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CRITICAL MAGNETIC FIELDS H_{c1} AND H_{c2} OF HIGH TEMPERATURE Bi-Sr-Ca-Cu-O SUPERCONDUCTORS [1)]

КРИТИЧЕСКИЕ МАГНИТНЫЕ ПОЛЯ H_{c1} И H_{c2} ВЫСОКОТЕМПЕРАТУРНЫХ СВЕРХПРОВОДНИКОВ Bi-Sr-Ca-Cu-O

TIMKO, M.,[2)] KOVÁČ, J.,[2)] DIKO, P.,[2)] MIŠKUF, J.,[2)] ZENTKOVÁ, A.,[3)]
SLANČO, P.,[2)] Košice

The discovery of superconductivity in the oxides La-Ba-Cu-O [1] has generated an intense search for high temperature conductors in related materials. Michel [2] recently reported superconductivity in the non-rare-earth-containing $Bi_2Sr_2Cu_2O_{7+}$ oxide with a transition temperature as high as 22 K. A new Bi-Sr-Ca-Cu-O composition has been found to exhibit a complete superconductivity transition at 80 K with well-defined resistance drops starting as high as 115 K [3]. In order to obtain more information about Bi-Sr-Ca-Cu-O superconduction system, we present here the results of the study of the temperature dependence of critical magnetic fields H_{c1} and H_{c2} determined by the magnetization measurements.

Samples of nominal composition $Bi_4Sr_3Ca_3Cu_4O_{16-x}$ used in this study were prepared by reacting Bi_2O_3, CuO, $Sr(NO_3)_2$ and $CaCO_3$ (of purity 99.9 %). The mixed powder was pressed into pellets. After heating at 800 °C for 4 hours and 860 °C for 64 hours in air the material was ground and pressed (600 MPa) into tablets. The heat treatment of the samples was as follows:

sample A: 890 °C, O_2 for 10 hours, fast cooling
sample B: 865 °C, O_2 for 16 hours, fast cooling
sample C: 865 °C, O_2 for 16 hours, slow cooling (2 °C/hour).

By the X-ray method the samples were determined as being a nearly monophase structure $Bi_2Sr_2Ca_1Cu_2O_{8-x}$.

Magnetization measurements were performed in an induction magnetometer. The magnetic field was produced by a superconducting solenoid, up to 6.5 T. The temperature was determined by a calibrated Cu ($T > 50$ K) and Allen—Bradley carbon resistor ($T < 50$ K) thermometers, after a correction for magnetoresistance. The ac susceptibility was measured by means of a mutual inductance bridge of the Hartshorn type. Measurements were done in the temperature range of 4.2—100 K.

The variation of the lower critical field H_{c1} and the upper critical field H_{c2} with temperature is shown in Fig. 1 and Fig. 2 respectively. It can be seen that the temperature dependence of $H_{c1}(T)$ and $H_{c2}(T)$ consits of two parts with a different course but they have the same character for all

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2) Institute of Experimental Physics, Slovak Academy of Sciences, KOŠICE, Czechoslovakia
3) Faculty of Sciences, P. J. Šafárik University, KOŠICE, Czechoslovakia

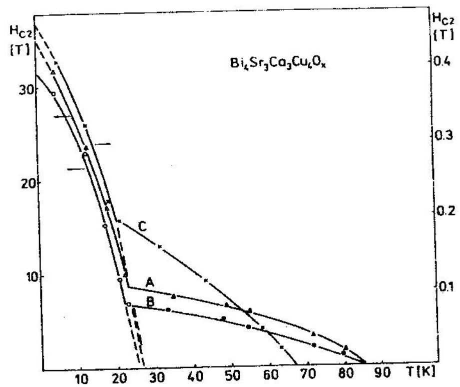

Fig. 1. Lower critical field H_{c1} of $Bi_4Sr_3Ca_3 \cdot Cu_4O_{16-x}$ obtained by magnetization measurements plotted against temperature T.

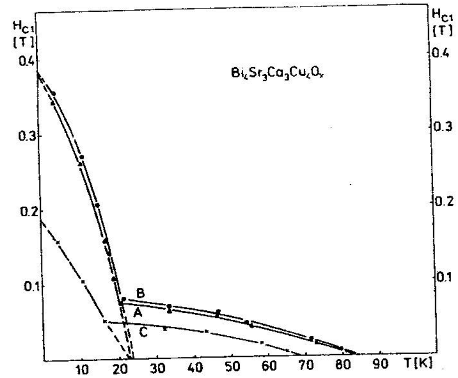

Fig. 2. Upper critical field H_{c2} of $Bi_4Sr_3Ca_3 \cdot Cu_4O_{16-x}$ obtained by magnetization measurements plotted against temperature T. Data marked by open symbols were determined by extrapolating the magnetization $M(H)$ curve linearly to zero.

