IEC 61788-7

Edition 3.0 2020-03

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Superconductivity – Part 7: Electronic characteristic measurements – Surface resistance of high-temperature superconductors at microwave frequencies

Supraconductivité – Partie 7: Mesurages des caractéristiques électronique – Résistance de surface des supraconducteurs haute température critique aux hyperfréquences



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Supraconductivité – Partie 7: Mesurages des caractéristiques électronique – Résistance de surface des supraconducteurs haute température critique aux hyperfréquences

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SUPERCONDUCTIVITY –

Part 7: Electronic characteristic measurements – Surface resistance of high-temperature superconductors at microwave frequencies

FOREWORD

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International Standard IEC 61788-7 has been prepared by IEC technical committee 90: Superconductivity.

This third edition cancels and replaces the second edition, published in 2006. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) informative Annex B, relative combined standard uncertainty for surface resistance measurement has been added;
b) precision and accuracy statements have been converted to uncertainty;
c) reproducibility in surface resistant measurement has been added.

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The text of this International Standard is based on the following documents:

FDIS	Report on voting
90/447/FDIS	90/452/RVD

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

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 61788 series, published under the general title *Superconductivity*, can be found on the IEC website.

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INTRODUCTION

Since the discovery of some Perovskite-type Cu-containing oxides, extensive research and development (R & D) work on high-temperature superconductors (HTS) has been, and is being, done worldwide, and its application to high-field magnet machines, low-loss power transmission, electronics and many other technologies is in progress.

In various fields of electronics, especially in telecommunication fields, microwave passive devices such as filters using HTS are being developed and are undergoing on-site testing [1][1] [2].

Superconductor materials for microwave resonators [3], filters [4], antennas [5] and delay lines [6] have the advantage of very low loss characteristics. The parameters of superconductor materials needed for the design of microwave low loss components are the surface resistance, (R_s) and the temperature dependence of the R_s. Knowledge of this parameter is of primary importance for the development of new materials on the supplier side and for the design of superconductor microwave components on the customer side.

R_s of high quality HTS films is generally several orders of magnitude lower than that of normal metals [7] [8] [9] [10], which has increased the need for a reliable characterization technique to measure this property. Traditionally, the R_s of niobium or any other low-temperature superconducting material was measured by first fabricating an entire three-dimensional resonant cavity and then measuring its Q-value [11]. The R_s could be calculated by solving the electro-magnetic field (EM) distribution inside the cavity. Another technique involves placing a small sample inside a larger cavity. This technique has many forms but usually involves the uncertainty introduced by extracting the loss contribution due to the HTS films from the experimentally measured total loss of the cavity.

The best HTS samples are epitaxial films grown on flat crystalline substrates and no high-quality films have been grown on any curved surface so far. What is needed is a technique that: can use these small flat samples; requires no sample preparation; does not damage or change the film; is highly repeatable; has great sensitivity (down to 1/1 000 the R_s of copper); has great dynamic range (up to the R_s of copper); can reach high internal powers with only modest input powers; and has broad temperature coverage (4,2 K to 150 K).

The dielectric resonator method is selected among several methods to determine the surface resistance at microwave frequencies because it is considered to be the most popular and practical at present. Especially, the sapphire resonator is an excellent tool for measuring the R_s of HTS materials [12] [13] [14]

The test method given in this document can also be applied to other superconductor bulk plates including low T_c materials.

This document is intended to provide an appropriate and agreeable technical base for the time being to engineers working in the fields of electronics and superconductivity technology.

The test method covered in this document is based on the VAMAS (Versailles Project on Advanced Materials and Standards) pre-standardization work on the thin film properties of superconductors.

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1 Numbers in square brackets refer to the bibliography.

SUPERCONDUCTIVITY –

Part 7: Electronic characteristic measurements – Surface resistance of high-temperature superconductors at microwave frequencies

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1 Scope

This part of IEC 61788 describes measurement of the surface resistance (R_s) of superconductors at microwave frequencies by the standard two-resonator method. The object of measurement is the temperature dependence of R_s at the resonant frequency.

The applicable measurement range of R_s for this method is as follows:

– Frequency: 8 GHz < f < 30 GHz

– Measurement resolution: 0,01 mΩ at 10 GHz

The R_s data at the measured frequency, and that scaled to 10 GHz, assuming the f^2 rule for comparison, is reported.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-815 apply.

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4 Requirements

The R_s of a superconductor film shall be measured by applying a microwave signal to a dielectric resonator with the superconductor film specimen and then measuring the attenuation of the resonator at each frequency. The frequency shall be swept around the resonant frequency as the centre, and the attenuation–frequency characteristics shall be recorded to obtain the Q- value, which corresponds to the loss.

The target relative combined standard uncertainty of this method is less than 20 % for the measurement temperature range from 20 K to 80 K.