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Fabrication and Characteristics of High-T_c Superconducting Flux Flow Transistors with High Transresistances

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Fabrication and characteristics of YBCO superconducting flux flow transistors are reported. The channels of flux flow are fabricated utilizing thinned bridges or made them onto step edge substrates. The I-V curves of fabricated devices exhibit vortex flow characteristics. The devices show a transistor behavior and operate at temperature of over 70 K, which are able to be cooled by a liquid nitrogen. Alternating modulation characteristics are also investigated. The transresistance of over 10 Ω is obtained.

1. Introduction

The high-T_c superconducting flux-flow transistor (SFTT) is expected as a millimeter wave solid state device and a high speed digital device.[1-9] The potential is based on vortex flow speed of 10^6 m/s higher than that of low-T_c supurconducting materials in the mixed state and that of Josephson flux flow devices. For the high-T_c materials, the SFFTs with high transresistances can be obtained because the high sensitivity of critical currents to applied magnetic field. Besides, the devices are able to be fabricated using only one layer high-T_c superconducting film without using difficult multilayer techniques.

The device is attracted a few of group's attentions.[10-15] In high-T_c superconductors, the $Y_1Ba_2Cu_3O_{7-y}$ seems to be rather difficult in contrast to Tl and Bi system for fabrication of SFFT operating at liquid nitrogen temperature, probably due to that the T_c is only about 10 K higher than 77 K. However, the $Y_1Ba_2Cu_3O_{7-y}$ thin film of T_c near 85K is easy to be obtained by using current growth techniques. Therefore, the key of fabricating the $Y_1Ba_2Cu_3O_{7-y}$ SFFT is to find the method of process to prevent the T_c of the channels reducing and to get high sensitivity.

In this presentation, we report the fabrication and characteristics of $Y_1Ba_2Cu_3O_{7-y}$ superconducting flux flow transistors. The devices are fabricated by making thinned bridges and forming the bridges onto step edge substrates. Reproducible transistor behaviors are observed and the operation temperature is over 70K. Alternating characteristics of the devices are investigated, which shows transresistances of over 10 Ω and output resistances of about 5 Ω.

2.Experimental

The $Y_1Ba_2Cu_3O_{7-y}$ thin films used for the SFFT were grown on $SrTiO_3$(100) substrates by chemical voper deposition. The films had strong c-axis orientation perpendicular to substrate surfaces and occured zero resistance temperatures over 80K. The thickness of the films is about 200 nm. The films were patterned to the SFFT device geometry by a photolithography technique, employing a ion dry etching process. Figure 1 shows a photography of topview for fabricated $Y_1Ba_2Cu_3O_{7-y}$ SFFT. There are 5 bridges in the device body. The bridge dimension is 5 μm wide, 5 μm ~ 15 μm long and window is 15 μm long. In conventional fabrication method, the bridges were thinned as a channel of vortex flow. To test the device without the heating effect from current, the control line was made to be 75 μm wide, in which the density of the control current is low and line center is far from the edge of the body. The space between control line and body is 10 μm.

We fabricated the bridges of SFFT onto step edge of $SrTiO_3$ substrates. The step height was about 100 nm~200 nm. The step edge was about 5 μm in width. It is conceivable that a inclined plane on step edge was formed. The angle between the inclined plane and the substrate surface was lower than 30 degree. Moreover, the water was not used in the whole process to reduce the damage of channels.

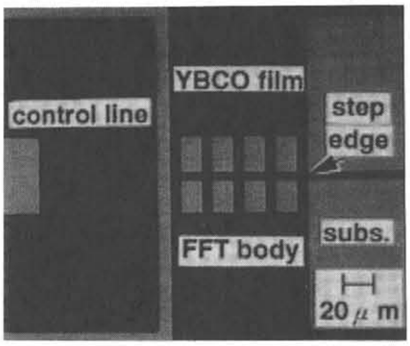


Figure 1 A photography of topview for fabricated $Y_1Ba_2Cu_3O_{7-y}$ superconducting flux flow transistor.

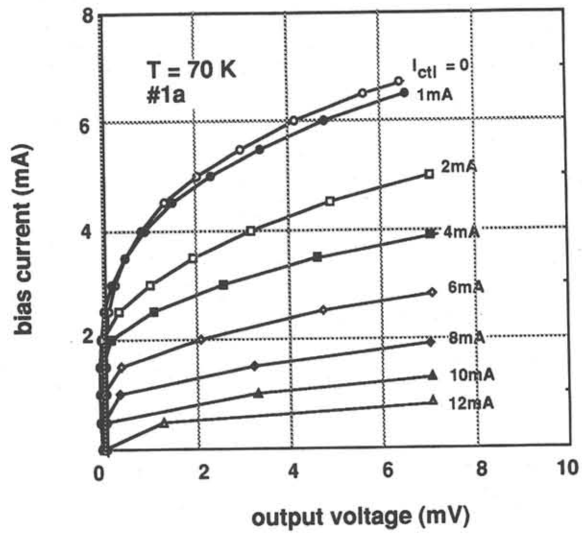
In this measurement, a cryostat shield by two layers of permalloy planes was utilized, in which a magnetic field outside was attenuated by a few of thousand times. The current-voltage characteristics were recorded using a source measure unit with a four terminals method.

