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Interlayer tunneling spectroscopy of mixed-phase BSCCO superconducting whiskers

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Abstract

In this work, we present a study on the interlayer tunneling spectroscopy (ITS) of mixed-phase BiSrCaCuO (BSCCO) superconducting whiskers. The tunneling experiments were carried out on the artificial cross-whisker (twist angle of 90°) junctions. A multiple superconducting energy gap in the cross-whisker junctions was observed, which is attributed to the presence of different doping levels of two $Bi_2Sr_2CaCu_2O_{8+\delta}$ phases (Bi-2212), rather than two different phases, in the BSCCO whiskers, namely $Bi_2Sr_2CaCu_2O_{8+\delta}$ and $Bi_2Sr_2Ca_2Cu_3O_{8+\delta}$ (Bi-2212 and Bi-2223). The temperature dependence of the energy gaps was discussed in the framework of the BCS T-dependence. On the other hand, the carrier concentration of the cross-whisker junction was changed by the carrier injection process. The effects of the carrier injection on the critical current, I_c, and the ITS of intrinsic Josephson junctions were investigated in details.

Keywords: intrinsic Josephson junction, carrier injection, cross-whisker junction, superconductivity, THz emission

(Some figures may appear in colour only in the online journal)

1. Introduction

A high-T_c superconducting BiSrCaCuO (BSCCO) system has a layered crystal structure along the c-axis in which the superconducting CuO_2 layers alternate with BiO and SrO layers [1]. Weak interlayer coupling between the layers along the c-axis leads to the formation of the atomic-scale intrinsic Josephson junctions (IJJs). The potential small-scale application of IJJs might be classified into two fundamental devices: (a) high-T_c SQUID systems, which are the most sensitive detectors of magnetic flux currently available and (b) Josephson devices which take advantage of the electromagnetic characteristics of Josephson junctions to perform traditional electronic functions [2]. Recently discovered THz emission, which provides a promising technology for many areas such as biological and biomedical science, non-destructive evaluation, homeland security, and quality control of food and agricultural products, emerges as one of the most crucial applications [3].

On the other hand, from the scientific point of view, interlayer tunneling spectroscopy (ITS) is an effective technique to determine both the superconducting energy gap and the quasi-particle density of state [4–6]. Tunneling spectroscopy represents a unique opportunity to probe bulk electronic properties of the crystal stack, independent of the adverse effect of the sample surface. In this respect, Koval *et al* [7, 8] reported that the superconductivity of the $Bi_2Sr_2CaCu_2O_{8+\delta}$ (Bi-2212) single crystals can be tuned by the carrier injection process. Additionally, carrier injection allows one to study the same sample without changing the chemical composition. When an intensive current is applied along the c-axis, the accelerated electrons are eventually trapped in the SrO or BiO layers. Via a charge compensation, these electrons, trapped in the insulator layers, induce a change of the hole concentration in the superconducting planes. Simultaneously, the trapped electrons give rise to an intrinsic electrostatic field inside the crystal, which invokes hole doping in the superconducting CuO_2 layer [9].

