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THE DEGRADATION PROBLEMS IN HTc Bi:2223 SUPERCONDUCTING TAPES

ABSTRACT *Continuous progress in the superconducting wires technology is dependent on the critical current enhancement of the high temperature oxide superconductors. The superconducting wires are however strongly influenced by the degradation effects. The present paper describes performed experimental investigations, of the degradation processes influence on the critical current of the BiSrCaCuO/Ag high temperature superconducting tapes.*

Keywords: *superconductivity, superconducting tapes, degradation effects, HTc Bi:2223 tapes*

1. INTRODUCTION

High temperature oxide superconductors are very promising materials for application in electric devices. Great progress has been achieved in respect of construction of new superconducting wires of the first generation based on

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BiSrCaCuO ceramics, while now much of the efforts is also devoted to the tapes of the second generation which are prepared using other representatives of the HTc ceramics of the composition YBaCuO. One of the technological problems of the production of these wires lies in achievement of tapes with critical currents characterized by large resistance to degradation effects (it is against ageing processes, temperature and external magnetic field variation [1]). The results of measurements the magnetic field dependence of the critical current for the BiSCCO tape is shown in Fig. 1. The decrease in the critical current with magnetic field is observed here. Problem of the technology of these tapes is therefore to reach their stable work. The present paper is devoted to an analysis of this subject

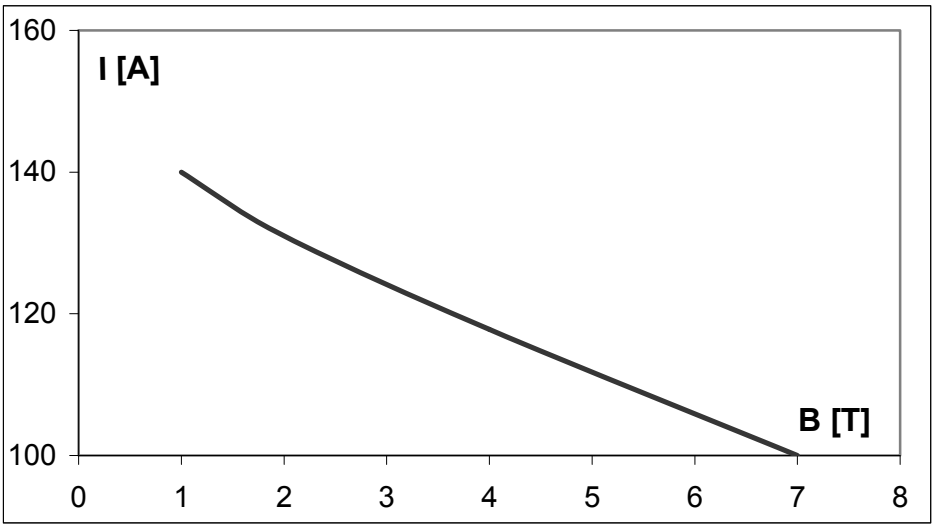

Fig. 1. Magnetic field dependence of the critical current of the HTc tape in liquid helium temperature

2. EXPERIMENTAL PROCEDURE

The critical current measurements were performed in the Bitter type electromagnet shown in Fig. 2. This water cooled electromagnet was constructed of copper pancake type plates joined electrically in the helical way and produced the magnetic field up to 15 T. The critical current measurements were performed by four probe technique using the sample-holder shown in the Fig. 3. The resistive criterion of the 1 μV/cm was applied when determining the critical current.

