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Acoustic emission from BiSrCaCuO superconducting samples

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Abstract

The aim of the paper was to show if the acoustic emission (AE) signals from BiSrCaCuO ceramic superconductors appear during normal state–superconductivity transition. These AE signals were previously observed from YBaCuO-type superconducting materials. The BiSrCaCuO samples were prepared and characterised. The resistance–temperature and current–voltage characteristics of these samples were measured. The critical temperature and critical current density were estimated. AE was measured from samples with and without current flow. The AE signals during sample temperature rise were observed at temperature near the critical value.

Keywords: Acoustic emission; Superconductor; BiSrCaCuO

1. Introduction

The acoustic emission (AE) method is recently widely used in many kinds of research. It is a very convenient and simple way of material testing, physical–chemical processes controlling or electrical devices diagnosis. This technique was also successfully implemented in the field of superconductivity. The very first studies were related to the examination of AE generated from NbTi wires and superconducting electromagnets [1,2]. A discovery of high-temperature superconductors (HTS) caused intensive development of AE method towards testing of new kind superconductive materials. In the beginning acoustic emission signals were detected from YBaCuO type HTS during their transition from the superconductive state to the normal state [3,4]. These examinations brought very interesting observations that AE generated from YBaCuO samples is connected with superconductor parameters. Moreover on the contrary to classical superconductors AE activity took place only during temperature transition. AE did not accompany current transition.

Although many interesting results were obtained, the mechanism of AE generation from superconductors is still not well understood. It is difficult to find satisfactory explanation of this phenomenon because the number of publications concerned these issues is limited.

The presented paper deals with another kind of HTS-BiSrCaCuO samples. The aim of this research was to test if AE can be detected also from this superconductor. BiSrCaCuO compounds like

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other HTS materials are recently widely used to build many kind of electric and electronic devices, also in superconductive cables. Therefore positive results of studies could be useful not only for theoretical consideration of the origin of the AE generation in ceramic HTS but also from the practical point of view.

2. Experimental

For the presented study HTS polycrystalline sample was used with nominal composition $Bi_2Sr_2Ca_2Cu_3O_{10}$ that was prepared using conventional mixed oxide solid-state reaction. Appropriate amounts o Bi_2O_3, $SrCO_3$, $CaCO_3$ and CuO were mixed thoroughly and calcinated at 820 °C. During the first heating the mixture was cooled and pulverised several times. After this procedure the powder was pressed to pellets 5 mm thick and about 10 mm in diameter. Finally samples were cut in perpendicular shape and provided with electrical contacts made of silver paste. In the last stage samples were heated for a few days at 840 °C and cooled down to room temperature. The whole synthesis was performed in air atmosphere at normal pressure. For prepared samples fundamentals critical parameters were determined on the basis of measured voltage–current and voltage–temperature characteristics, which are shown in Fig. 1. The transition onset temperature was found to occur at 105 K and the offset one at about 103 K.

AE detection was carried out in experimental setup, which is depicted in Fig. 2. The principles of AE measurement were described in detail in previous papers [3–5]. The most important part of measuring system was AE analyser (DEMA) and PZT transducer with 200 kHz resonant frequency. Such kind of detector was applied because results of earlier examinations showed that the frequency of registered AE impulses from HTS is close to 200 kHz [6]. The tested BiSrCaCuO sample was attached to the PZT transducer with a special holder inside the liquid nitrogen cryostat. In order to avoid attenuation of detected signals a thin layer of silicon grease was spread between superconductor and transducer surfaces.

AE was examined during the temperature transition of the sample without current flow or when current was passing through the sample but with a value much less than the critical one. All measurements were carried out in zero external magnetic field. The temperature of the sample was monitored by means of copper-constantan thermocouple, which was placed near the superconductor and PZT detector surfaces. Measurements of AE signals were taken at temperature rise of about 3 K/min. in the temperature range from 77 to 120 K.

