INTERNATIONAL STANDARD

IEC 61788-3

First edition
2000-12

Superconductivity –

**Part 3:
Critical current measurement –
DC critical current of Ag-sheathed Bi-2212 and Bi-2223 oxide superconductors**

Supraconductivité –

*Partie 3:
Mesure du courant critique –
Courant critique continu des oxydes supraconducteurs Bi-2212 et Bi-2223 avec gaine en argent*

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International Electrotechnical Commission 3, rue de Varembé Geneva, Switzerland
Telefax: +41 22 919 0300 e-mail: inmail@iec.ch IEC web site http://www.iec.ch

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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SUPERCONDUCTIVITY –

**Part 3: Critical current measurement –
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and Bi-2223 oxide superconductors**

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 61788-3 has been prepared by IEC technical committee 90: Superconductivity.

The text of this standard is based on the following documents:

FDIS	Report on voting
90/80/FDIS	90/86/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 3.

Annexes A and B are for information only.

The committee has decided that the contents of this publication will remain unchanged until 2005. At this date, the publication will be

- reconfirmed;
- withdrawn;
- replaced by a revised edition, or
- amended.

A bilingual version of this standard may be issued at a later date.

INTRODUCTION

In 1986 J.G. Bednorz and K.A. Mueller discovered that some Perovskite type Cu-containing oxides show superconductivity at temperatures far above those which metallic superconductors have shown. Since then, extensive R & D work on high-temperature oxide superconductors has been and is being made worldwide, and its application to high-field magnet machines, low-loss power transmission, electronics and many other technologies is in progress [1].[1]

Fabrication technology is essential to the application of high-temperature oxide superconductors. Among high-temperature oxide superconductors developed so far, BiSrCaCu oxide (Bi-2212 and Bi-2223) superconductors have been the most successful at being fabricated into wires and tapes of practical length and superconducting properties. These conductors can be wound into a magnet to generate a magnetic field of several tesla [2]. It has also been shown that Bi-2212 and Bi-2223 conductors can substantially raise the limit of magnetic field generation by a superconducting magnet [3].

In summer 1993, VAMAS-TWA16 started working on the test methods of critical currents in Bi-oxide superconductors. In September 1997, the TWA16 worked out a guideline (VAMAS guideline) on the critical current measurement method for Ag-sheathed Bi-2212 and Bi-2223 oxide superconductors. This pre-standardization work of VAMAS was taken as the base for the IEC standard, described in the present document, on the d.c. critical current test method of Ag-sheathed Bi-2212 and Bi-2223 oxide superconductors.

The test method covered in this International Standard is intended to give an appropriate and agreeable technical base to those engineers working in the field of superconductivity technology.

The critical current of composite superconductors like Ag-sheathed Bi-oxide superconductors depends on many variables. These variables need to be considered in both the testing and the application of these materials. Test conditions such as magnetic field, temperature and relative orientation of the specimen and magnetic field are determined by the particular application. The test configuration may be determined by the particular conductor through certain tolerances. The specific critical current criterion may be determined by the particular application. It may be appropriate to measure a number of test specimens if there are irregularities in testing.

[1] The numbers in brackets refer to the bibliography.

SUPERCONDUCTIVITY –

Part 3: Critical current measurement – DC critical current of Ag-sheathed Bi-2212 and Bi-2223 oxide superconductors

1 Scope

This part of IEC 61788 covers a test method for the determination of the d.c. critical current of short and straight Ag- or Ag alloy-sheathed Bi-2212 and Bi-2223 oxide superconductors that have a monolithic structure and a shape of round wire or flat or square tape containing mono- or multicores of oxides.

This method is intended for use with superconductors that have critical currents less than 500 A and *n*-values larger than 5. The test is carried out with and without applying external magnetic fields. In the test of the tape specimen in magnetic fields, the magnetic fields are parallel or perpendicular to the tape surface. The test specimen is immersed either in a liquid helium bath or a liquid nitrogen bath during testing. Deviations from this test method that are allowed for routine tests and other specific restrictions are given in this standard.

