УДК 538.945 + 538.955 + 539.126.334

μSR-INVESTIGATION OF THE HIGH-T_c SUPERCONDUCTOR $HoBa_2Cu_3O_{7-\delta}$

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A high-T_c superconductor $HoBa_2Cu_3O_{7-\delta}$ ($T_c \sim 93$ K) has been investigated by the μSR-method in a zero external magnetic field, the sample being cooled from the temperature much higher than T_c to T=4.2 K. The fast increasing of the muon spin depolarization in the temperature range 10-4.2 K is observed, which indicates the fluctuating production of the magnetic ordering in this sample.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

Исследование высокотемпературного сверхпроводника $HoBa_2Cu_3O_{7-\delta}$ μSR-методом

В.Н.Дугинов и др.

Исследован μSR-методом высокотемпературный сверхпроводник $HoBa_2Cu_3O_{7-\delta}$ ($T_c \sim 93$ K) в нулевом внешнем магнитном поле при охлаждении образца от температуры, значительно превышающей T_c, до температуры T= 4,2 K. В области температур 10-4,2 K наблюдается быстрая деполяризация спина мюона, свидетельствующая о флуктуационном образовании магнитоупорядоченного состояния в исследуемом соединении $HoBa_2Cu_3O_{7-\delta}$.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

Nowadays the phenomena in high-T_c superconductors like $RBa_2Cu_3O_{7-\delta}$, R being the rare-earth elements with high atomic magnetic moments, arouse great interest /1, 2/ .

In our experiment a high-T_c superconductor $HoBa_2Cu_3O_{7-\delta}$ has been investigated by the μSR-method. The experiment was perfor-

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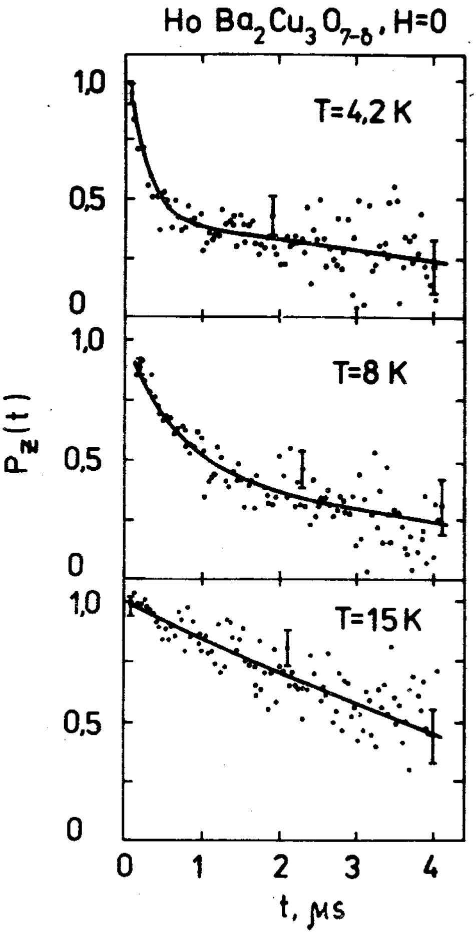

Fig.1. Muon spin relaxation functions in $HoBa_2Cu_3O_{7-\delta}$ at different temperatures in the zero external magnetic field. The solid curves are plotted according to formula (1).

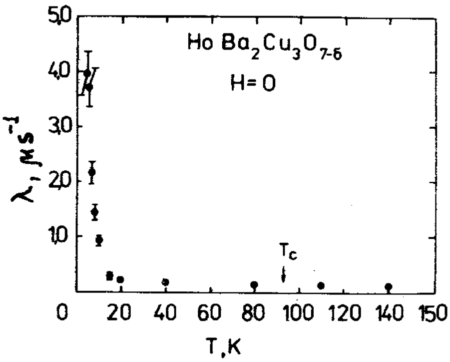

Fig.2. Temperature dependence of the muon spin relaxation rate λ in the zero external magnetic field.

