Progress in Superconductivity Vol.3 No.1 pp99-103 31 October 2001

Interlaboratory Comparison of Critical Current Measurements on Ag-sheathed Bi-2223 tapes

Kyu Won Lee[a], Gi-Youl Han[a,b]
[a] *Korea Research Institute of Standards and Science, Taejon, Korea*
[b] *Chungbuk National University, Cheongju, Chungbuk, Korea*
Received 20 August, 2001

Bi-2223선재의 임계전류 측정기술 비교

이규원[a], 한기열[a,b]

Abstract

We have conducted two runs of interlaboratory comparison on Ag-sheathed Bi-2223 tapes to evaluate the level of measurement techniques for the critical current measurement. Two classes of specimens were prepared for parallel and serial routings and sent to four participating laboratories. The critical currents of specimens were measured at 77 K in zero magnetic field. In the first comparison, we used twenty different Bi-2223 tapes as specimens for comparison and participating laboratories measured the specimens using their own instruments and procedures. As a result, the scattering of data on the first comparison showed −3.0% to +12.2% for the parallel routing and −0.7% to +15.1% for the serial routing. Major sources of these variations were attributed to different measurement techniques. Thus, the second comparison of measurement was done on the same specimens under specified measurement conditions, particularly in terms of cooling procedure and sweep rate of the test current. The variations for the second comparison were decreased −3.1% to +3.2% for the parallel routing and −1.8% to +7.7% for the serial routing.

keywords : Ag-sheathed Bi-2223 tape, critical current measurement, interlaboratory comparison, I-V curve.

I. Introduction

Since the discovery of the high-T_c superconductor, many laboratories have developed the fabrication technology of Ag–sheathed Bi-2223 tapes and their applications for magnets or electric power fields.

The critical current of the Ag-sheathed Bi-2223 superconducting tape is the most important parameter as well as the critical temperature for the practical application of the high-T_c superconductor. However, most research institutes or universities have used different instruments and methods in measuring the critical current of Bi-2223 tape.

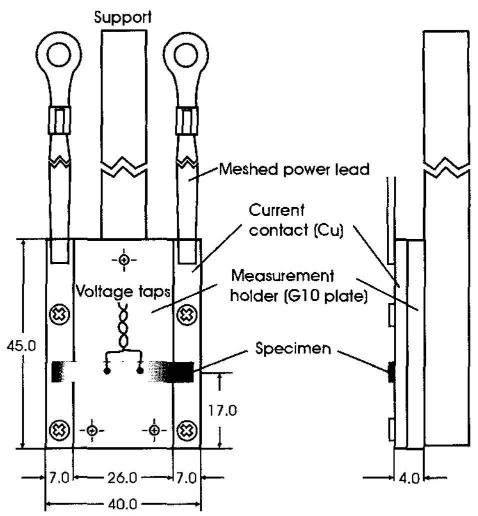
It is necessary that critical current measurement technologies of existing laboratories are compared with each other in order to establish a standard procedure of measurement on Ag-sheathed Bi-2223 tapes. An interlaboratory comparison is an essential procedure of the research needed to provide a measurement standard of the critical current. A comparison can be used to evaluate the accuracy of

*corresponding author. Fax: +82 42 868 5234
e-mail: kwlee@kriss.re.kr

existing laboratory and provide a technical basis for a future standard.

Many foreign laboratories have conducted interlaboratory comparison for such purpose. NIST of USA have conducted six US laboratories on the Bi-2223 tapes[1]. Similar comparisons had performed independently in Japan[2] and other countries[3]. In many cases, the variations in their first comparisons showed unacceptably large, thus, the second comparisons were conducted with additional controls that lead to acceptable variations. The variation of the first comparison, which was 10% to 14%, was reduced to 3% to 4% in the second comparison[1].

We have conducted two runs of interlaboratory comparison to evaluate the level of the measurement technique and provide a technical basis for a national measurement standard. In this paper, we report the comparison result with four participating laboratories using Ag-sheathed Bi-2223 tapes.



(Front view) (side view)

Fig. 1. Construction of sample holder.

