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PROGRAM AND ABSTRACTS

PROPERTIES OF HTS JOSEPHSON JUNCTIONS WITH IRREGULAR BOUNDARIES*

A.A.Golubov, V.M.Krasnov,
Institute of Solid State Physics, 142432, Chernogolovka, Moscow District, Russia
M.Yu.Kupriyanov
Institute of Nuclear physics Moscow State University, 119899, GSP, Moscow, Russia.

The analysis of the experimental data obtained in tunnel junctions with high critical current density [1] and HTS SNS devices have shown that a tunnel barrier in these structures is not small, and it likely to be a series of constrictions, each having rather large transparency. Therefore, a small ballistic SNcNS and ScNS constrictions are suitable starting point to discuss more complicated models for these junctions.

Properties of constrictions NcS are well understood in the framework of the model of Blonder, Tinkham and Klapwijk (BTK) [2]. In their approach, current through a constriction is fully determined by amplitudes of normal and Andreev reflections at the NS interface. The model assumes that both N and S metals are in thermal equilibrium and that both are spatially homogeneous. Whereas the condition of thermal equilibrium is generally fulfilled for the constriction geometry, another condition of spatial homogeneity of superconducting electrodes is less general.

In the present paper the stationary and nonstationary properties of ballistic constriction NcS'S and ScS'S with disordered electrodes are analyzed theoretically. It was assumed that the size of the constriction is smaller than electron mean free path. The potential drop takes place at the constriction, and therefore the electrodes are in thermal equilibrium, while one of the electrodes is a S'S sandwich in a dirty limit. Amplitudes of Andreev and normal reflections are related to the solution of stationary Green function problem in an inhomogeneous S'S electrode. This provides the generalization of the BTK model for a spatially inhomogeneous case. Relation between quasiparticle current in NcS'S junctions and energy spectrum of S'S proximity sandwich is found for arbitrary parameters of S' and S materials and suppression parameters at the S'S interface.

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DESIGN AND SIMULATION OF THE SIMPLEST RSFQ CIRCUITS BASED ON HTS BICRYSTAL JOSEPHSON JUNCTIONS*

A.Yu. Kidiyarova-Shevchenko, M.M. Hapaev, P.N. Shevchenko, T.V.Filippov, and M.Yu.Kupriyanov.
Institute of Nuclear Physics, Moscow State University, Moscow 119899 GSP, Russia.

Nowadays RSFQ logic/memory cells family based on nonhysteretic Josephson junction is one of the most promising sets of digital superconductive devices that employ Josephson effect [1]. In the last few years a lot of the circuits were fabricated using low-Tc Nb technology [2,3] (with Jc≅1000A/cm and IcRn≅200mV) and experimentally tested at frequencies of up to 20 GHz. Further increasing of operating frequency requires the use of submicron Josephson junctions with higher value of IcRn product. Recently the first reliable submicron junctions and circuits havez been implemented [4]. Another promising direction is to use HTS Josephson junctions which have rather high IcRn product (about 1 mV at 4.2 K [5]) and nonhysteretic current-voltage characteristic. At present moment bicrystal Josephson junctions seem to be applicable in digital circuits due to small (15%) on-chip spread of the Ic. The goal of this paper is simulation and design of the simplest HTS RSFQ devices based on these junctions.

The theoretical analysis of the requirements for the HTS IC technology based on bicrystal junctions to be used for fabrication of RSFQ circuits was done. It takes into account the geometry limitations as well as the large values of the inductance and mutual inductances intrinsic to HTS technology.

Special software was developed for calculation of the self and mutual inductances in HTS RSFQ circuits. The adaptation of existing PSCAN program for the simulation the processes in HTS RSFQ devices was also done. Two HTS circuits were simulated and optimized: Josephson Transmission Line and balanced comparator. Balanced comparator is a an important part of the superconducting samplers and ADC, digital SQUIDs. It can be used for the experimental determination of the thermal noise in HTS Josephson junctions. The different operational modes of HTS balanced comparator were investigated. It was optimized to reach the maximum value of the operational frequency and maximum stability of bias current to external fluctuations. Theoretical simulations showed that optimal temperature for proper operation of the balanced comparator is close to 55K and maximum operational frequency at this temperature is close to 10GHz. The bias current fluctuations as high as 30mA do not influence on the sensitivity of the balanced comparator.

