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Welding — Micro joining of 2nd generation high temperature superconductors —

Part 1: General requirements for the procedure

Soudage — Micro-assemblage des supraconducteurs à haute température de 2ème génération —

Partie 1: Exigences générales pour la procédure

Reference number
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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 10, *Quality management in the field of welding*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

A list of all parts in the ISO 17279 series can be found on the ISO website.

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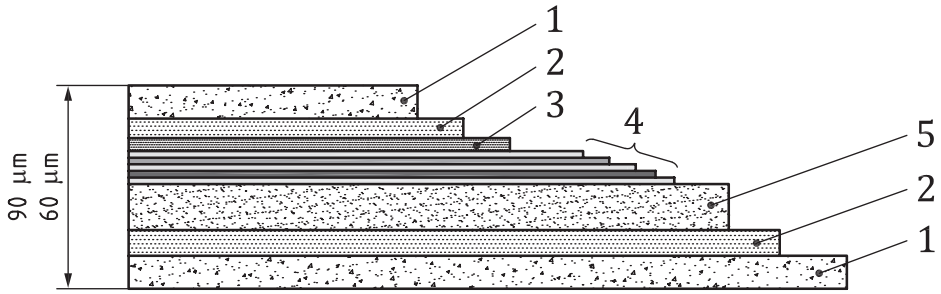
Introduction

The increasing use of 2nd generation high temperature superconductors (2G HTSs) and invention of resistance-free joining on 2G HTSs have created the need for this document in order to ensure that joining is carried out in the most effective way and that appropriate control is exercized over all aspects of the operation. ISO standards for micro-joining and joint evaluation procedure are accordingly essential to get the best and uniform quality of 2G HTS joint.

The technique in this document regarding resistance-free micro-joining is patent-registered and was reported to patent.statements@iso.org using the "Patent Statement and Licensing Declaration Form".

A superconductor is a material that conducts electricity without resistance and has diamagnetism below critical temperature, T, critical magnetic field, B_c, and critical current density, J_c. Once set in motion, electrical current flows forever in a closed loop of superconducting material under diamagnetism.

A 2G HTS consists of multi-layers and its total thickness is around between 60 µm and 100 µm with or without surrounding copper stabilizer. The superconducting layer made from $ReBa_2Cu_3O_{7-x}$ (ReBCO, abbreviated term of $ReBa_2Cu_3O_{7-x}$) is only between 1 µm and 2 µm thick depending on manufacturer's specifications. Re stands for Rare Earth materials, of which gadolinium, yttrium and samarium are used for 2nd generation high temperature superconducting materials. Figure 1 shows schematic drawing of typical multiple layers with surrounded copper stabilizer, and the constituents and thicknesses of each layer in the 2G HTS. The two layers of No. 1 in Figure 1 does not exist in stabilizer-free 2G HTS.



Key

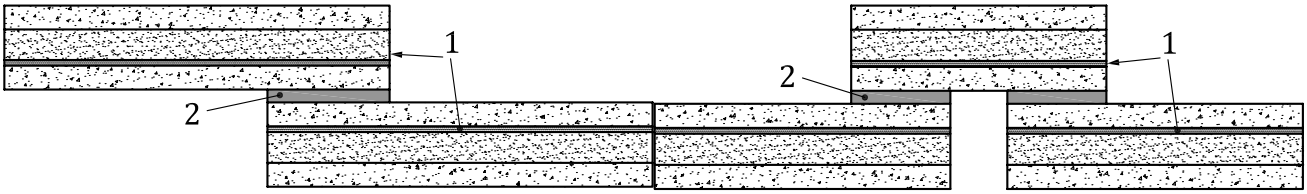
1	20 µm Cu stabilizer	4	5 buffing layers (total 160 nm)
2	2 µm Ag overlayer	5	50 µm hastelloy substrate
3	between 1 µm and 2 µm ReBCO super-conducting layer		

NOTE Not to scale.

Figure 1 — Typical 2G HTS multi-layers, and the constituents and thicknesses of each layer

Currently soldering, brazing or any filler is applied in superconducting industry as shown in Figure 2, which shows high electrical resistance at the joint providing fatal flaw in the superconductor.