II. Test Specimens and Comparison Procedure

For the interlabroratory comparison of the critical current measurement, two classes of Ag-sheathed 2223 tapes from different manufacturers, which we describes X(19 filaments) and Y(61 filaments), were prepared to isolate dependence of the test specimens. The thermal expansion coefficients of G10 and SST 304 substrates are known to be similar to that of Ag-sheathed Bi-2223 tape[4]. The Ag-sheathed Bi-2223 tapes were premounted to G10 and SST 304 substrates, as shown in Fig. 1, to protect the specimens from deformation during cooling at 77 K and degradation during transportation between laboratories.

Both current contacts on a substrate were made of 2 mm thick-copper block to reduce contact resistance and flow a few tens Ampere of test current. Dimension of the substrate was 40 mm × 45 mm and the substrate was attached to a bakelite support of 35 cm-long bar to be immersed into liquid nitrogen. The Ag-sheathed Bi-2223 tapes were quickly soldered to reduce thermal damage using the Pb-Sn alloy.

Test current from a power supply at room temperature to the current contacts at 77 K flowed through two meshed power leads for not twisting during cooling as shown in Fig. 1. The voltage drop of the test specimen between current contacts was measured using two twisted copper wires of 0.1 mm diameter.

For the interlaboratory comparison, total twenty specimens were prepared as shown in Table 1, and two routing methods of the specimen were selected: serial and parallel routings. Four common specimens(SGX, SGY, SSX and SSY) were serial-routed, which means that they were sent from KRISS, measured at each of the participating laboratories in sequence, and then returned to KRISS.

Other sixteen specimens were categorized to four groups for parallel routing. KRISS measured the groups and each of laboratories measured their group(PGX_i, PGY_i, PSX_i and PSY_i), and then returned to KRISS. In the parallel routing, each laboratory measured different group of four specimens. More specified specimen nomenclature was listed in Table 1.

The critical currents of specimens were measured at 77 K in zero magnetic field.

For convenience and consistency, all laboratories adopted an electric field criterion of 1 μV/cm to define their critical current values on the I-V curve . Since KRISS hosted all the comparisons, KRISS used a precision measurement system consisted of a current source, a shunt, and a nanovoltmeter. The system was controlled by a personal computer. We calibrated them before measuring the specimens.

Table1. Nomenclature of the specimens.

Interlaboratory Comparison	Participating Laboratories	Test Specimens	
		G10	SUS304
Serial Routing	All Participating Labs	SGX, SGY	SSX, SSY
Parallel Routing	Lab1	PGX1, PGY1	PSX1, PSY1
	Lab2	PGX2, PGY2	PSX2, PSY2
	Lab3	PGX3, PGY3	PSX3, PSY3
	Lab4	PGX4, PGY4	PSX4, PSY4

When we measured the specimens at KRISS, we slowly cooled the specimens not to be damaged. Fast ramping the test current on the specimen can induce an additional voltage. To yield consistent results, we applied the same ramp rate of 2 A/min.

III. Results and Discussion

A. First interlaboratory comparison

Fig. 2 is the result of the first parallel routing. The x-axis presents the participating laboratories denoted by Lab 1 to Lab 4. The data on the y-axis, measured at participating laboratories, were normalized with respect to the value of KRISS. As shown in Fig. 2, the measurement data are scattered from –3.0% to +12.2%. The data of Lab 1 are approximately 8.0% to 12.2% higher than that of KRISS. Other laboratories show the variations of about –3.0% to +5.8%.

Fig. 3 is the result of the first serial routing. The x-axis shows the sequence in which measurements were made. The specimens were first measured at KRISS, then at the four laboratories in serial, and then remeasured at KRISS.

The normalized critical currents of the four specimens with respect to the KRISS's initial values are plotted on the y-axis. The measurement data are scattered from –0.7% to +15.1% except for SSX's data. In the data of SGX, the measured value of Lab 1 is more than 15% higher than KRISS's initial data. Other three specimens's data measured at Lab1 also show higher values than those of KRISS as shown in the data of parallel routing. The more detailed I-V characteristic curves of SGX specimen were summarized in Fig. 4.

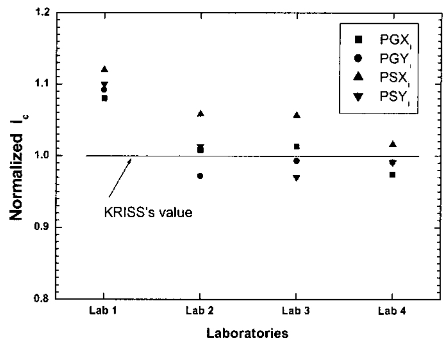


Fig. 2. Results of the first parallel routing.

