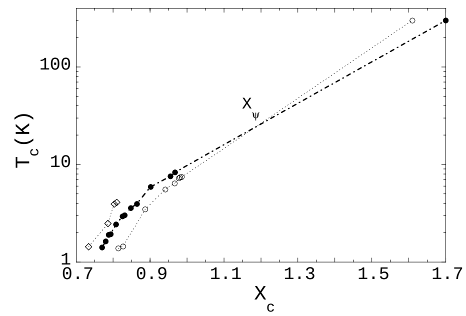

Fig. 2. T_c versus x_c for H (○),D (●) and T(◇) experimental data plotted with the theoretical results

sites increases and these optical modes should become non local. These optical modes are correlated with the superconductivity in the Pd-H(D,T) systems [9].

Moreover, the following data should be considered: i) unexplained experimental evidences ($R/R_0 \leq 1$) at 300K; ii) susceptibility measurements show a paramagnetic-diamagnetic transition above x=0.7 [10]; iii) well known superconducting transition at low temperature and high x [6]. iv) $T_c \geq 9$K for stable samples with x ≥ 1 [5].

A fluctuation process of the superconducting state that is responsible for Pd-H(D) electrical resistance decrease (x $\geq x_0$) is suggested and consequently condensation of macroscopic superconducting state occurs at x $= x_c$ [11]. These processes are described:

$$\left(\frac{R}{R_0}\right)_{lin} = 1 + mx \quad ; \quad \left(\frac{R}{R_0}\right)_{exp} = \beta e^{-\gamma(x-x_0)} \quad (1)$$

the second eq.1 considers the thermodynamic fluctuation of the superconducting state:

$$\gamma\,(x - x_0) = \frac{U}{KT} \quad ; \quad U = \left(\frac{H_c^2(T)\xi^3(T)}{8\pi}\right)\cdot n \qquad (2)$$

where U is the free-energy increment [11] or the condesation energy of the superconducting domains around T_c, n is the number of domains at fixed concentration x in $x_0 \leq$ x $\leq x_c$. Using equations (2):

$$\gamma(T) = \frac{H_c^2(T)\xi^3(T)}{KT} \qquad ; \qquad n = (x - x_0) \qquad (3)$$

the prefactor β [11] is correlated to the frequency described in the fluctuation theory. The value x=x_c, where R/R_0 is zero, is the end of the thermodynamic fluctuations and the Pd-H(D,T) system is in a macroscopic superconducting state. Hence, the U value calculated at x_c is the condensation energy of the macroscopic superconducting state. The fit of the experimental R/R_0 data are shown in fig.1 and the T_c vs x_c is shown in fig.2.

3. Conclusion

Results of the proposed phenomenological theory that consider the simultaneity of two processes as the parallel beetwen the two R/R_0 (linear and exponential) are:

i) T_c=300K for γ_H=12.4, γ_D=11.2, x_c(H)=1.6, x_c(D)=1.7. The condensation energy of the superconducting states is U_H=270meV and U_D=273meV

ii) x_c(D) $\geq x_c$(H) for T_c(D)=T_c(H)=300K shows a normal isotopic behavior (T_c(D) $\leq T_c$(H)) (fig.2);

iii) x_ψ where T_c(D)=T_c(H) is the threshold point from the inverse (T_c(D) $\geq T_c$(H)) to normal (T_c(D) $\leq T_c$(H)) isotopic behavior;

There is a correlation between condensation energy values and experimental data [12] on potential barrier between O-sites and T-sites in PdH. Probably to achieve high T_c in highly loaded PdH(D) system the occupation of T-sities is important.

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