YBCO Thin Films SQUIDs Fabricated on Bicrystal Substrates

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Abstract. Properties of the dc SQUIDs made of YBCO thin film deposited on $SrTiO_3$ and ZrO_2 bicrystal substrates and the properties of the fabricated Josephson junctions have been studied. It is found that the characteristics of the junctions are similar to those of the SNS structures. The magnetic field sensitivity has achieved a value of $\delta B \sim 10^{-12}$ T/Hz$^{1/2}$ at frequencies higher than 25 Hz and $T = 4.2$ K.

1. Introduction

One of the possible ways to create HTS SQUIDs is using a bicrystal substrate of suitable misorientation angle to fabricate the HTS Josephson junctions [1].

The goal of this work is to fabricate single-level dc SQUIDs made on bicrystal ZrO_2 and $SrTiO_3$ substrates and studying their characteristics as well as the nature of the Josephson junctions.

2. Device fabrication

YBCO thin films were deposited by a laser ablation process [2] on ZrO_2 and $SrTiO_3$ bicrystal substrates with a misorientation angle in the basal plane close to 35-40° and 18-20° respectively.

The deposited films had usually a mirror-like surface. The *X*-ray diffraction pattern of the films typically showed only (001) type reflexes corresponding to a well oriented thin film with the *c*-axis normal to the substrate.

The films had a thickness d = 0.3-0.5 μm and a resistance in the normal state at 100 K $\rho \simeq 130$ $\mu\Omega\times$cm for ZrO_2 and $\rho \simeq 300$ $\mu\Omega\times$cm for $SrTiO_3$. The critical temperature T_c of the films for both types of substrates lies in the range T_c = 82-90 K.

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The Josephson junctions and the interferometer loops were fabricated by the laser ablation process [3]. Dayem type microbriges across the boundary had a width W in the limits 10-20 μm for different samples. Loop areas of 1600 μm^2 and 2500 μm^2 were used for dc interferometers. The density of the critical current j_c was about 100-200 A/cm^2 for all junctions.

3. The parameters of the junctions.

The I-V curves of the junctions made on $SrTiO_3$ substrates were close to those followed from the RSJ model [4], while the ones of the junctions made on ZrO_2 had a "humped" form, which is typical for inhomogeneous Josephson structures. This difference in the spatial homogeneity of the junctions was also confirmed by the dependences of the critical current I_c on the magnetic field H. For the junctions on ZrO_2 we have not found any $I_c(H)$ variations, while for the those on $SrTiO_3$ we have obtained usual diffraction-like dependences with a period corresponding to the geometrical cross-section of the junctions.

Absolute values of the characteristic voltage V_c were usually less than 2.5 mV at T = 4.2 K. The temperature dependences of the parameter V_c (see fig.1) were in a reasonable agreement with the theoretical prediction [5] for the SNS sandwich type junctions with paramagnetic impurities in the N-layer (spin-flip time τ_s equals to $0.5\hbar/\pi T_c$).

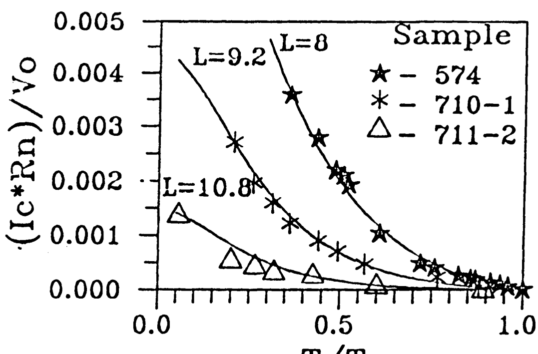

Figure 1. Temperature dependence of the characteristic voltage for the junctions made on $SrTiO_3$ substrates (710-1, 711-2) and ZrO_2 substrate (574), $L = d/\xi^*_N$ is the normalized thickness of the N layer ($V_o = 2\pi k_B T_c/e$).

4. Interferometer characteristics.

Typical modulation voltages V of the current-biased dc interferometers versus applied magnetic flux Φ_e at 4.2 K are presented in fig.2. The peak-to-peak magnitude of V-Φ_e curves of the samples on the $SrTiO_3$ substrates were several times greater than those on ZrO_2. In both cases the oscillation periods were determined by the geometrical loop of the interferometers and hysteresis of the V-Φ_e curves was practically absent.

The noise measurements have been made in a flux-locked loop and the flux-to-voltage factor was determined from the magnitude of the minimal jump of the SQUID output voltage. It was found that $S_\phi \sim 10^{-3}$ $\Phi_o/Hz^{1/2}$ (at frequencies f > 25 Hz) at 77.3 K for samples fabricated on both types of substrates. However the samples on $SrTiO_3$ usually had better noise characteristics at low temperatures. For example, the best sample 673-1 demonstrated noise level $S_\phi \simeq 10^{-6}$ $\Phi_o/Hz^{1/2}$. This value corresponds to the field sensitivity close to 10^{-12} $T/Hz^{1/2}$ at T = 4.2 K.

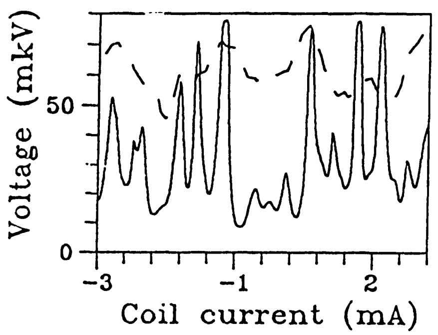

Figure 2. Voltage vs. flux curves for the interferometers 604-1 (ZrO_2, dashed line) and 710-1 ($SrTiO_3$, solid line).

5. Conclusion

The obtained results show that dc SQUID fabrication using $SrTiO_3$ bicrystal substrates is more preferable than on ZrO_2.

The achieved level of the magnetic field sensitivity could be improved by using multiturn high-T_c thin film input coils.

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