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\(_2\)Ba\(_4\)Sr\(_4\)Cu\(_{3}\)O\(_x\), Sn\(_2\)Ba\(_4\)Ca\(_1\)Cu\(_3\)O\(_x\), Sn\(_2\)Ba\(_4\)Mg\(_1\)Cu\(_3\)O\(_x\), Sn\(_2\)Sr\(_4\)Ca\(_1\)Cu\(_3\)O\(_x\), Sn\(_2\)Sr\(_4\)Mg\(_1\)Cu\(_3\)O\(_x\), Sn\(_2\)Sr\(_4\)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 an air atmosphere.

Among the synthesized compounds only Sn\(_2\)Ba\(_4\)Sr\(_4\)Cu\(_{3}\)O\(_x\) showed remarkable conductivity (\(\rho \sim 10 \text{ Ohm}\cdot\text{cm}\)). Other compounds were practically dielectrics (\(\rho > 1000 \text{ Ohm}\cdot\text{cm}\)). Presence of a possible superconductivity in Sn\(_2\)Ba\(_4\)Sr\(_4\)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\(_2\)Ba\(_4\)Sr\(_4\)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\(_2\)Ba\(_{0.7}\)Sr\(_{0.3}\)K\(_{0.7}\)Cu\(_{3}\)O\(_x\) and Sn\(_2\)Ba\(_{0.7}\)Sr\(_{0.3}\)Y\(_{0.7}\)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 superconductive phase with the onset temperature \(T_c \approx 55\text{K}\). 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\(_{0.5}\)Ca\(_{0.5}\)Cu\(_3\)O\(_x\) and Sn\(_2\)Ba\(_{0.5}\)Sr\(_{0.5}\)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\(_3\)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\(_{0.5}\)Y\(_{0.5}\)Cu\(_3\)O\(_x\) has clearly expressed superconductive properties 76%. The magnetic moment was measured in an external field \(H = 100 \text{ Oe}\). At \(T < 86\text{K}\) 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 $Sn_2Ba_2Sr_0.5Y_{0.5}Cu_3O_x$. 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 $Sn_1Ba_2Sr_0.5Y_{0.5}Cu_3O_x$. 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