3.Result and discussion

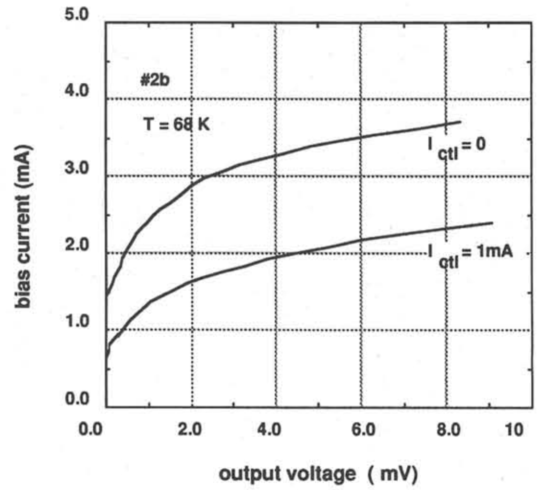
For fabricated devices, the each bias current vs output voltage characteristic of the channels exhibits a vortex flow behavior in region over critical currents and no Josephson effect was observed at temperature from 10K to 77K. In figure 2 (a), the bias current vs output voltage(said as vortex flow voltage) curves as a function of control currents I_{ctl} at 70K for typical device as well as a transistor operation are shown. With the control current increase, a remark change of the curves is seen. It is indicated that the output voltage is able to be modulated by control currents through magnetic field and vortex field. The figure 2 (b) shows the output characteristics of another device with higher transresistance. We believe that formed inclined planes of thin films in channel would have a low lower critical field H_{c1} confronting control magnetic field. This is resulted in anisotropy of the $Y_1Ba_2Cu_3O_{7-y}$ thin films. The H_{c1} along a,b plane of crystals is lower than that of in c axis direction.[16-18]

Measurements on important parameters of high T_c SFFT were performed. A critical magnetic field, over which the vortex flow voltage occur, was measured by a new method. [19] we found that the critical magnetic field is about 0.9 G for the $Y_1Ba_2Cu_3O_{7-y}$ SFFT at 70 K. The vortex flow velocity was also estimated from the magnetic field dependence of I-V curves.[13-14] The order of 10^6 m/s for our devices was obtained.

In order to confirm operation of the $Y_1Ba_2Cu_3O_{7-y}$ SFFT, the alternating characteristics were investigated



(a)



(b)

Figure 2 Current-voltage characteristics as a function of control currents for typical $Y_1Ba_2Cu_3O_{7-y}$ SFFT.

using the measure system shown in Fig. 3. The bias current was about 3 mA. A direct current of about 1mA was also supplied to the control line. An alternating current of about 0.1 mA (peak to peak) and 1KHz was applied to the input of the device to modulate the control current. And then peak to peak voltage of 1.2 mV with a small warp was observed from the output. Figure 4 shows the alternating signal at the output. Hence we obtained the alternating transresistance of about 12 Ω for our device. The output resistance was also found to be 3~5 Ω.

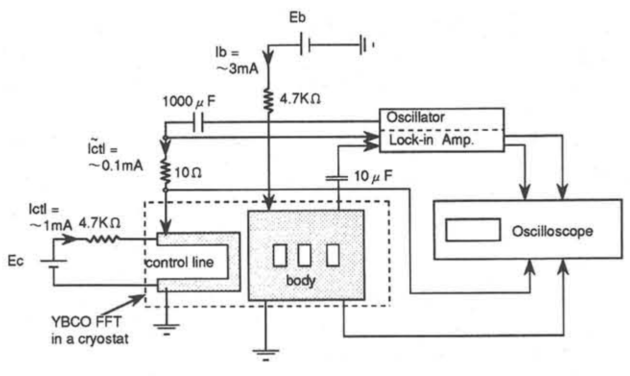


Figure 3 Simplified diagram of the system used to measure alternating modulation

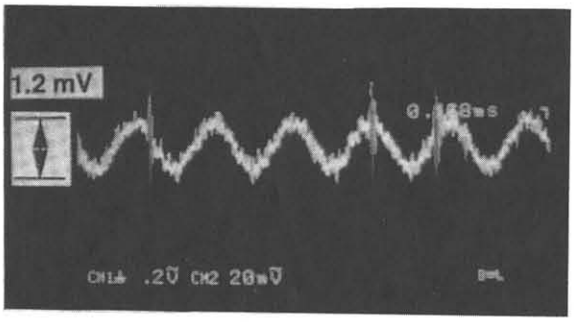


Figure 4 A photography of observed alternating signal at output of the $Y_1Ba_2Cu_3O_{7-y}$ SFFT.

4.Conclusion

We have reported fabrication and characteristics of $Y_1Ba_2Cu_3O_{7-y}$ superconducting flux flow transistors. Reproducible transistors operating over 70K were obtained. The critical magnetic field of the channel was found to be 0.9 G at 70K and the vortex flow velocity was estimated to be order of 10^6 m/s. Alternating characteristics showed transresistances of over 10 Ω and output resistances of 3~5 Ω for made device.

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