Fig. 2. View of the water cooled Bitter type electromagnet

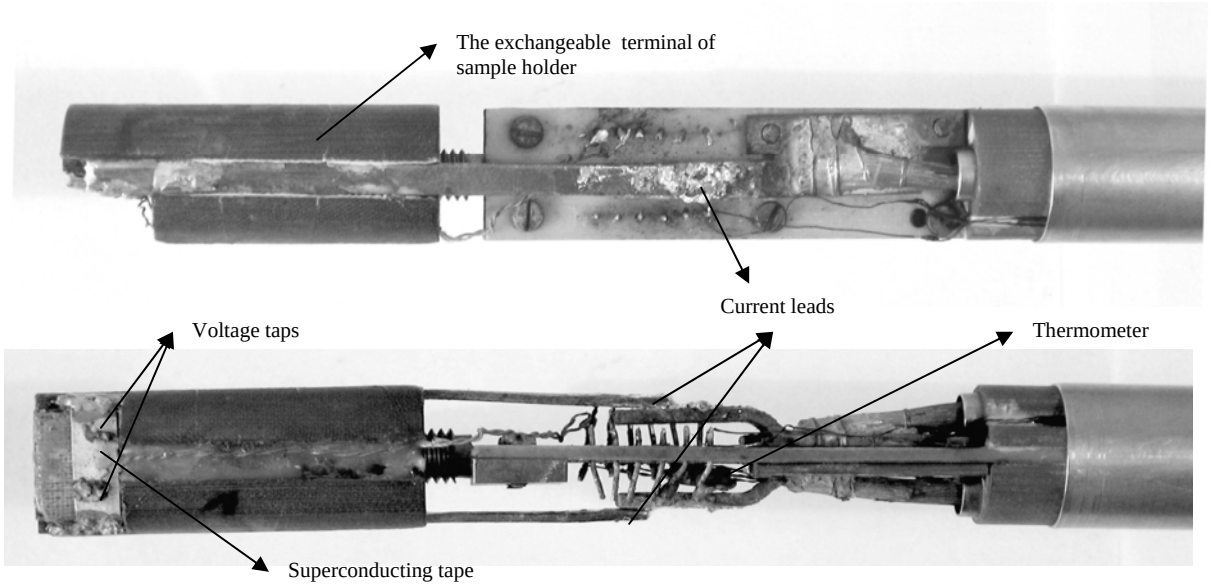

Fig. 3. View of the experimental sample holder for current-voltage characteristics measurements, with the mounted superconducting tape Bi-2223

The magnetic hysteresis measurements were performed in the superconducting magnet using the method of the vibrating sample magnetometer (VSM). The sample was mounted in the cryostat and cooled by the cryogenic bath – liquid nitrogen or helium.

3. THE DEGRADATION PROCESSES IN THE BSCCO TAPES

The stability is one of the parameters characterizing the superconducting materials and devices. According to recently elaborated international standard [2] this parameter describes the method of the maintenance the superconducting properties of the device despite of the existence disturbances of the electromagnetic, thermal and mechanical nature. The stabilization is described by the term 815-06-18 of the International Electrotechnical Vocabulary Part 815: Superconductivity, PN-IEC 60050-815. With the stability problems are associated the ageing processes, which influence the critical parameters of the superconducting tapes too, as well as the processes of the multiple cooling of these tapes, which even in more rapid way lead to the degradation effects.

The measurements of the critical current of superconducting tapes have been performed in order to analyze the above effects.

Figure 4 presents the result of the measurements of the critical current of the Bi-2223 tape in the temperature of liquid nitrogen. While comparing the results of the Figs. 1 and 4 it can be stated that much stronger decrease of the critical current with magnetic field is observed for enhanced temperature. The critical current falls down almost to zero at magnetic field equal to about 6 T at a temperature of 77 K, while at 4,2 K the critical current decreased only on about 30 % for the same conditions. For comparison in the Fig. 5 is shown the magnetic field dependence of the critical current measured on the tape cooled to liquid nitrogen temperature three times. Not too large changes are observed in that case comparing Figs. 4 and 5, which indicates to good stability properties of tape in this temperature, while generally critical current strongly depends on the history of the cooling processes as well as on the direction of magnetic field versus the tape surface too. Results of the critical current measurements are given performed for the perpendicular geometry of the magnetic field and current only. The results of the investigations the influence of the number of the cooling cycles of the Bi-2223 tape, on the critical current magnetic field