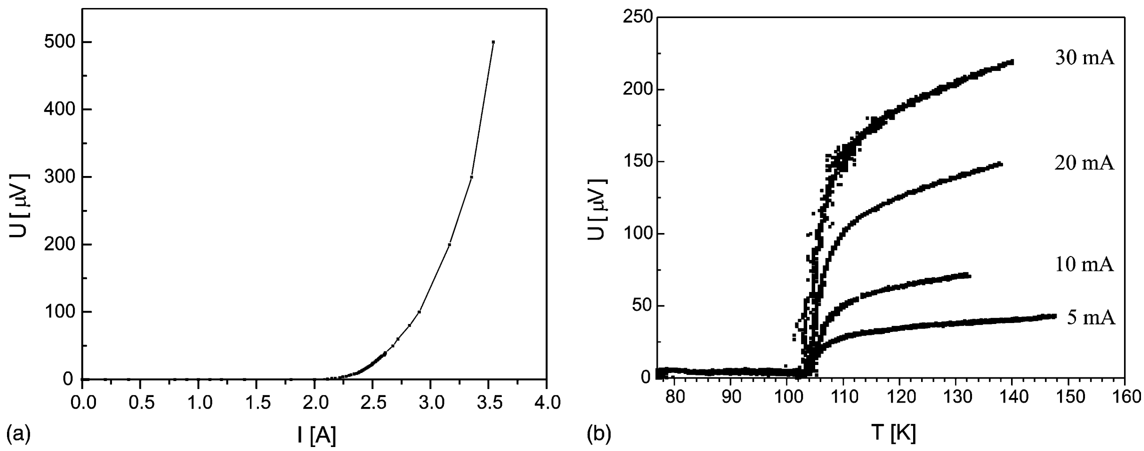

Fig. 1. Voltage–current (a) and voltage–temperature (b) characteristics for tested $Bi_2Sr_2Ca_2Cu_3O_{10}$ sample.

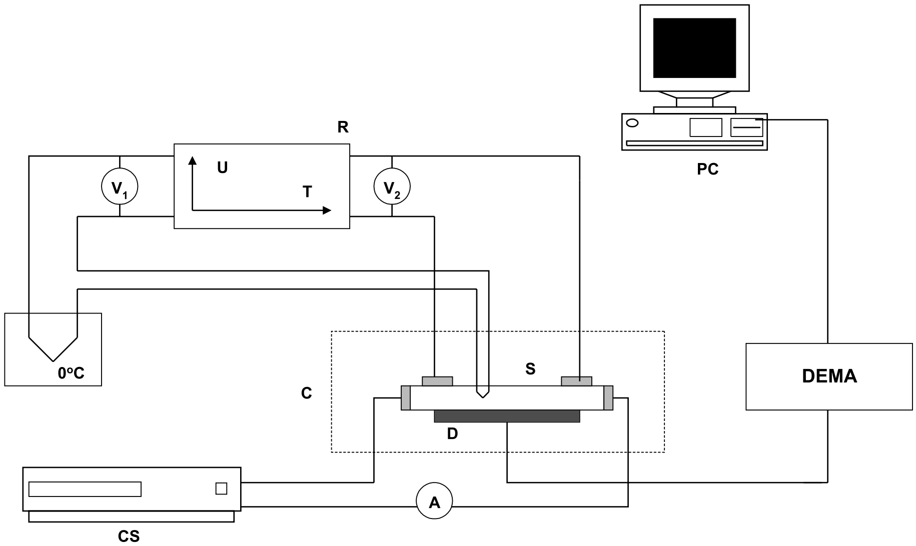

Fig. 2. Block diagram of measuring system. DEMA—AE analyser; D—detector; S—HTS; C—cryostat; CS—current supply; R—register; V_1—millivoltmeter for temperature measurement; V_2—microvoltmeter for voltage drop of superconductor sample measurement.

The applied AE analyser permitted measurement of various AE parameters. In the experiment AE rate was registered. The AE rate is defined as a number of signal amplitudes whose values exceed the given discrimination threshold during a unit count period (in the experiment it was 0.1 s).