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a) Lap joint **b) Bridge joint**

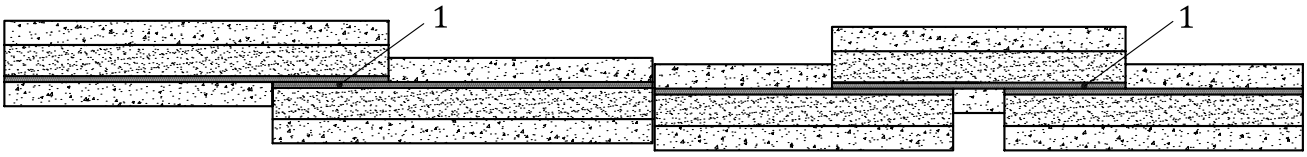
Key

1 superconducting layer

2 solder

Figure 2 — Soldering to join 2G HTS

However, this document focuses on the direct autogenous joining of between 1 µm and 2 µm-thick superconducting layers of 2G HTSs as shown in Figure 3 without filler metals and recovery of superconducting properties by oxygenation annealing process, which shows almost no electrical resistance at the joint.



a) Lap joint **b) Bridge joint**

Key

1 superconducting layer

Figure 3 — Direct autogenous joining of two superconducting layers of 2G HTSs for superconducting joint

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Welding — Micro joining of 2nd generation high temperature superconductors —

Part 1:
General requirements for the procedure

1 Scope

This document provides concepts, specification and qualification of 2G HTS joining procedure. A welding procedure specification (WPS) is needed to provide a basis for planning joining operations and for quality control during joining. Joining is considered as a special process in the terminology of standards for quality systems. Standards for quality systems usually require that special processes be carried out in accordance with written procedure specifications. This has resulted in the establishment of a set of rules for qualification of the joining procedure prior to the release of the WPS to actual production. This document defines these rules.

This document does not cover soldering, brazing or any fillers, which are currently available in the industry. It can be applied for joining of all kinds of 2G HTSs.

This document does not apply to 1st Generation Bismuth Strontium Calcium Copper Oxide (1G BSCCO) type HTS and Low Temperature Superconductor (LTS) Joining.

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.

ISO 15607:2003, *Specification and qualification of welding procedures for metallic materials — General rules*

ISO 17279-2, *Welding — Micro-joining of 2nd generation high temperature superconductors — Part 2: Personnel qualification for micro-joining and testing*

ISO/TR 25901 (all parts), *Welding and related processes — Vocabulary*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/TR 25901 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
high temperature superconductor
HTS
superconducting material with critical temperature higher than liquid nitrogen boiling point

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3.2
low temperature superconductor
LTS
superconducting material with critical temperature lower than liquid nitrogen boiling point

3.3
2nd generation high temperature superconductor
2G HTS
superconducting material with critical temperature higher than liquid nitrogen boiling point, made of rare earth and other elements like barium, copper and their oxides

Note 1 to entry: A first generation high temperature superconductor (1G HTS) is a superconducting material with critical temperature higher than liquid nitrogen boiling point, made of bismuth strontium calcium copper oxides.

3.4
pressurized partial micro-melting diffusion
partial micro-melting of the two faying surfaces of 1 μm- to 3 μm-thick superconducting layers and atoms diffusion in partially micro-molten pool and solid state of the superconducting layers by pressurized force

3.5
oxygenation annealing
process to restore the oxygen stoichiometry in an oxygen-rich environment and to recover superconducting properties

Note 1 to entry: Structure and superconducting properties of 2G HTS are strongly affected by the oxygen stoichiometry. Joining of 2G HTS at high temperature induces oxygen out-diffusion causing a phase change from a superconducting orthorhombic phase to a non-superconducting tetragonal phase.

3.6
pressurized solid-state diffusion
atoms diffusion in solid state of the two faying surfaces of 1 μm- to 3 μm-thick superconducting layers with pressurized force

3.7
bridge joint
joint with a third 2G HTS piece overlapped as a bridge on top of two 2G HTS pieces

Note 1 to entry: See Figure 3 and Figure 5.

4 Symbols and abbreviated terms

The abbreviatied terms listed in ISO 15607:2003, Table 1, relevant to joining procedure for 2G HTS, shall apply.

5 Requirements

5.1 Joint design

5.1.1 General

The joint shall be designed in accordance with defined requirements that support the end use of the product. Documentation shall clearly define the essential information of the joint and any special requirements, e.g. fracture critical, durability critical, mission critical, or safety critical, that are imposed over and above the general requirements. Essential process controls shall be defined to substantiate that all design requirements can be met by the joints that were produced in accordance with welding procedure specification (WPS) and testing and inspection requirements.

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