The theoretical description and simulation of the resonant modes on HTS JTL current-voltage characteristics was done. Investigation of the parameters of the modes as a functions of inductances showed that JTL can be used as a tool for measurements of mutual inductance value. The method for the extracting inductances from the experimental data was developed. The layouts for HTS transmission line and balanced comparator has been developed and optimized in accordance with the design rules developed for technology in KFA Julich.

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PREPARATION AND CHARACTERIZATION OF BSCCO-2212 BIEPITAXIAL JOSEPHSON JUNCTIONS ON $SrTiO_3$ SUBSTRATES

A. Pfuch, A. Wiese, F. Schmidl, L. Dörrer, P. Seidel
Institut für Festkörperphysik, Friedrich-Schiller-Universität Jena, Helmholtzweg 5, D-07743 Jena, Germany
S.N. Polyakov, E.K. Kov'ev, M.Y. Kupriyanov
Institute of Nuclear Physics, Moscow State University, 119899 GSP, Moscow, Russia

We have prepared biepitaxial BSCCO-2212 Josephson junctions on $SrTiO_3$ substrates by laser ablation of 20nm thick MgO seed layers and of 100nm thick BSCCO-2212 superconducting layers. The preparation of these films and multilayers was described elsewhere [1,2]. After MgO deposition and due to covering with a photoresist mask parts of the MgO layer were removed by wet chemical etching. 45° in-plane grain boundaries in the BSCCO films were created at the border of the MgO covered parts because of a 45° lattice rotation of BSCCO-2212 on the MgO-cleaned $SrTiO_3$ surface and the not dislocated growth of BSCCO-2212 on the MgO seed layer.

The crystal properties of the multilayer structures were investigated by XRD and RBS measurements. It was found that the crystal structure of the BSCCO-2212 films can be improved by depositing additional buffer layers usually used in biepitaxy technology (MgO, CeO_2) [3]. χ_{min} values of less than 40% for the Bi peak, comparable with our single BSCCO-2212 films on $SrTiO_3$ [1], were found from RBS channeling measurements for BSCCO/MgO multilayers.

Microbridges and SQUIDs with linewidths of 3 to 7μm were patterned by common photolithography and Ar^+ ion milling. By four-probe-techniques we measured current-voltage characteristics (IVC) which can be described by the resistively shunted junction (RSJ) model. In particular cases we found hysteretic IVC's at low temperatures. The junctions were superconducting up to temperatures of about 60K. The normal resistance of the junctions R_N was found to be independent at lower temperatures and increasing near T_C. The decrease of the critical currents of the junctions at increasing temperature can be described by a power law $I_C \sim (1-T/T_C)^\alpha$. The value of the exponent α will be discussed. We have measured the critical current modulation due to an external magnetic field. Flux modulation voltages of the junctions and of dc-SQUID structures were obtained up to temperatures of approximately 50K. Due to microwave radiation we observed Shapiro steps in the IVC's of the junctions. First noise measurements of our dc-SQUID structures showed a field sensitivity of $2\times10^{-4}\phi_0/\sqrt{Hz}$ for frequencies higher than 100Hz.

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NORMAL RESISTANCE OF ASYMMETRIC HTS JOSEPHSON JUNCTIONS WITH SEMICONDUCTOR OXIDE INTERLAYERS*

A.I.Devyatov, M.Yu.Kupriyanov
Institute of Nuclear Physics Moscow State University, 119899 GSP, Russia

The development of the technology of HTS Josephson junctions with semiconductor oxide interlayers is in progress now in several laboratories [1-3]. In spite of intensive technological efforts concentrated in this direction the on-chip spread of critical current Ic and normal junction resistance Rn are still in the range of several hundred percent. Recent theoretical analysis [4] has implied that the resonant tunneling transport via localized states in the barrier material is a suitable mechanism for the normal and supercurrent transport in the junctions. With such a mechanism it is possible to give the reasonable explanation of the "long range proximity effect" and of the spread of the junctions parameter due to relatively small amount of the resonant channels [2,3]. Another factors responsible for the spread of Ic and Rn are the asymmetry and irregularity in transparency of the boundaries. At first glance it would seem that it give rise to the exponentially large variation of resistance due to shifting the space location of the optimal LS.

