# Cathodoluminescence in a high-temperature superconductor Y-Ba-Cu-O

V. N. Andreev, B. P. Zakharchenya, S. E. Nikitin, F. A. Chudnovskiĭ, E. B. Shadrin, and É. M. Sher
*A. F. Ioffe Physicotechnical Institute, Academy of Sciences of the USSR, Leningrad*

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Cathodoluminescence initiated by a superconducting phase transition at 105 K was detected in the ceramic Y-Ba-Cu-O.

In the present letter we report the observation and study of cathodoluminescence initiated by a superconducting phase transition in ceramic samples based on Y-Ba-Cu-O.

The ceramic samples were synthesized in the form of pellets 8 mm in diameter and 2 mm thick. The samples were annealed at a temperature of 1000 °C in a porcelain crucible for 4 h. The cathodoluminescence was studied using a freshly cleaved surface of a ceramic sample in order to prevent its contamination and to eliminate spurious luminescent signals. The luminescence was pumped by an electron beam with an energy 6–7 keV and a current density up to 300 $\mu$A per cm$^2$. We studied samples of the composition $YBa_2Cu_3O_7$ (1-2-3) and multiphase samples of the composition $Y_{1.2}Ba_{0.8}CuO_{4-\delta}$. We observed the following effects in these samples.

No cathodoluminescence was observed in samples of the compostion 1-2-3, whose Meissner effect amounted to 80–100% relative to lead. The multiphase samples in which the Meissner effect amounted to 7% relative to lead exhibited, even at room temperature, a blue cathodoluminescence in the form of spots covering about two-thirds of the surface area of the cleaved plane (Fig. 1).

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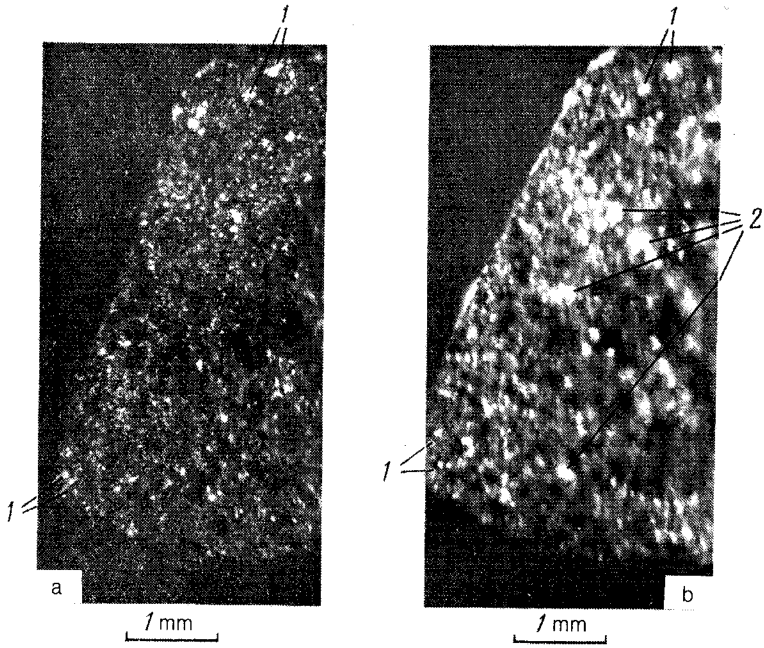


FIG. 1. Cleaved plane of a superconducting ceramic which luminescence as a result of exposure to an electron beam. a—At 300 K; b—at 93 K; 1—blue luminescence; 2—red luminescence.

Upon lowering the sample's temperature to 105 K, the luminescence intensity increased by approximately an order of magnitude. At the same time, small regions (about 0.2 mm in diameter) of red luminescence, whose intensity and number increased as the temperature was lowered to 93 K, appeared in the dark spaces between the blue luminescence spots. The pattern then became stabilized.

If the experimental procedure is changed, specifically, if cooling precedes electron bombardment, the red luminescence reaches a full intensity (at 80 K) about 10 s after the electron beam is applied, whereas the blue luminescence increases instantaneously. Neither luminescence in this case exhibits an appreciable afterglow.