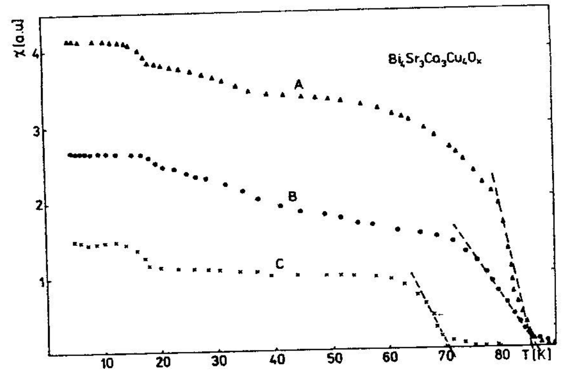

Fig. 3. Temperature dependence of AC susceptibility for the $Bi_4Sr_3Ca_3Cu_4O_{16-x}$ compound.

samples. On the contrary, the critical fields for sample C were obtained significantly lower than the ones for samples A and B and the transition temperature shifted to a lower temperature as well. The temperature dependence of the ac susceptibility is shown in Fig. 3. It can be seen that two superconductivity transitions have occurred. The first at ~20 K is the same for all samples and the second at 86 K and 68 K for the samples A, B and C respectively. The midpoint of the transition is estimated as a middle temperature of the decrease of susceptibility between 90 % and 10 % of its value.

The values of $H_{c1}(0)$ and $H_{c2}(0)$ for the Bi-Sr-Ca-Cu-O compound for both phases together with the other data relevant to our samples are listed in Table I. and Table II.

Table I

	THE FIRST PHASE	THE SECOND PHASE	SAMPLE
$-(dH_{c2}/dT)_{T_c}$	1.80 T/K	0.23 T/K	A
	1.69 T/K	0.14 T/K	B
	0.02 T/K	0.006 T/K	C
$-(dH_{c1}/dT)_{T_c}$	20.62 mT/K	1.68 mT/K	A
	22.60 mT/K	1.75 mT/K	B
	8.82 mT/K	1.5 mT/K	C
T_c	23 ± 1.5 K	84 ± 1.5 K	A
	24 ± 1.5 K	84 ± 1.5 K	B
	23 ± 1.5 K	68 ± 1.5 K	C
TRANSITION TEMPERATURE MIDPOINT		83 ± 1.5 K	A
		80 ± 1.5 K	B
		68 ± 1.5 K	C
$H_{c2}(0)$	34.8 T	10.2 T	A
	31.8 T	8.6 T	B
	0.46 T	0.27 T	C
$H_{c1}(0)$	0.385 T	0.094 T	A
	0.390 T	0.095 T	B
	0.19 T	0.060 T	C
$H_{c2}^{+}(0)$	30.6 T	13.5 T	A
	28.7 T	8.2 T	B
	0.34 T	0.26 T	C

From the magnetization $M(H)$ curves in the increasing field the Ginsburg – Landau parameters $\varkappa_2$ were obtained [4] and the extrapolation of $\varkappa_2$ up to T_c gave $\varkappa$. The obtained $\varkappa_2$ has to be taken as the lowest limit since the equilibrium magnetization lies between the hysteresis curves in the increasing and the decreasing field. The slope of the $H_{c2}(T)$ curve at T_c also be used for estimating the zero-temperature critical field $H_{c2}^{+}(0)$ using the weak-coupling formula [4]

$$H_{c2}^{+}(0) = 0.693\,[(-dH_{c2}/dT)_{Tc}]\,T_c .$$

Table II

	THE FIRST PHASE	THE SECOND PHASE	SAMPLE
THERMODYNAMIC CRITICAL FIELD	3.66 T	0.98 T	A
	3.50 T	0.90 T	B
	0.30 T	0.13 T	C
$GL\ \varkappa$	6.7	7.4	A
	6.4	6.8	B
	1.9	1.5	C

To summarize, we have determined by heat treatments the temperature dependence of the critical magnetic field for the Bi-Sr-Ca-Cu-O compound. The obtained data are characterized by an unusual course of the $H_{c1}(T)$ and $H_{c2}(T)$ curves. The critical parameters of the investigated samples are strongly dependent on the condition of the heat treatment. The slow cooling of this material leads to the reduction of the critical fields and of the transition temperature. Concluding we can say that there are two phases (structural or superconducting) in the investigated samples.

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