TEMPERATURE DEPENDENCE OF HALL COEFFICIENT IN HTSC

I. V. Nazarkin, R. F. Konopleva

Numerous investigations of high-T_c superconductors (HTSC) contribute to reveal a large number of unusual properties of these compounds. In a number of cases parametrical dependence of electroresistance, Hall constant, warmthconductivity, EPR and other parameters differ much differ from the similar ones in type II traditional superconductors, that they say about anomalous properties of the HTSC (anomalous Hall effect [1]). Such anomalies have been observed both close to superconducting transitions at $T > T_c$ and in existence region on the normal (nonsuperconducting) phase of the metalorganical compounds at $T > T_c$ which nature in HTSC remains unknown for the time being. Therefore the study of the properties of the resistance in HTSC state is the topical problem. A considerable number of the works is devoted to temperature dependence of the Hall coefficient in HTSC [2]–[4]. It is possible to refer the maximumes on the $R(T)$ dependence by $T > T_c$, which was revealed in several yttrium, bismuth and thallium high — temperature compounds to the category of the anomalous [2 - 4]. The aim of this work is to attempt model description of the nonmonotonous temperature dependence of the Hall coefficient with the maximum in the temperature region $T \gg T_c$ according to the normal phase of HTSC when linear character of the $\rho(T)$ dependence is maintained in the same temperature intervale.

Let us follow the band structure presented in the Fig.1 when describing this model. Note also that the further reasoning deal with conductivity of HTSC in the normal phase on a metallic side of the metal-insulator transition.

The similar approach based on applicaton of the simplest band model which takes into account existence of a narrow admixture band used with succsess for the explanation of the transport properties including temperature dependence Zeebek and Hall coefficients in $YBaCuO$ and $LaSrCuO$ [5]. Howewer, the nonmonotous character of the temperature dependence R_h was not considered in [5].

The aim of the model produced in the Fig.1 is to explain the anomalous behaviour of the Hall coefficient in the resistive state of the HTSC. As it can be seen from Fig.1 the admixture levels overlapping with the valence band creates the local state in it.

Let us show that such mutual band arrangement bring to the apperance the maximum on the temperature dependence of the Hall coefficient at the temperatures which essentially exceeded T_c. Let us write the electroneutral equation for holes in the band structure presented in Fig.1 [6].

$$p + N_d = N a_a \left[1 + \beta \exp(\mu + E_a/k_0 T)\right]^{-1} = N_a C \tag{1}$$

where p — hole concentration; N_d — oxygen atom concentration; N_a — oxygen vacancies concentration; E_f — Fermi level position; k_o — Boltzmann constant; g — generation spin factor.

Differentiating both part of Eq.(1) on T

$$\frac{\partial p}{\partial T} \mid_{T=T_{\max}} = N_a C_{\max} (C_{\max} - 1) \left(\frac{\partial \mu}{\partial T} \mid_{T=T_{\max}} - \frac{E_a}{k_0 T^2} \right) \tag{2}$$

and comparing the derivative with zero in the point of the maximum we obtain for extremum temperature:

$$T_{\max} = -\frac{3}{3k_0} E_a \tag{3}$$

where E_a — pozition of the acceptor levels relatively the top the valence band.

Inasmuch as shown from Eg.(3) $T_{\max}$ and Boltzmann constants are both positive, E_a must be less then zero. In other words E_a levels dispose under the valence band top, which is equal to zero in accpted here designation system.

Thus if the valence and admixture band structure and their mutual arrangement are such as shown in Fig.1, the temperature dependence of the current carries concentration determined by Eq.(1) will be have the maximum determined by Eq.(3).

Evidently, the more band overlapping schematically shown in Fig.1 the more displased the maximum $R_h(T)$ in the region of the high temperature which varying from 170 K [4] Fig.2 to 70 K [2]. On the other hand as the admixtire centers concentrations increases so does the region width of the delocalization states $W = E_1 - E_2$. The decrease of the local states concentration near Fermi level caused the Hall constant growth observed in experiment [2].

Thus, in the frame of the suggested model it is possible to describe nonmonotonous character of the temperature dependence of the Hall coefficient by $T > T_c$.