Substantial parts of the test method covered in this standard are in common with, or similar to, those for Nb_3Sn composite superconductors (IEC 61788-2). Special features newly found for oxide superconductors may be classified into two groups. The first group is specific to oxide composite superconductors, including mechanical fragility originating from the presence of weak links, cryogen gas bubble formation, aging degradation, magnetic flux flow and creep, large anisotropy, hysteresis in critical current with magnetic field sweep, etc. The second group is due to the short length of the specimen used in the standard. A critical current measurement on such a specimen may easily pick up different voltage signals due to thermal electromotive force, inductive voltage, thermal noise, current redistribution, specimen motion relative to the holder, etc. Current transfer voltages may be present due to the short distance from a current contact to a voltage tap. Short specimen length may reduce mechanical tolerance against the Lorentz force, for example, by promoting the formation of cryogen gas bubbles within the composite.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 61788. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of IEC 61788 are encouraged to investigate the possibility of applying the most recent edition of the normative document indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60050-815:2000, *International Electrotechnical Vocabulary (IEV) – Part 815: Superconductivity*

IEC 61788-2:1999, *Superconductivity – Part 2: Critical current measurement – DC critical current of* Nb_3Sn *composite superconductors*

3 Terminology

For the purpose of this standard, the definitions given in IEC 60050-815 and the following definitions apply.

3.1

critical current (I_c)

current at which a specified electric field strength (electric field) criterion (E_c) or resistivity criterion (ρ_c) is reached in the specimen at a certain value of a static applied magnetic field at a specified temperature either in a liquid helium bath or a liquid nitrogen bath at a constant pressure. For either E_c or ρ_c, there is a corresponding voltage criterion U_c for a specified sample length.

3.2

Bi-2212 and Bi-2223 oxide superconductors are defined in the chemical formulae as follows:

Bi-2212; $Bi_2Sr_2CaCu_2O_x$ (x = ~ 8),

Bi-2223; $(Bi,Pb)_2Sr_2Ca_2Cu_3O_x$ (x = ~10).

4 Requirements

The critical current of a superconductor shall be measured by applying a direct current (*I*) to the superconductor specimen and then measuring the voltage (*U*) generated along a section of the specimen. The current shall be increased from zero and the voltage-current (*U*-*I*) characteristic generated and recorded.

The target precision of this method is a coefficient of variation (standard deviation divided by the average of the critical current determinations) that is less than 5 % for the measurement at 0 T and near 4,2 K or 77 K.

The use of a common current transfer correction is excluded from this test method. Furthermore, if a current transfer signature is pronounced in the measurement, then the measurement shall be considered invalid.

It is the responsibility of the user of this standard to consult and establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use. Specific precautionary statements are given below.

Hazards exist in this type of measurement. Very large direct currents with very low voltages do not necessarily provide a direct personal hazard, but accidental shorting of the current leads with another conductor, such as tools or transfer lines, can release significant amounts of energy and cause arcs or burns. It is imperative to isolate and protect current leads from shorting. Also the energy stored in the superconducting magnets commonly used for the background magnetic field can cause similar large current and/or voltage pulses or deposit a large amount of thermal energy in the cryogenic systems causing rapid boil-off or even explosive conditions. The use of cryogenic liquids is essential to cool the superconductors, which allows the transition into the superconducting state. Direct contact of skin with cold liquid transfer lines, storage dewars or apparatus components can cause immediate freezing, as can direct contact with a spilled cryogen. It is imperative that safety precautions for handling cryogenic liquids be observed.

5 Apparatus

5.1 Measurement holder material

The measurement holder shall be made from an insulating material or from a conductive non-ferromagnetic material that is either covered or not covered with an insulating layer.

The critical current may inevitably depend on the measurement holder material due to the strain induced by the differential thermal contraction between the specimen and the measurement holder.

