SUPERCONDUCTIVITY IN THE Sn-Ba-Sr-Y-Cu-O SYSTEM


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Since Bednorz and Müller /1/ discovered high-$T_c$ superconductivity in the La-Ba-Cu-O compound, several families of superconducting oxides have been synthesized /2/. In this paper we report the results of search for superconductivity in the compounds based on tin which has a lone electron pair like Bi, Tl, Pb.

The following compounds were synthesized: Sn$_1$Ba$_1$Sr$_1$Cu$_3$O$_x$, Sn$_1$Ba$_1$Ca$_1$Cu$_3$O$_x$, Sn$_1$Ba$_1$Mg$_1$Cu$_3$O$_x$, Sn$_1$Sr$_1$Ca$_1$Cu$_3$O$_x$, Sn$_1$Sr$_1$Mg$_1$Cu$_3$O$_x$, Sn$_1$Ca$_1$Mg$_1$Cu$_3$O$_x$. The initial components were oxides and carbonates of the appropriate elements. Standard firing-grinding procedure was used. Final heating was carried out at 960°C during 12 hours. Then the samples were cooled inside the furnace. All the synthesis cycles were carried out in air atmosphere.

Among the synthesized compounds only Sn$_1$Ba$_1$Sr$_1$Cu$_3$O$_x$ showed remarkable conductivity ($\rho \sim 10$ Ohm·cm). Other compounds were practically dielectrics ($\rho > 1000$ Ohm·cm). Presence of a possible superconductivity in Sn$_1$Ba$_1$Sr$_1$Cu$_3$O$_x$ was defined by using the Meissner effect. At low temperature a deviation from paramagnetic behaviour is observed. The hysteresis loops obtained at lower temperatures undoubtly testify to the presence of a superconductive phase in the sample. However, the part of the superconductive phase in the Sn$_1$Ba$_1$Sr$_1$Cu$_3$O$_x$ ceramic turned out to be small, less than 2%, which agrees with the estimation from magnetic data. In order to increase the content of the superconductive phase two-valent cations Ba, Sr were partially substituted by univalent (K) and three-valent ones (Y). Two samples were obtained: Sn$_{1-x}$Ba$_x$Sr$_{1-x}$Y$_{1-x}$Cu$_3$O$_x$ and Sn$_{1-x}$Ba$_x$Sr$_{1-x}$Y$_{1-x}$Cu$_3$O$_x$. The former is a typical paramagnet without any anomaly down to 4.2K. The latter has shown the magnetic and electric properties undoubtly indicating the presence of a superconductivity phase with the onset temperature $T_c \approx 55K$. The superconductive properties of the sample do not seem to be caused by the phase YBaSrCu$_3$O$_7$ /3/. This conclusion follows from the study of the Sn$_2$Sr$_2$Ba$_{0.5}$Y$_{0.5}$Cu$_3$O$_x$ and Sn$_2$Ba$_2$Sr$_1$Y$_{0.5}$Cu$_3$O$_x$ samples that were synthesized by analogy with the recent communications on superconductivity in Pb$_2$Sr$_2$(Y, Ca)$_1$Cu$_2$O$_8$ /4, 5/. One may expect equal probability of the YBaSrCu$_3$O$_7$ content for both samples, however their electrical properties are quite different. The compound Sn$_2$Sr$_2$Ba$_{0.5}$Y$_{0.5}$Cu$_3$O$_x$ is a good dielectric while Sn$_2$Ba$_2$Sr$_1$Y$_{0.5}$Cu$_3$O$_x$ has clearly expressed superconductive properties /6/. The magnetic moment was measured in an external field $H = 100$ Oe. At $T < 86K$ the sample exhibits a clearly defined diamagnetic behaviour characteristic of superconductors. At these temperatures the hysteresis loop has the form typical of high-$T_c$ superconductors. The amount of the superconductive phase in this sample, as a magnetic estimation in powder, is $\sim 15\%$ of the volume of the sample.
A comparative analysis of the X-ray powder diagrams leads us to believe that the main motive of the $Y_1Ba_2Cu_3O_7$ structure is preserved in the structure of $Sn_2Ba_2Sr_0.5Y_{0.5}Cu_3O_7$. The unit cell parameters are: $a = 4.1\ \text{Å}$, $c = 12.4\ \text{Å}$ (or multiple).

We have also used the same procedure for $Sn_1Ba_2Sr_{0.5}Y_{0.5}Cu_3O_7$. The sample is a typical paramagnet without any anomaly down to 4.2 K.

The presence of superconductivity in the system based on tin allows us to suggest that other cations, besides the well-known Bi, Tl, Pb, having the lone electron pair effect, should also form superconductive compounds. If we limit ourselves to consideration of copper-containing oxides, we may suppose that definite alkali-earth ions (or their combination) would suit for each of the ions: Hg, Sb, In, ... in order to form a superconductive phase.

References