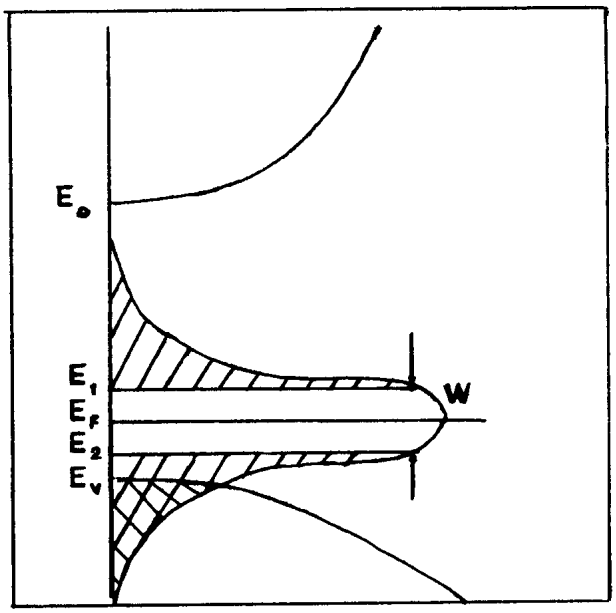

Fig.1. Band structure of the HTSC which takes into account the partial overlapping admixture potential with valence band:
E_c — conductance band; E_v — valence band; E_f — Fermi energy; E_1, E_2 — energies separated local and nonlocal states in admixture band

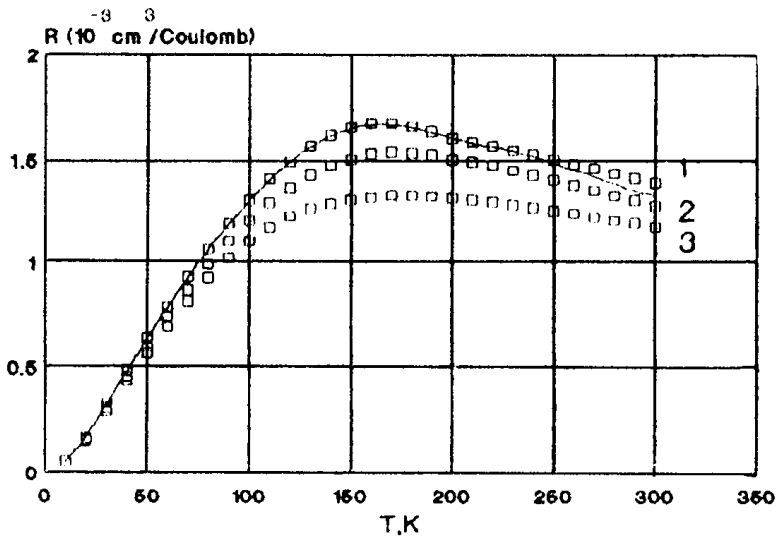

Fig.2. Temperature dependence of Hall coefficient in $Tl_2Ba_2CuO_{6+y}$ samples in magnetic field $H = 9$ Tl at different external pressure [4]:
curve 1: 0.0 GPa; curve 2: 1.0 GPa; curve 3: 2.0 GPa
Solid line — according to Eq.(1)

REFERENCES

1. *Gor'kov L.P., Kopnin N.B.* //Uspekhi Fiz.Nauk, 1988. V.156. P.117.
2. *Alfronte M., Genoud J.Y., Fischer O.* Hall effect in $Y_2Ba_4Cu_7O_x$ ceramics with $14.1 < x < 15.1$.
   //Phys.Rev.B., 1992. V.45. N°14. P.8189.
3. *Mackenzie A.P., Hughes S.D., Cooper J.R.et al.* Low-temperature all effect in $Bi_2Sr_2CuO_{6-\delta}$.
   //Phys.Rev.B., 1992. V.45. N°1. P.527.
4. *Kubo Y., Monako T.* T^2-dependence of universe Hall mobility observed in overloped Tl-cuprates. //Physica C, 1992. V.197. P.378.
5. *Moshalkov V.V.* //Physica C, 1988. V.156. P.473.
6. *Shalimova K.V.* Physics of Semiconductors. M.: Nauka, 1979.