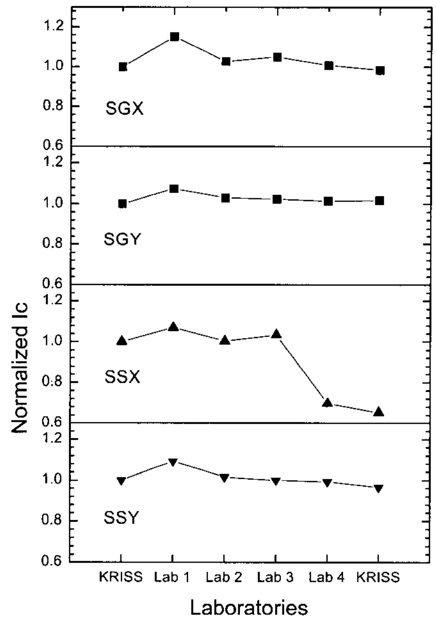


Fig. 3. Results of the first serial routing.

The I-V curve measured at Lab1 is shifted to about 15% higher current while other I-V curves are close together. When we enlarge the I-V curve of Lab 3 in the Fig. 4, an anomaly in the I-V curve can be found as shown in Fig. 5. We thought that Lab 3 had some software problem in measuring the voltage of specimen.

In the Fig. 3, the values of SSX specimen were suddenly dropped after measurement of Lab 3. This was perhaps suspected due to a damage and

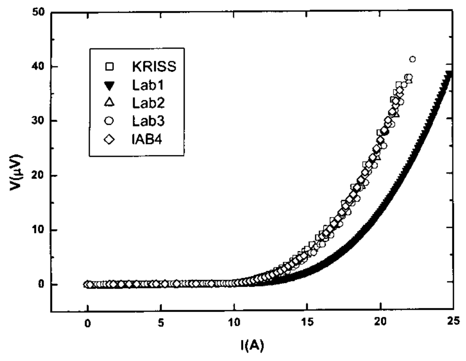


Fig. 4. Summarized I-V curves of SGX specimen for the first serial routing.

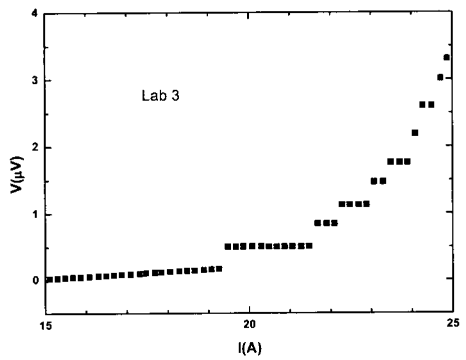


Fig. 5. Some anomaly of I-V curve of SGX specimen measured by Lab 3 during the first serial routing.

degradation during routing or bubbling between Bi-2223 and Ag-sheath .

B. Second interlaboratory comparison

For the first comparison, we did not provide any experimental condition such as cooling rate or current ramp rate and the laboratories did not used a common method. In the second comparison, all of the participating laboratories adopted a common method which was recommended by IEC TC90[4]. For example, specimen should be slowly cooled not to affect damage and ramp rate of test current should be less than 2 A/min and so on. When the laboratories define their critical currents, laboratories should correct the baseline voltage if the I-V curve near critical current showed significant the baseline deviation from zero voltage.

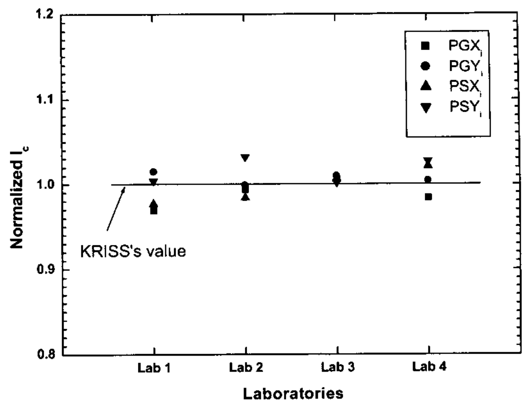


Fig. 6. Results of the second parallel routing.