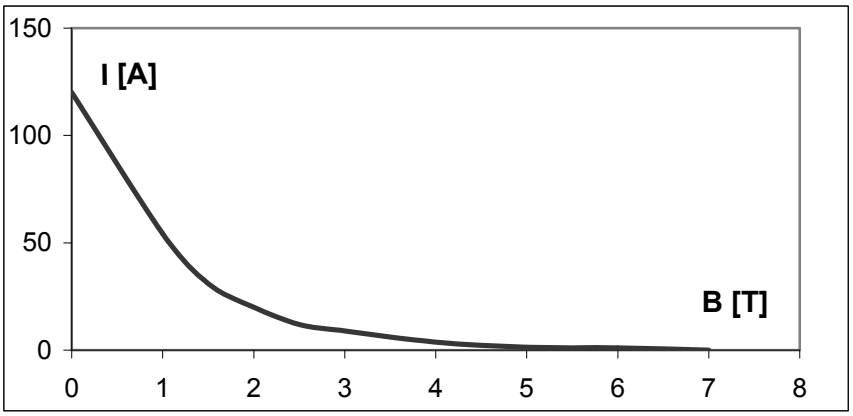

Fig. 4. The critical current magnetic field dependenceof the Bi-2223 tape in the liquid nitrogen temperature

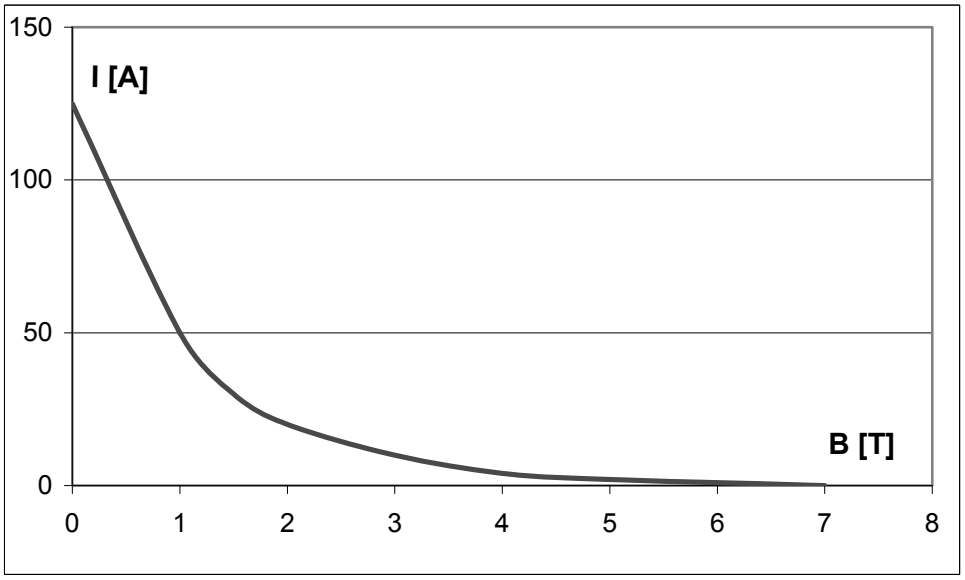

Fig. 5. The critical current magnetic field dependence of the Bi-2223 for third cycle of cooling the sample in the liquid nitrogen

dependence are collected in Figures 6-7, for cooling media liquid helium or nitrogen bath respectively. Independently of the sample position the critical current decreases with the value of the cooling cycles, which indicates to the existence of the degradation effects much stronger in the liquid helium. It is a new result suggesting that tapes retain their superconducting properties in more stable form in higher temperatures, as follows from comparison of Figs. 6 and 7. The critical current almost disappears in tapes cooled in helium bath three times, while for cooling in liquid nitrogen bath critical current does not vanish

even after a 6-fold cooling process. These effects have technical importance and may be connected with the deformation of the tape introduced in the cooling process and creation then of mechanical defects as dislocations and micro-cracks, which deform the structure of the ultra-thin filaments, in the simplest case leading to the decrease in their cross-section.