The emission spectra of the tested multiphase samples (Fig. 2) contain broad peaks whose positions match the centers of mass of the characteristic groups of lines which are present in the spectra of the cathodoluminescence of free yttrium oxide and in the spectrum of the initial mixture which is used in synthesizing a superconducting ceramic. The distinguishing feature of these spectra is the fact that, in addition to a strong broadening of the peaks, which occurs after the ceramic is synthesized, the peaks acquire an unusual temperature dependence. At 300 K, for example, the spectrum contains a blue band (4000 Å) but has no peaks in its yellow region (5700 Å) and red region (6400 Å), which are characteristic of yttrium oxide and the initial mixture. As the temperature is lowered, the cathodoluminescence spectra acquire a

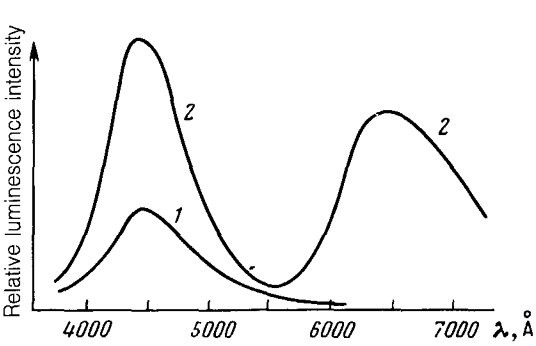


FIG. 2. Cathodoluminescence spectra of superconducting ceramic samples. 1—At 300 K; 2—at 93 K.

pronounced peak in the 6400-Å band. This band intensifies at 105 K, while retaining the 4400-Å blue band, with virtually no emission in the yellow region, which is the most characteristic region for the cathodoluminescence spectra of $Y_2O_3$ both in the low-temperature region and the high-temperature region.

A study of the temperature dependence of the magnetic susceptibility of our samples showed that this dependence has structural features at temperatures 90–105 K (Fig. 3) (this study also showed the presence of some paramagnetism, which was particularly noticeable at 105 K). These observations correlate with the temperature dependence of cathodoluminescence.

The x-ray diffraction study of the cleaved plane of the multiphase ceramic samples showed that they have free yttrium oxide and two unidentified *X* and *Y* phases, in addition to a well-developed 1-2-3 phase.

The intensification of the secondary electron emission of ceramic samples near the temperature of the superconducting transition, which was observed in Ref. 1, also manifested itself in the form of small spots which were randomly distributed on the sample's surface. This observation is consistent with our results, since the cathodoluminescence centers are excited, according to the generally accepted ideas, by the secondary electrons.[2] The excitation of secondary electrons, on the other hand, is particularly effective in the case of the bombardment of a very rough surface[3] which forms on a superconducting ceramic sample.

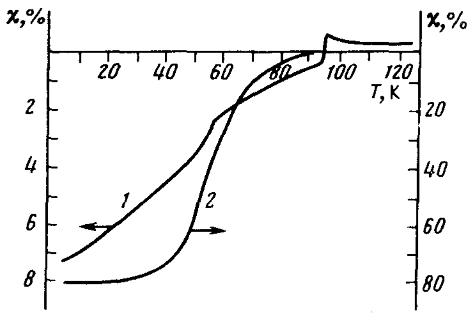


FIG. 3. Temperature dependence of the magnetic susceptibility. 1—Multiphase sample; 2—sample of the 1-2-3 composition.

The characteristic features which we have identified lead us to assume that the following factors are responsible for the excitation of cathodoluminescence.

The electron beam bombards the cleaved ceramic plane which is a surface with randomly distributed crystallites. The bombardment therefore occurs at various angles, which greatly increases the number of reflected and secondary electrons. The dielectric yttrium oxide crystals, which are embedded in the superconducting Y-Ba-Cu-O matrix, in this case play the role of luminescence centers. If we assume that the luminescence originates primarily from the regions where the dielectric phase comes in contact with the superconducting phase, the luminescence parameters can probably be controlled by the superconducting phase by basically changing the nature in which the energy migrates across the contact boundary during the superconducting phase transition. Changes in the cathodoluminescence spectrum thus may indicate the onset of a transition to the superconducting state.

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[2]A. V. Moskvin, Cathodoluminescence, Parts 1 and 2, Moscow-Leningrad, 1948–1949, p. 846.
[3]A. R. Shul'man and S. A. Fridrikhov, Study of Solids with Secondary Electrons, Nauka, Moscow, 1977, p. 552.

Translated by S. J. Amoretty