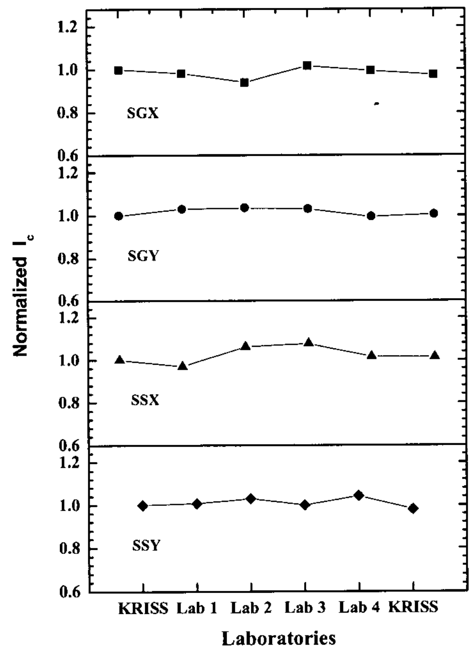


Fig. 7. Results of the second serial routing.

Results of the second comparison through parallel routing are shown in Fig. 6.

The data of the laboratories were also normalized with respect to the value of KRISS measurement. All of the data were plotted between –3.1% and +3.2%. Comparing with the first comparison(-3.0% to +12.2%), scattering of these data wase significantly decreased. Especially, the data of Lab 1 and Lab 3 were shifted to the KRISS's reference value.

Results of the second serial comparison are shown in Fig. 7.

All data are plotted in the range of −1.8% to +7.7% except for the SGX data of Lab 2. The SGX data of Lab 2 was much decreased from +2.7% of the first comparison to −6.0% of the second comparison while KRISS's values did not show any significant variation during both comparisons.

In the case of SSX, the critical current had been dropped during the first comparison. However, the changed value of critical current was fairly kept during the second comparison.

Before the second comparison of each laboratory, we gave notice their anomaly or problem to corresponding laboratories and recommended to use a standard procedure given by IEC TC 90[4]. Lab 1 calibrated their measurement system and Lab 3 revised their software. Some laboratories corrected baseline if there were deviation from zero voltage. The ramp rate of test current was recommended to use 2 A/min.

We speculate that such experimental control and common procedure could contribute better consistency in the second comparison.

For most applications of superconductivity, an acceptable coefficient of variation(the standard deviation divided by the average value) in critical current measurements is known to be 2% to 4%[1]. The coefficients of variation for this second serial comparison were calculated from 1.4% to 3.9%. Our coefficients of variation seem to be fairly good.

IV. Summary

We have conducted a series of interlaboratory comparisons of critical current on Ag-sheathed Bi-2223 tape to evaluate the level of measurement techniques and establish a technical basis for providing a national measurement standard. In the first comparison, scattering of the measurement data were −3.0% to +12.3% for parallel routing and −0.7% to +15.1% for serial routing, respectively.

After the participating laboratories solved their problems and adopted a common procedure for the second comparison, the scattering of the second comparison showed significantly decreased.

From the data of the second serial comparison, calculated coefficients of variation were 1.4% to 3.9%. These values are acceptable for most applications of superconductivity.

Through this interlaboratory comparison, we could lead to improvement of measurement techniques and have an opportunity on disseminating a standard procedure of IEC TC90 for participating laboratories. These results could also contributed to providing an important technical basis for national standard on critical current measurement.

Acknowledgements

The authors thank Drs. S. S. Oh and J. M. Yoo for generously providing us with Bi-2223 specimens for this interlaboratory comparison. We also thank four participating laboratories for sharing much time in measuring the many specimens.

References

[1] J. A. Wiejaczka and L. F. Goodrich, "Interlaboratory comparison on high-temperature superconductor critical-current measurements", J. Res. of NIST, Vol. 102, 29-52, 1997.

[2] K. Itoh, Y. Murakami, M. Yuyama and H. Wada, "VAMAS critical current Round Robin Test on a 2212 BSCCO Ag-sheathed tape", IEEE Trans. on Appl. Supercond, Vol. 5, 544-547, 1995.

[3] C. Hua, "First critical current Round Robin Test on the Ag-sheathed 2223 BSCCO tape at China", Physica C, Vol. 282-287, 1997.

[4] IEC 61788-3 "DC critical current of Ag-sheathed Bi-2212 and Bi-2223 oxide superconductors", 1999.