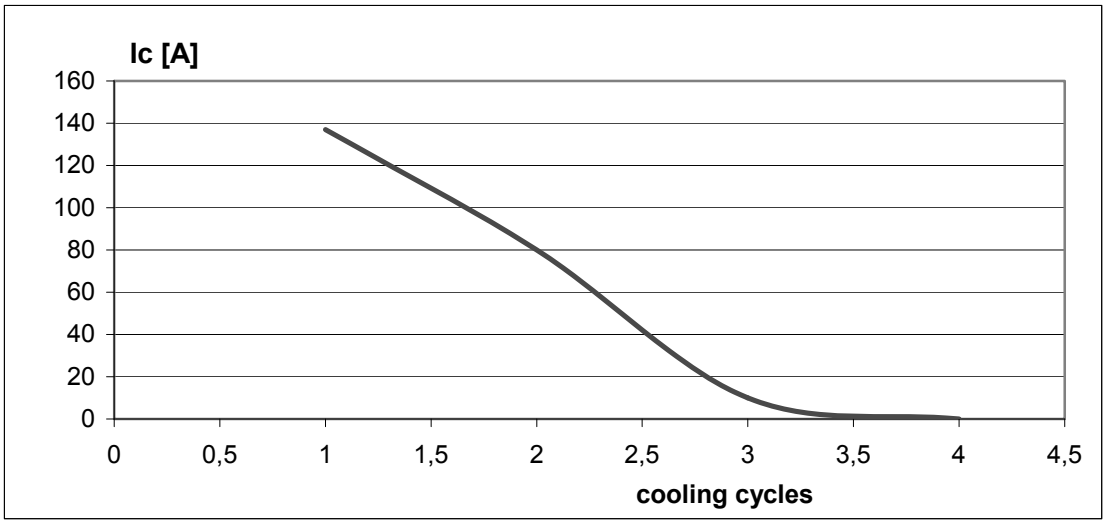

Fig. 6. Critical current of the Bi-2223 tape versus the number of cooling cycles into liquid helium bath

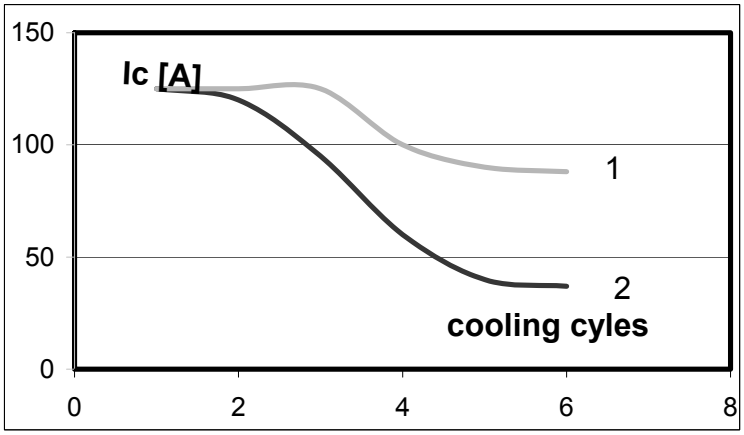

Fig. 7. Critical current of the Bi-2223 tape versus the number of cooling cycles into liquid nitrogen bath, for two pieces of tape marked by numbers (1 and 2)

The above statement is also confirmed by the investigations of the influence the bending strain on the critical current magnetic field dependence of the Bi-2223 tapes. The results are shown in Fig. 8. The upper curve gives the result measured at liquid nitrogen temperature for a straight sample, while with decreasing bending radius critical current falls down too. One of the reasons of the decrease in the critical current of high temperature superconducting tapes is connected with the mechanical destruction arising during mounting the sample and for instance winding the superconducting coils. Then the bending strain appears, which is the reason of various mechanical deformations leading to micro-cracks appearance as well as of the internal tensions. The experimental

