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INTERNATIONAL STANDARD

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Superconductivity – Part 15: Electronic characteristic measurements – Intrinsic surface impedance of superconductor films at microwave frequencies

Supraconductivité – Partie 15: Mesures de caractéristiques électroniques – Impédance de surface intrinsèque de films supraconducteurs aux fréquences micro-ondes

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SUPERCONDUCTIVITY –

Part 15: Electronic characteristic measurements – Intrinsic surface impedance of superconductor films at microwave frequencies

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

FDIS	Report on voting
90/280/FDIS	90/283/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 2.

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

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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INTRODUCTION

Since the discovery of high T_C superconductors (HTS), extensive research has been performed worldwide on electronic applications and large-scale applications with HTS filter subsystems based on $YBa_2Cu_3O_{7-\delta}$ (YBCO) having already been commercialized [1][1].

The merits of using HTS films for microwave devices such as resonators, filters, antennas, delay lines, etc., include i) possibility of microwave losses from HTS films being extremely low and ii) no signal dispersion on transmission lines made of HTS films due to extremely low microwave surface resistance (R_S) [2] and frequency-independent penetration depth (λ) of HTS films, respectively.

In this regard, when it comes to designing HTS-based microwave devices, it is important to measure the surface impedance (Z_S) of HTS films with $Z_S = R_S + jX_S$ and $X_S = \omega\mu_0\lambda$ (here ω and μ_0 denote the angular frequency and the permeability of vacuum, respectively, X_S, the surface reactance, and $X_S = \omega\mu_0\lambda$ is valid at temperatures not too close to the critical temperature T_C of HTS films).

Various reports have been made on measuring the R_S of HTS films at microwave frequencies with the typical R_S of HTS films as low as 1/100 - 1/50 of that of oxygen-free high-purity copper (OFHC) at 77 K and 10 GHz. The R_S of conventional superconductors such as niobium (Nb) could be easily measured by using Nb cavities by converting the resonator quality factor (Q) to the R_S of Nb. However, such conventional measurement method could no longer be applied to HTS films grown on dielectric substrates, with which it is basically impossible to make all-HTS cavities. Instead, for measuring the R_S of HTS films, several other methods have been useful, which include the microstrip resonator method [3], the coplanar microstrip resonator method [4], the parallel plate resonator method [5] and the dielectric resonator method [7-10]. Among the stated methods, the dielectric resonator method has been very useful due to that the method enables to measure the R_S in a non-invasive way and with accuracy. In 2002, the International Electrotechnical Commission (IEC) published the dielectric resonator method as a measurement standard [11].

The test method given in this standard enables measurement not only of the intrinsic surface resistance but also the intrinsic surface reactance of HTS films, regardless of the film's thickness, by using a single sapphire resonator that differs from the existing IEC standard (IEC 61788-7:2006), which is limited to measuring the surface resistance of superconductor films having a thicknesses of more than 3λ at the measured temperature by using two sapphire resonators. In fact, the measured surface resistances of HTS films with different thicknesses of less than 3λ mean effective values instead of intrinsic values, which cannot be used for directly comparing the microwave properties of HTS films among one another [12, 13]. Use of a single sapphire resonator as suggested in this standard also makes it possible to reduce uncertainty in the measured surface resistance that might result from using two sapphire resonators with sapphire rods of even slightly different quality.

The test method given in this standard can also be applied to HTS coated conductors, HTS bulks and other superconductors having established models for the penetration depth.

This standard 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 standard has been discussed at the VAMAS (Versailles Project on Advanced Materials and Standards) TWA-16 meeting.

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[1] Numerals in square brackets refer to the Bibliography.

SUPERCONDUCTIVITY –

Part 15: Electronic characteristic measurements – Intrinsic surface impedance of superconductor films at microwave frequencies

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1 Scope

This part of IEC 61788 describes measurements of the intrinsic surface impedance (Z_S) of HTS films at microwave frequencies by a modified two-resonance mode dielectric resonator method [13, 14][2]. The object of measurement is to obtain the temperature dependence of the intrinsic Z_S at the resonant frequency f_0.

The frequency and thickness range and the measurement resolution for the intrinsic Z_S of HTS films are as follows:

– frequency: up to 40 GHz;

– film thickness: greater than 50 nm;

– measurement resolution: 0,01 mΩ at 10 GHz.

The intrinsic Z_S data at the measured frequency, and that scaled to 10 GHz, assuming the f^2 rule for the intrinsic surface resistance R_S ($f < 40$ GHz) and the f rule for the intrinsic surface reactance X_S for comparison, shall be reported.

2 Normative references

The following referenced documents are indispensible for the application 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 60050-815:2000, *International Electrotechnical Vocabulary – Part 815: Superconductivity*

IEC 61788-7:2006, *Superconductivity – Part 7: Electronic characteristic measurements – Surface resistance of superconductors at microwave frequencies*

3 Terms, definitions and general concepts

3.1 Terms and definitions

For the purposes of this document, the definitions given in IEC 60050-815, one of which is repeated here for convenience, apply.

3.1.1
surface impedance
impedance of a material for high frequency electromagnetic wave which is constrained to the surface of the material in case of metals and superconductors

NOTE The surface impedance governs the thermal losses of superconducting RF cavities.

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2 Numerals in square brackets refer to the Bibliography.