Effect of Mg impurity on the superconductivity of metal oxides of the system Bi-Sr-Ca-Cu

E. M. Gololobov, N. A. Prytkova, Zh. M. Tomilo, D. M. Turtsevich, and N. M. Shimanskaya
Institute of Solid State Physics and Semiconductors, Academy of Sciences of the Belorussian SSR

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The superconducting transition temperatures T_c of the metal-oxide systems $Bi_2Sr_2CaMg_xCu_2O_y$ and $BiSrCaMg_xCu_2O_y$ were found to be independent of the magnesium concentration. A strong degradation of T_c was found to occur in the system $Bi_2Sr_2Ca_{1-x}Mg_xCu_2O_y$ as the Mg concentration was increased.

The discovery of high-temperature superconductivity in the Bi-Sr-Ca-Cu-O system,[1,2] in which there are no rare-earth elements, has generated a considerable interest in this system. An experimental study[1,3] of a more complex system Bi-Al-Sr-Ca-Cu-O showed that the T_c does not change appreciably as a result of the addition of aluminum.

We have synthesized a high-T_c superconducting system Bi-Sr-Mg-Ca-Cu-O and then studied it experimentally. We obtained the compositions $Bi_2Sr_2CaMg_xCu_2O_y$, $BiSrCaMg_xCu_2O_y$, and $Bi_2Sr_2Ca_{1-x}Mg_xCu_2O_y$, where $0 \leqslant x \leqslant 1.0$. The samples were synthesized by the solid-phase reaction method in air at temperatures in the range 800–870 °C. To synthesize the required compositions, we used thoroughly dried, finely divided Bi_2O_3, MgO, and CuO oxide powders and $SrCO_3$ and $CaCO_3$ carbonate powders. The x-ray phase analysis of the synthesized powdered samples was carried out in a CuKα radiation using a DRON-3 diffractometer. Figure 1 shows some typical diffraction patterns of samples of various compositions.

The temperature dependence of the electrical resistance $R(T)$ was measured by the four-point method in the temperature interval 4.2–300 K at a constant current of 0.5–2 mA. Figure 2 is a plot of $R(T)/R(300\ K)$ for several samples of various compositions. The temperature of the onset of the transition to the superconducting state, T_c^0, and the temperature at which the transition ends, T_c^E, determined from these plots, are shown in Fig. 3a. As can be seen, the introduction of magnesium into the superconducting metal oxide $Bi_2Sr_2CaMg_xCu_2O_y$ in the amount up to $x = 0.3$ has virtually no effect on the values of T_c^O and T_c^E. A further addition of magnesium to $x = 1.0$ changes the values of T_c^O and T_0^E only slightly. A similar curve for the temperature of the onet of the superconducting transition and the temperature at which it ends, plotted as a function of the amount of magnesium introduced, is also appreciable to the $BiSrCaMg_xCu_2O_y$ compositions. At 300 K the electrical resistance of the samples studied varied in the range 12–100 m$\Omega\cdot$cm.

Replacement of calcium by magnesium in the composition $Bi_2Sr_2Ca_{1-x}Mg_xCu_2O_y$ leads to a strong degradation of T_c^0 and even stronger degra-

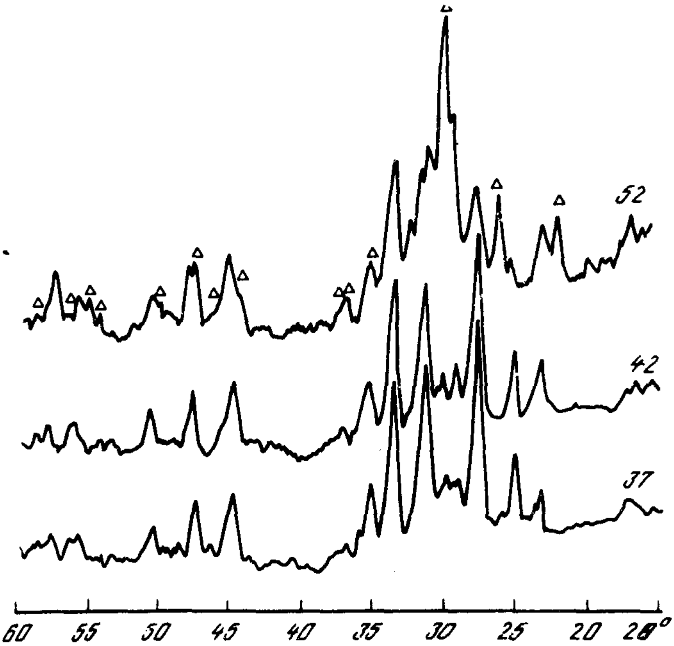

FIG. 1. Diffraction patterns of the samples. 37—$Bi_2Sr_2CaCu_2O_y$; 42—$Bi_2Sr_2CaMg_{0.5}Cu_2O_y$; 52—$Bi_2Sr_2Ca_{0.5}Mg_{0.5}Cu_2O_y$.

dation of T_0^E. After a total replacement of calcium, the composition $Bi_2Sr_2MgCu_2O_y$ remains a superconductor with $T_c^0 = 10$ K and $T_c^E = 4.2$ K.

