Evidence for high temperature superconducting phases in $PdH$

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Abstract

New superconducting phases with a high critical transition temperature ($T_c$) have been found in stable Palladium-Hydrogen ($PdH_x$) samples for stoichiometric ratio $x=H/Pd \geq 1$, in addition to the well-known low critical transition temperature ($0 \leq T_c \leq 9$) when $x$ is in the range ($0.75 \leq x \leq 1.00$). New measured superconducting phases with critical temperature in the range $51K \leq T_c \leq 295K$ occur. This $T_c$ varies considerably with every milli part of $x$ when $x$ exceeds unit. A superconducting critical current density $J_c \geq 6.1 \cdot 10^4$ Acm$^{-2}$ has been measured at 77K with $H_{DC} = 0T$.

Key words:
$PdH$; HTSC; new superconducting material

1. Introduction

In 1972 $PdH_x$ was shown to be a superconductor at 6.6K [1] [2]. Later the maximum $T_c$ of 9K was found at the stoichiometric ratio $x=1$ [3][4]. It is an open question [5] if for $x \geq 1$ the PdH system has a greater $T_c$ in respect to the previous measurements [1-5]. It is not easy to produce $PdH_x$ samples with high and stable $x$, in order to perform resistivity measurements versus temperature. In fact the $H^+$ in interstitial sites of Pd lattice is extremely mobile [5] and a decreasing of $x$ is natural during temperature cycles. Moreover the superconductivity in Pd-H(D,T) system shows an inverse isotopic effect [6][7][8] that suggests complicated electron-phonon interaction and because the superconductivity appears only when $x \geq 0.6$, it is extremely important to know and maintain constant the stoichiometry. In this paper resistive superconducting transition in presence of DC magnetic field and critical current density at 77K will be discussed for $PdH_x$ wires with high $x$.

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2. Experimental Results

H has been loaded into Pd wires (diameter of 50µm; length of 30cm) used as cathode in an electrochemical cell. Cell geometry, electrolyte, loading procedure and experimental set-up have been described in the reference [9]. The $x$ value was obtained indirectly by ac electrical resistance measurement (1KHz, 20mA) of the $PdH_x$ during the dc electrochemical hydrogen loading process [9][10]. The measured electrical resistance of $PdH_x$ is a function of the mean stoichiometric ratio $x$ with a well known resistance curve at room temperature [10].

The superconducting critical temperature is measured by ac resistance measurement versus temperature using a thermally controlled He gas flow cryostat provided with a superconducting magnet. The ac electrical current amplitude was 2mA and the frequency 107Hz. After H loading, the wire sample was wrapped around a glass cylinder, then the two ends were welded with Ni wire using silver print because of the brittleness of the sample. After, the Ni wires were soldered to four copper wire contacts for the resistance measurement. Figure 1 shows two different electrical resistance
transition curves for the same sample. In plot (A) a $T_c$ at 51.6K is observed with $H_{DC} = 0$T. Plot (B) shows a double transition with $T_c$’s at about 31.3K and 18.8K when $H_{DC} = 1$T. When an external magnetic field of $H_{DC} = 0.1$T was applied, the superconducting transition temperature was still observed at approximately 51.6K. There is more than one superconducting phase, due to the non homogeneity of x inside the sample. Small decreases of PdH resistance show that only a little portion of the wire is in the superconducting state. Different resistance values with or without DC magnetic field should indicate the presence of magnetic resistance due to a complicated Fermi’s surface [11].

Critical current density measurements in LN$_2$ have been done on other samples using a different experimental set-up. In fact, to prevent the wire break (Pd spot welded on Pt contact) after the electrochemical H loading procedure, the same sample holder has been cooled down to LN$_2$ temperature. A dc power supply has been connected to the wire and the dc voltage drop along the wire has been measured in grounded configuration. The measured voltage drop amplitude ($10^{-4}$ V/cm) is higher than the usual value used in this measurement ($10^{-6}$ V/cm) because of the grounded electrical set-up. Figure 2 shows the I-V characteristics of two PdH wires highly H loaded and stable at room temperature, then quenched at LN$_2$ temperature. Increasing the dc electrical current, the dc voltage drop remains almost constant. The resistance remains null up to a dc electrical current of 1.15A then the resistance starts to increase. The critical current density, at earth magnetic field, of about $J_c \approx 6.1 \cdot 10^4$ A/cm$^2$ has been shown in fig.2. The second wire shows (fig.3) a greater critical current density $J_c \geq 6.1 \cdot 10^4$ A/cm$^2$. We can only write the disequality because of the experimental limitation on electrical current. It is important to underline that the total wire length (6 cm) shows a superconducting behaviour at LN$_2$ temperature for both samples.

### 3. Conclusion

We present in this letter new superconducting phases in PdH system [12]. This finding has been reached thanks to the experimental procedure to obtain high and stable x in Pd. The critical current density at 77K seems promising for future technological applications.

### References