Heat capacity peculiarity of 90 K samples of $YBa_2Cu_3O_{6+x}$ above T_c

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Abstract

The temperature dependence of heat capacity of superconductors $YBa_2Cu_3O_{6+x}$ system (with x=0.85, 0.90, 0.95) was investigated above T_c. For all the samples the "small" anomalies in intervals 110-180 K (T_{low}), 205-235 K (T_m) and 250-290 K (T_h) were discovered. The analysis with involving data for $TmBa_2Cu_3O_{6.95}$ and $GdBa_2Cu_3O_{6.95}$ shows that one may consider some of these anomalies as a characteristic property of the 90 K samples.

Key words: Superconductivity; normal state; heat capacity; $YBa_2Cu_3O_{6+x}$ system

We had examined experimental data on heat capacity of 90 K samples $YBa_2Cu_3O_{6+x}$ [1] in wide temperature range of a normal state and had discovered three anomalies. The observation of both the anomalies in heat capacity and features in other physical properties of compounds $YBa_2Cu_3O_{6+x}$ above T_c raises the question about their origin. We discuss the possible causes of discovered anomalies involving also data for $TmBa_2Cu_3O_{6.95}$, $GdBa_2Cu_3O_{6.95}$ (see below) and $NdBa_2Cu_3O_{6.87}$ [2].

Experimental heat capacity $C_p(T)$ in temperature range of a normal state can be presented by expression

$C_p(T) = C_{harm}(T) + \gamma\ T + A(T_0 - T)^{\alpha} + \delta\ C(T)$.

Term $C_{harm}(T)$ describes harmonic lattice part. Term $\gamma\ T$ describes linear electron part and linear anharmonic contribution [3]. Term $A(T_0-T)^{\alpha}$ describes possible nonlinear anharmonic contribution and also possible contribution from a stepwise oxygen ordering at ortho-tetra transition [2].

For all the samples the smooth contributions were found and then the term $\delta C(T)$ was extracted. The localized peaks, which considerably exceeded the experimental spread, revealed themselves in three temperature intervals: 110-180 K (T_{low}), 205-235 K (T_m) and 250-290 K (T_h). Typical behavior of $\delta\ C(T)$ is shown in Fig.1.

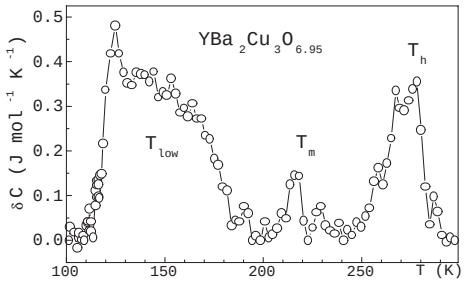

Fig. 1. Small anomalies in heat capacity of $YBa_2Cu_3O_{6.95}$.

Anomaly T_{low} is a wide peak with a substructure. In work [4] the modification of optical absorbtion spectrum (confined to finite temperature interval 112-155 K) for $YBa_2Cu_3O_{6.85}$ was detected. It is possible that these phenomenon are interdependent.

Anomaly T_m usually has two close in their hight peaks with maximums at 215 K and 230 K. At the same temperatures, the magnetic phase transitions in pure CuO take place (213 K and 230 K). On the one hand, one may not exclude absolutely the presence of the CuO impurity as nonconsumed original reactant or

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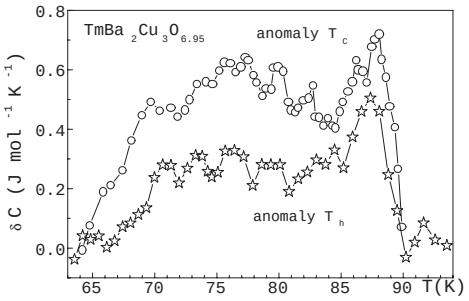

Fig. 2. Comparison of the form of anomalies T_h and T_c.

as a product of oxydation of copper calorimeter parts. On the other hand, only the further research may exclude the possibility of dependence of this anomaly on the nature of compound as such. (See, for example, [5]).

