Tutorial

The Dielectric Resonator Method as an International Measurement Standard for the Microwave Surface Resistance of High-T_c Superconductor Films

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The microwave surface impedance (Z_s) of superconductors has been regarded as one of the most important physical parameters for understanding electrodynamics inside superconductors as well as for various microwave applications including quality control of microwave devices. As a measurement method for the Z_s of high-T_c superconductor (HTS) films, dielectric resonator method has been very popular and was recently adopted as an international measurement standard by International Electrotechnical Commission (IEC) for the microwave surface resistance (R_s), i.e., the real part of Z_s, of HTS films in 2002. Here we review issues related with the measurement method, which include measurement errors in the R_s of superconductor films, dynamic range for the R_s, merits of the dielectric resonator method over other measurement methods, and its applicability for characterizing the physical properties and the structural properties of superconductor films and coated conductors in the microwave region.

Firstly, we briefly introduce various measurement methods for the R_s of superconductor films, which include microstrip resonator method, coplanar resonator method, parallel plate resonator method, and the dielectric resonator method.

In the second part, we introduce working principles of the dielectric resonator method including basic concepts for proper design of dielectric resonators. Merits of using dielectrics with relatively high dielectric constant and low loss tangent are described.

In the third part, we review the factors that limit the measurement accuracy of the dielectric resonator method and recent progresses with regard to reduction of the measurement errors. Two-tone resonator method that enables to measure the dielectric loss of the dielectric and the R_s of superconductor films is introduced along with the designing principles for the resonator.

In the fourth part, a modified two-tone dielectric resonator method that enables to measure the surface resistance R_s, the surface reactance X_s (i.e., the imaginary part of Z_s having informations on the penetration depth of superconductors), as well as the dielectric loss of the dielectric. Experimental results for the Zs of $YBa_2Cu_3O_{7-\delta}$ films and MgB_2 films are described.

Lastly, various applications of the dielectric resonator method for non-invasive investigation of homogeneity in the R_s of large superconductor films, uniformity in the critical current density of coated conductors through measurements of the R_s, as well as the thickness of thin metallic and superconductive films are described along with the possibility of establishing a new international measurement standard for the intrinsic Z_s of HTS films.