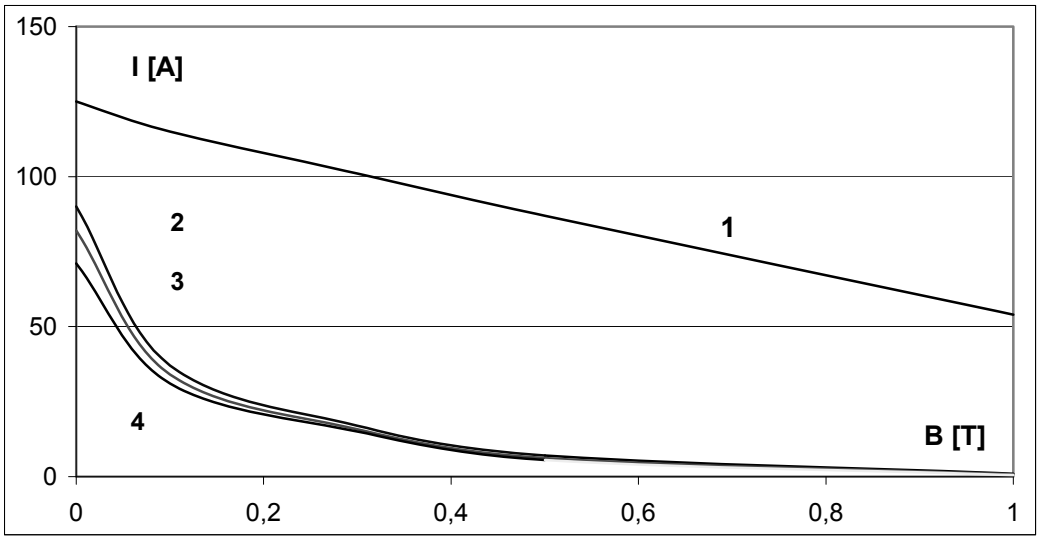

Fig. 8. The influence of the bending strain on the critical current – magnetic field dependence of the superconducting Bi-2223 tape in temperature 77 K: 1 – straight sample, 2 – tape bent to the diameter of 22 mm, 3 - tape bent to the diameter of 19 mm, 4 - tape bent to the diameter of 16 mm

results of the influence of this effect on the critical current magnetic field dependence shown in the Fig. 8 really indicates that the critical current strongly decreases with the bending strain, what is in accordance with other experimental data [3].

In the next figure are shown photographs of the two pieces of the HTc tapes one straight one used for critical current magnetic field dependence measurements and second one after the measurements performed for investigations bending process. The structure of second sample is damaged. It can be connected among other with the penetration of liquid nitrogen inside the tape structure and then as result of warming process gaseous nitrogen bubbles are formed, which lead to destruction of the filaments and matrix. Other

important observed experimentally effect which influences the critical current is the speed of the warming process between liquid nitrogen and room temperatures.

Fig. 9. Photograph of two pieces of HTc tapes: (up) deformed by applying bending strain and performing then the measurements, (down) straight nondeformed sample

For higher speeds of warm up process the measured critical current was less destroyed. This effect requires still further careful observations with the aim to find it's physical interpretation.

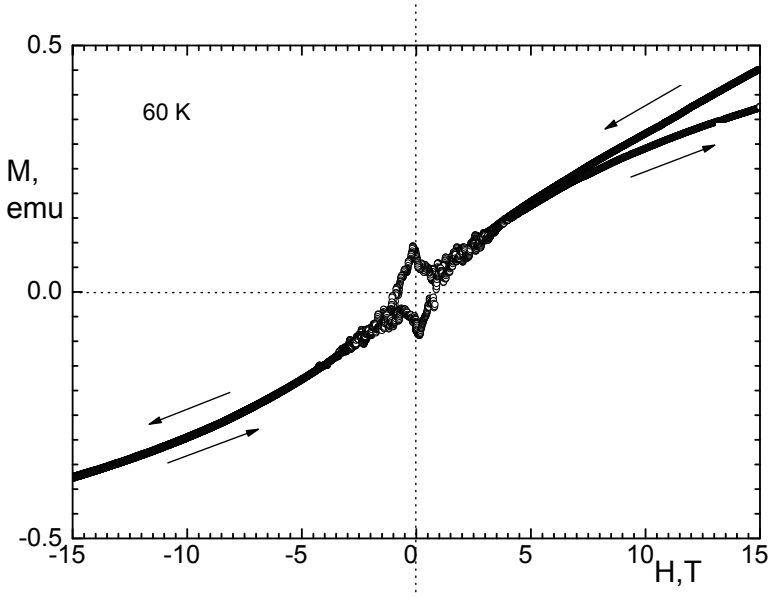

Fig. 10. The magnetic hysteresis curve of the Bi-2223 tape at temperature of 60 K. Arrows indicate the direction of magnetic field variation

Figs. 10-12 present the results of magnetic hysteresis measurements, which are also a useful tool for determining the critical current. Observed large hysteresis is proportional to the critical current values. Due to the ceramic structure of the HTc superconductors, it is however not so easy to find direct quantitative correlation between the results of measurements of critical current obtained in resistive way presented previously and by the magnetization method. The ceramic structure of HTc tapes leads to existence of intergrain and intragrain currents, which can cause the differences in the results of critical current values obtained by various methods. Observed transition of the magnetization onto the paramagnetic side indicates the existence of the magnetic impurities in the tape structure.