3. Results

The results of AE measurements from $Bi_2Sr_2Ca_2Cu_3O_{10}$ sample are presented in Figs. 3 and 4. The AE rate shown in Fig. 3 was registered in the non-current sate. Acoustic emission illustrated

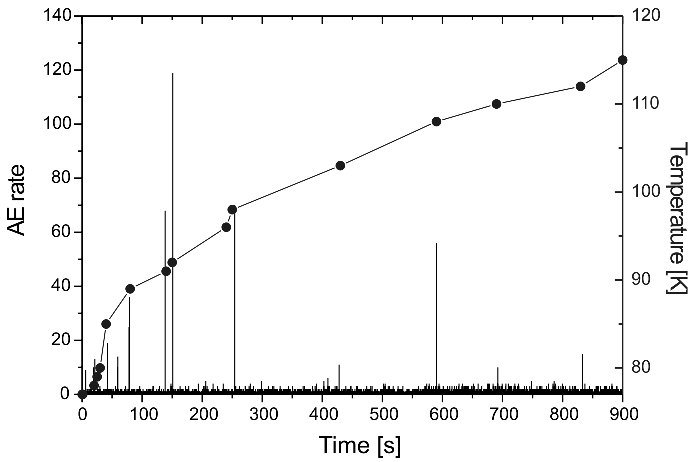

Fig. 3. AE from $Bi_2Sr_2Ca_2Cu_3O_{10}$ sample without current flow. Discrimination level 0.7 V, signal amplification 50 dB, PZT detector frequency 200 kHz.

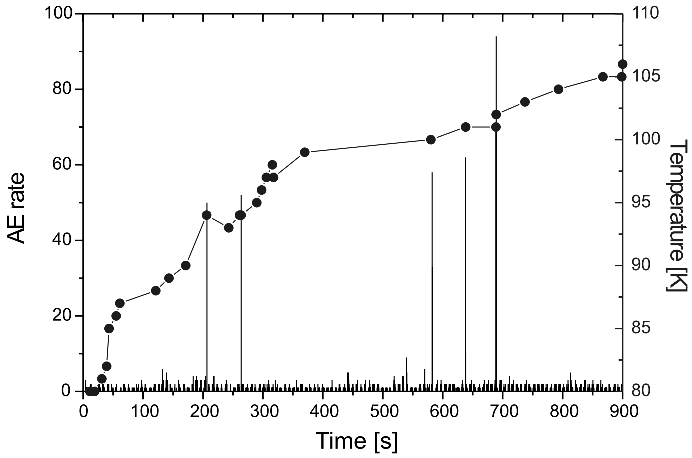

Fig. 4. AE from $Bi_2Sr_2Ca_2Cu_3O_{10}$ sample during current flow ($I = 30$ mA). Discrimination level 0.7 V, signal amplification 50 dB, PZT detector frequency 200 kHz.

in Fig. 4 corresponds to the case when small current was passing through the sample. In both cases the same signal amplification and discrimination level were applied.

4. Discussion and conclusions

The obtained results indicate that AE signals occur during temperature transition from superconductive to the normal state of $Bi_2Sr_2Ca_2Cu_3O_{10}$ sample. The AE activity was similar to that observed for other HTS like YBaCuO superconductors. For all tested HTS samples acoustic emission signals appeared only during temperature transition, before superconductor reach the normal state, but no AE was observed under influence of current flow exceeding critical value of tested sample at fixed temperature.

In Figs. 3 and 4 two groups of pulses can be observed at about 90 and 105 K. It is in a good agreement with multiphase character of BiSrCaCuO superconducting materials with critical temperatures 40, 80 and 110 K. The superconducting properties could be improved by Pb and Sb addition.

Comparing Figs. 3 and 4 one can notice that AE distribution is slightly different. In the case of non-current-state AE impulses are closer to each other, whereas AE signals measured during the temperature rise with small current passing through the sample are broadened and form two main groups.

Acknowledgements

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