Anomaly T_h has a maximum at 275 K. One can think that some amount of H_2O was adsorbed by ceramic sample and the presence of anomaly results from melting this water at 273.15 K. However, the values T_h for compounds $NdBa_2Cu_3O_{6.87}$ [2] and $GdBa_2Cu_3O_{6.95}$ (see below) exceed significantly the temperature 273.15 K. They are close to 285 K, which excludes completely the connection of this anomaly with melting the water.

We discovered that temperature T_h is connected with temperature of superconducting transition by the ratio $T_h \simeq 3T_c$. Besides, one can notice that the form of anomaly T_h replicates the form of superconducting anomaly T_c. An illustration in Fig.1 makes it clear for the sample $YBa_2Cu_3O_{6.95}$. Moreover, the individual profile of anomaly T_h was discovered to replicate the profile of anomaly T_c in small details, as in Fig.2 for the sample $TmBa_2Cu_3O_{6.95}$. Here anomaly T_h was shifted to the region of superconducting anomaly T_c by dividing the values of temperatures by 3. In above examples anomaly T_h appears as a sort of temperature "echo" of superconducting anomaly T_c.

Additional test giving another evidence of the phenomenon of temperature echo is presented below. Temperature of superconducting phase transition for $TmBa_2Cu_3O_{6.95}$ is $T_c = 91.3$ K, and it is $T_c = 94.3$ K for $GdBa_2Cu_3O_{6.95}$ (heat capacities of both these samples were obtained in the same calorimeter with the same conditions of experiment [6]). If there is temperature echo at $T_h \simeq 3T_c$, then this echo can be expected as a minor peak at $T_h \approx 274$ K (for $TmBa_2Cu_3O_{6.95}$) and at $T_h \approx 283$ K (for $GdBa_2Cu_3O_{6.95}$). To check this expectation the difference between the molar heat capacities of these compounds was calculated in temperature interval 150-300 K (Fig.3). All the errors the source of which are the imperfections in experimental technique are automatically excluded here. (It should be noted that no anomaly Tm is found here).

Indeed, through the typical spread, one can see a

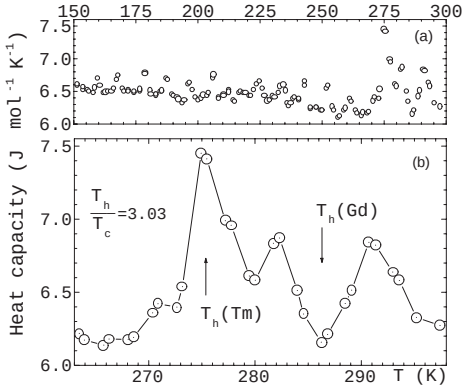

Fig. 3. Difference of molar heat capacities of compounds $TmBa_2Cu_3O_{6.95}$) and $GdBa_2Cu_3O_{6.95}$) a) in the interval 150-300 K, b) the same in large scale in the interval 265-295 K.

maximum at 274 K corresponding to expected peak T_h for $TmBa_2Cu_3O_{6.95}$ and a minimum at 285 K corresponding to expected peak T_h for $GdBa_2Cu_3O_{6.95}$. So, the obtained results allow one to consider the anomaly T_h as a temperature "echo" of the superconducting anomaly T_c.

In conclusion, for the studied samples $YBa_2Cu_3O_{6+x}$ the three small anomalies T_{low}, T_m and T_h were discovered in temperature interval 100-320 K. Anomaly T_h looks like phase transition and represents by itself the temperature echo of superconducting anomaly T_c. This phenomenon is new, now its physical mechanism is unknown. It seems to be that T_h is temperature of origination of superconductivity.

Anomaly T_m can be the consequence of the presence of untraced impurity CuO. However, one may not exclude the possibility that this anomaly results from the nature of compound $YBa_2Cu_3O_{6+x}$.

The nature of anomaly T_{low} is unknown yet. It is possible that anomalies T_{low} and T_h have the same nature and are connected with the anisotrpy of superconducting gap (or pseudogap).

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