We investigated the influence of these factors on the normal junction resistance and found that decrease of the transparency of one of the boundaries results in two competitive processes. The first one is the increase of the resistance due to shift of the optimal position of the LS from the middle of the barrier to the boundary. The second is the decrease of the resistance due to rise in the number of electrons involved into the tunneling. This effect is the consequence of nonconservation of the electron momentum projection on the boundary plane specific to the resonant tunneling via LS. It was shown that the shift of the optimal position of LS due to irregularity in the boundary transparency does not result in drastical changes in the resistance due to increase of the number of electrons involved into the tunneling.

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GROWTH OF α-Al_2O_3 BICRYSTAL SUBSTRATES BY BRIDGMAN METHOD*

B.M.Allaudinov, E.K.Kov'ev,
Crystallography Institute Russian Academy of Science
M.Yu.Kupriyanov and S.N.Polyakov
Institute of Nuclear Physics Moscow State University, 119899, GSP, Russia.

Up to now fabrication of the HTS Josephson junction on a bicrystal substrates provides real possibilities for fabrication HTS devices. This type of structures characterized by the reliable on-chip reproducibility of their basic parameters. For example, the tolerances of the critical current and normal junction resistance at the level of the order of 20% are achieved. The further development in this field is limited by the quality of the bicrystal substrates. The existing method of their fabrication based on solid-phase intergrowing [1] of two misoriented single crystals have several principal limitation.

First, it is rather difficult to control the missorientation of the crystal in all crystallographic directions with the accuracy better than one degree.

Second, the resulting boundary characterized by a large density of dislocation making the properties of the Josephson junctions irregular in the direction parallel to the boundary even the case of so-called "special boundaries".

It is also necessary to point out that the price of the bicrystal substrates fabricated by existing methods is ten times larger compare to the one of the single crystal substrate.

These difficulties can be avoided if one would be able to use the naturally grown bicrystal for making substrates. In this paper we reported the main result in the development of the new technology for growth the α-Al_2O_3 bicrystals by horizontal and vertical Bridgman methods. The (101·0) and (11·02) crystal planes in the both parts of the sample are parallel to each other, while (11·20) planes makes the 12^0,14^0,18^0 angles relating to the boundary.

In the horizontal method the bicrystal growth in a specially design Mo bath in horizontal direction. The typical size of the fabricated bicrystal is 150x90x20 mm. The average time of growth is close to 40 hours. It was found that the mutual crystallographical orientations of the single crystals making the boundary remains constant during the growth process and coincide with the ones of the seed bycristal. Unfortunately it is rather difficult in this approach to stabilized the geometrical location of the boundary. Small variation of the temperature in the directions perpendicular to the growth direction resulting in shifting of the boundary from the middle position. This deviations accompanied by increasing the density of dislocations in the vicinity of the boundary. Sometimes this even leads to the microcracks formation.

This difficulties to a large extend can be avoided in the vertical geometry of growth. The special manipulator has been developed for control the orientation of the part of the seed bicrystal with the accuracy better that 0.3^0 in all three crystallographycal directions. The bicrystal growth in a Mo tube with diameter of the order of 10 mm. The length of the samples are in the range of 80-100 mm. The average time of growth is close to 30 hours. The absence of the direct contact between the bicrystal and the atmosphere during the grown process in the last methods permits to stabilize the geometrical location of the bycrystal boundary and greatly suppress the density of dislocations.

The quality of the bicrystals was investigated by optical and X-ray diffraction methods. It was found by X-ray diffractometry that the missorientaton angles in three crystallographic directions has the accuracy 0.5^0. The full width at half maximum of the rocking curve (1012), (1010) and (1202) reflections near the boundary closed to 20-30 arc. sec.

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