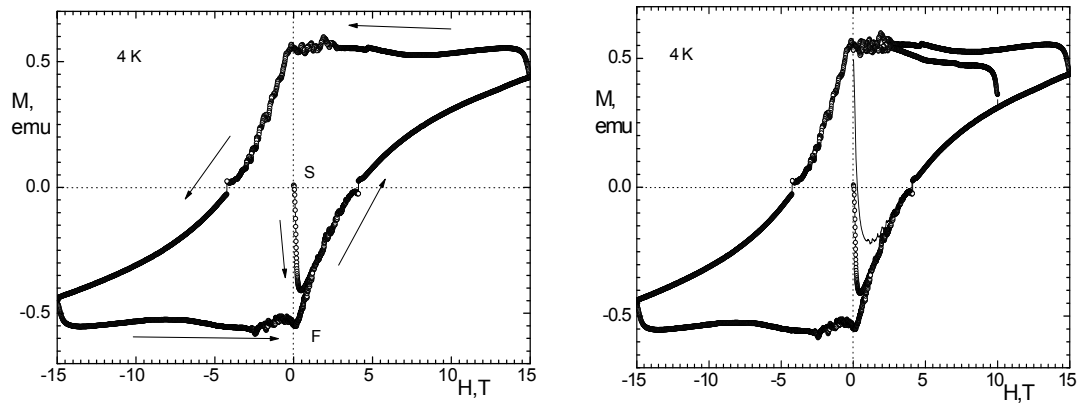

Fig. 11. The magnetic hysteresis curves of the Bi-2223 tape at the temperature of 4 K

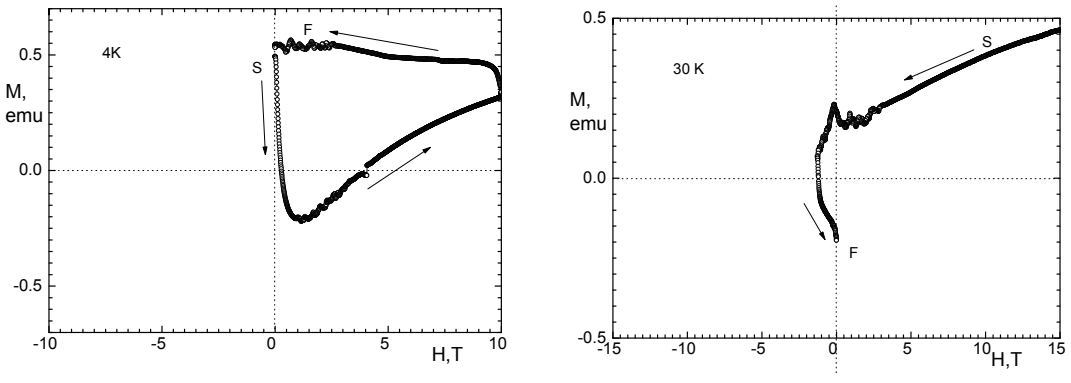

Fig. 12. Examples of measured pieces of the large hysteresis loops of the magnetization curves of the HTc superconducting tape

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PROBLEMY DEGRADACJI W TAŚMACH NADPRZEWODNIKOWYCH HTc Bi:2223

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STRESZCZENIE *Postęp w technologii przewodów z nadprzewodników wysokotemperaturowych zależy od dalszego podwyższenia wartości prądu krytycznego i osiągnięcia jego stabilności. Przewody nadprzewodnikowe podlegają efektom degradacji. W artykule opisano wykonane badania doświadczalne wpływu procesu degradacji na prąd krytyczny taśmy z nadprzewodnika wysokotemperaturowego BiSrCaCuO/Ag*