

INTERNATIONAL STANDARD

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**Superconductivity –
Part 17: Electronic characteristic measurements – Local critical current density
and its distribution in large-area superconducting films**

**Supraconductivité –
Partie 17: Mesures de caractéristiques électroniques – Densité de courant
critique local et sa distribution dans les films supraconducteurs de grande
surface**



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INTERNATIONAL ELECTROTECHNICAL COMMISSION

SUPERCONDUCTIVITY –

**Part 17: Electronic characteristic measurements –
Local critical current density and its distribution
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FDIS	Report on voting
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INTRODUCTION

Over twenty years after their discovery in 1986, high-temperature superconductors are now finding their way into products and technologies that will revolutionize information transmission, transportation, and energy. Among them, high-temperature superconducting (HTS) microwave filters, which exploit the extremely low surface resistance of superconductors, have already been commercialized. They have two major advantages over conventional non-superconducting filters, namely: low insertion loss (low noise characteristics) and high frequency selectivity (sharp cut) [1]¹. These advantages enable a reduced number of base stations, improved speech quality, more efficient use of frequency bandwidths, and reduced unnecessary radio wave noise.

Large-area superconducting thin films have been developed for use in microwave devices [2]. They are also used for emerging superconducting power devices, such as, resistive-type superconducting fault-current limiters (SFCLs) [3–5], superconducting fault detectors used for superconductor-triggered fault current limiters [6, 7] and persistent-current switches used for persistent-current HTS magnets [8, 9]. The critical current density J_c is one of the key parameters that describe the quality of large-area HTS films. Nondestructive, AC inductive methods are widely used to measure J_c and its distribution for large-area HTS films [10–13], among which the method utilizing third-harmonic voltages $U_3 \cos(3\omega t + \theta)$ is the most popular [10, 11], where ω , t and θ denote the angular frequency, time, and initial phase, respectively. However, these conventional methods are not accurate because they have not considered the electric-field E criterion of the J_c measurement [14, 15] and sometimes use an inappropriate criterion to determine the threshold current I_{th} from which J_c is calculated [16]. A conventional method can obtain J_c values that differ from the accurate values by 10 % to 20 % [15]. It is thus necessary to establish standard test methods to precisely measure the local critical current density and its distribution, to which all involved in the HTS filter industry can refer for quality control of the HTS films. Background knowledge on the inductive J_c measurements of HTS thin films is summarized in Annex A.

In these inductive methods, AC magnetic fields are generated with AC currents $I_0 \cos \omega t$ in a small coil mounted just above the film, and J_c is calculated from the threshold coil current I_{th} , at which full penetration of the magnetic field to the film is achieved [17]. For the inductive method using third-harmonic voltages U_3 , U_3 is measured as a function of I_0 , and the I_{th} is determined as the coil current I_0 at which U_3 starts to emerge. The induced electric fields E in the superconducting film at $I_0 = I_{th}$, which are proportional to the frequency f of the AC current, can be estimated by a simple Bean model [14]. A standard method has been proposed to precisely measure J_c with an electric-field criterion by detecting U_3 and obtaining the n -value (index of the power-law E - J characteristics) by measuring I_{th} precisely at various frequencies [14, 15, 18, 19]. This method not only obtains precise J_c values, but also facilitates the detection of degraded parts in inhomogeneous specimens, because the decline of n -value is more remarkable than the decrease of J_c in such parts [15]. It is noted that this standard method is excellent for assessing homogeneity in large-area HTS films, although the relevant parameter for designing microwave devices is not J_c , but the surface resistance. For application of large-area superconducting thin films to SFCLs, knowledge on J_c distribution is vital, because J_c distribution significantly affects quench distribution in SFCLs during faults.

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