Analysis of x-ray diffraction patterns showed that the crystal lattice of superconducting metal oxides $Bi_2Sr_2CaMg_xCu_2O_y$ and $BiSrCaMg_xCu_2O_y$ has a tetragonal or pseudotetragonal structure with the parameters close to $a \approx b \approx 5.4$ Å and $c \approx 30.7$ Å, as reported in Refs. 4 and 5. The lattice parameters $a(x)$ and $c(x)$ determined by us

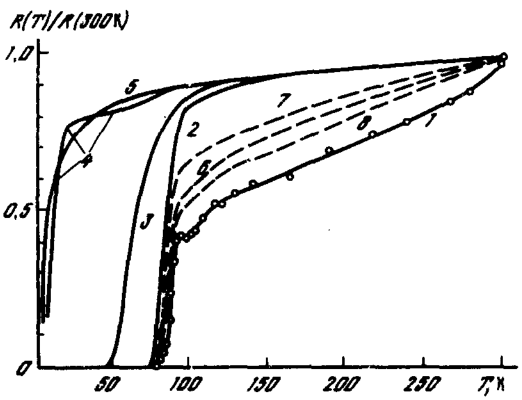

FIG. 2. $R(T)/R$ curves (300 K) for samples of the system Bi–Sr–Ca–Mg–Cu–O. 1—$Bi_2Sr_2CaCu_2O_y$; 2—$Bi_2Sr_2Ca_{0.8}Mg_{0.2}CuO_y$; 3—$Bi_2Sr_2Ca_{0.5}Mg_{0.5}Cu_2O_y$; 4—$Bi_2Sr_2Ca_{0.2}Mg_{0.8}Cu_2O_y$; 5—$Bi_2Sr_2Mg_xCu_2O_y$; 6—$Bi_2Sr_2CaMg_{0.3}Cu_2O_y$; 7—$Bi_2Sr_2CaMg_{0.8}Cu_2O_y$; 8—$Bi_2Sr_2CaMgCu_2O_y$.

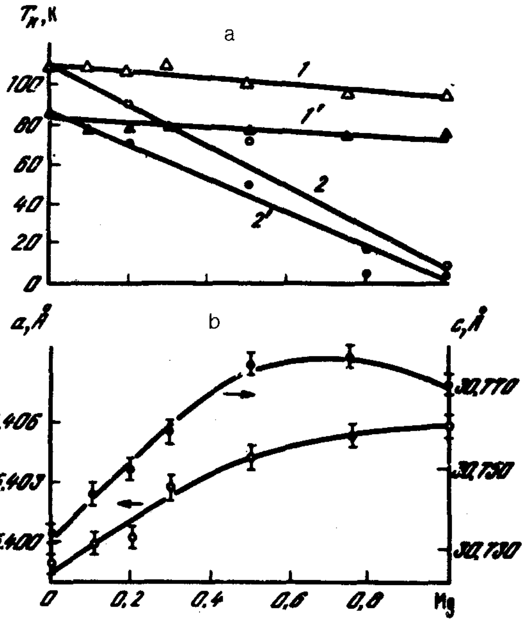

FIG. 3. Magnesium concentration versus (a) T_c^0 and T_c^E of the system $Bi_2Sr_2CaMg_xCu_2O_y$ (1 and 1′) and of the system $Bi_2Sr_2Ca_{1-x}Mg_xCu_2O_y$ (2 and 2′); (b) lattice constants a and c of the system $Bi_2Sr_2CaMg_xCu_2O_y$.

are plotted in Fig. 3b as a function of the magnesium content in the composition $Bi_2Sr_2CaMg_xCu_2O_y$. According to our studies, it can be assumed that Mg-based phases are not formed in the metal oxide superconductors indicated above and that the lattices of the compositions which we have studied contain magnesium.

Some samples of the compositions $Bi_2Sr_2CaCu_2O_y$ and $BiSrCaCu_2O_y$ has a small amount of the high-T_c superconducting phase with $T_c^0 \approx 117$ K, as can clearly be seen on the $R(T)/R$ (300 K) curves.

Study of the phase composition of samples of the system $Bi_2Sr_2Ca_{1-x}Mg_xCu_2O_y$ showed that in addition to the formation of a high-T_c superconducting phase characteristics of $Bi_2Sr_2CaCu_2O_y$ $(x = 0)$, there is the formation of another phase (or phases), whose volume increases with increasing amount of magnesium.

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