The total strain induced in the specimen at the measuring temperature shall be minimized to be within ±0,1 %. If there is an excess strain due to the differential thermal contraction of the specimen and the holder, the critical current shall be noted to be determined under an excess strain state by identification of the holder material.

Suitable measurement holder materials are recommended in A.4.1. Any one of these may be used.

When a conductive material is used without an insulating layer, the leakage current through the holder shall be less than 1 % of the total current when the specimen current is at I_c (see 8.5).

5.2 Measurement holder construction

The holder shall have a flat surface on which a straight specimen can be placed.

The current contact shall be rigidly fastened to the measurement holder to avoid stress concentration in the region of transition between the holder and the current contact. It is important to have no difference in level between the mounting surfaces of the current contacts and the mounting specimen holder.

6 Specimen preparation

6.1 Reaction heat treatment

Reaction heat treatment shall be carried out according to the manufacturer's specification which includes reaction temperature, period and atmosphere, oxygen partial pressure, specimen cooling and warming rates, specimen protection method against mechanical strain, examination of deformation and surface condition of specimen and error limits which must not be exceeded. Temperature variations within the furnace shall be controlled such as not to exceed those limits.

Reaction heat treatment can be skipped when it has already been carried out by the manufacturer.

6.2 Specimen mounting for measurement

After the reaction heat treatment, the ends of the specimen shall be trimmed to suit the measurement holder.

The specimen shall be mounted to the flat surface of the holder and both ends shall be soldered to the current contact blocks (see A.6 for solder material).

For the test in magnetic fields, a low-temperature adhesive (such as epoxy) shall be used to bond the specimen to the measurement holder to reduce specimen motion against the Lorentz force.

The bond shall be strong enough to keep the specimen in place against the Lorentz force, in the case where the applied magnetic field is perpendicular to the specimen surface.

The length of a specimen to be measured shall be defined as follows:

$$L_1 = 2 \times L_2 + L + 2 \times L_3 \geq 5 \times W \quad (1)$$

$$L_2,\ L,\ L_3 \geq W \quad (2)$$

where

L is the distance between the voltage taps;

L_1 is the length of a specimen to be measured;

L_2 is the length of the soldered part of the current contact;

L_3 is the distance from a current contact to a voltage tap;

W is the width or diameter of a specimen to be measured.

For a specimen with a large current-carrying capacity, L_2 shall be larger. L shall be larger for a measurement that needs high sensitivity and L_3 shall be larger when current transfer voltage cannot be neglected.

In the case of the wire specimen the angle between the specimen axis and the magnetic field shall be (90 ± 9)°. This angle shall be determined with an accuracy of ±2°.

In the case of tape specimens, there are two options in addition to the requirement that the angle between the longitudinal specimen axis and the magnetic field shall be (90 ± 9)°. In one option, the magnetic field shall be perpendicular to the specimen surface, the angle deviation being within ±7°. In the second option, the magnetic field shall be parallel to the specimen surface, the angle deviation being within ±3°.

The voltage taps shall be placed in the central part along both the specimen length and the specimen width.

All soldering shall be conducted as quickly as possible so as not to cause thermal damage to the specimen. Soft voltage leads shall be used and twisted before soldering.

The distance between the voltage taps, L, shall be measured to an accuracy of 5 %. This voltage tap separation shall be greater than the specimen width.

7 Measurement procedure

For testing, the specimen and the holder shall be mounted in a test cryostat consisting of a liquid helium or nitrogen dewar, a magnet (when necessary) and a support structure.

The specimen shall be immersed in cryogen for the data acquisition phase. The specimen may be cooled slowly in cryogen vapour, or inserted slowly into the cryogen bath, or, in the case of cooling to the 4,2 K range, first slowly immersed in liquid nitrogen and then liquid helium. The specimen shall be cooled from room temperature to liquid helium (or liquid nitrogen) temperature over a time period of at least 5 min.