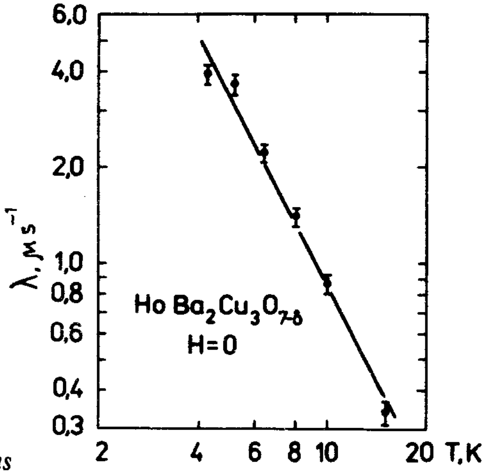

Fig.3. Temperature dependence of λ(T) in the temperature range 4.2-15 K. The solid line is plotted according to formula (2).

med at the Laboratory of Nuclear Problems (JINR, Dubna) in the phasotron muon beam. The sample was a disk ~40 mm in diameter and ~10 mm thick. The disk's face was perpendicular to the direction of the muon beam polarization. The superconducting transition temperature, determined in resistivity measurenents, was about 93 K. Investigations of the sample were performed in a zero external magnetic field in the temperature range 4.2-140 K.

To fit the experimental data the relaxation function was taken to be:

$$P_z(t) = \frac{1}{a_\Sigma}[a e^{-\lambda(T)\cdot t} + (a_\Sigma - a) e^{-\sigma^2 t^2}], \tag{1}$$

where a is the decay asymmetry of the μ^+-fraction stopped, as we suppose, at the sites nearest to Ho-atoms; $\lambda(T)$ is the muon spin relaxation rate for this fraction; a_Σ is the total decay asymmetry determined in the experiment at $T \gg T_c$ in the magnetic field $H_\perp$ transversal to the initial muon polarization; σ is the muon spin relaxation rate for the muon fraction stopped at the sites far from Ho-atoms. It was assumed that a, a_Σ and σ are constant at all temperatures ($a = 0.097 \pm 0.002$; $a_\Sigma = 0.155$; $\sigma = 0.182 \pm 0.008$). Values of $\lambda(T)$ were selected individually for each spectrum. Figure 1 shows the experimental dependences $P_z(t)$ and those computed by eq.(1).

The muon spin relaxation rate $\lambda(T)$ as a function of the temperature is plotted in Fig.2. As is seen, there is no visible change in λ from $T = 140$ K up to $T \sim 15$-20 K. This means, that there are no signs of magnetic ordering above ~15-20 K. However, the fast increasing of λ is observed below ~15-20 K, which can be explained by the fluctuating formation of magnetic ordering (ferro- or antiferromagnetic) in the paramagnetic phase of the superconductor near the magnetic phase transition temperature. The dependences $P_z(t)$ in Fig.1 also indicate the fast increasing of the muon spin relaxation rate when the temperature approaches 4.2 K.

The analysis of the $\lambda(T)$-dependences at $T < 15$ K showed (Fig.3), that the observed increasing of λ with decreasing temperature can be expressed as:

$$\lambda(T) = \frac{C}{(T - T_{cr})^\beta}, \tag{2}$$

where $T_{cr} = (0 \pm 1)$ K, $\beta = 1.9 \pm 0.3$.

The magnetic ordering in $HoBa_2Cu_3O_{7-\delta}$ is connected with holmium atoms whose unfilled 4f-shell has a magnetic moment of $10\,\mu_B$. In pure holmium these moments are ordered at $20 \lesssim T \lesssim 132$ K as helicoidal antiferromagnetic and at $T < 20$ K as helicoidal ferromagnetic. The magnetic ordering in the high-T_c superconductor $HoBa_2Cu_3O_{7-\delta}$ observed in the experiment points to coexistence of superconductivity and magnetism in this substance.

The same result was obtained in Ref.[3], where the magnetic phase transition was observed in $GdBa_2Cu_3O_{7-\delta}$ at 2.3 K.

We thank V.Yu.Yushankhaj for helpful discussions and I.A.Gaganov for assistance in measurements.

R e f e r e n c e s

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Received on May 10, 1988.