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C—2—6 Hysteresis Loop in Current-Voltage Curve for $BaPb_{0.7}Bi_{0.3}O_3$ Josephson Junction Array in a Microwave Field

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Microwave-induced dc voltage as high as a few milli-volts and a hysteresis loop between two voltage steps of opposite polarity are presented,using a $BaPb_{0.7}Bi_{0.3}O_3$ Josephson tunnel junction array. Furthermore,switching of the induced voltage by current injection of only a few micro-amperes($\sim$50 A/cm^2) is demonstrated.

Polycrystalline $BaPb_{0.7}Bi_{0.3}O_3$ film possesses multi-tunnel Josephson junctions at grain boundaries(1) and is expected to be further developed for use as a future microwave receiver and a computer logic element. The critical temperature is about 9 K. The grain size ranges from 0.2 to 0.3 μm. A sample of 0.35 μm thick ,12 μm wide and 12 μm long is soaked in liquid helium(4.2K). About 1.8 GHz microwave signals are guided through a coaxial cable to its end,which is separated from the sample by 2.5 mm. The film is oriented so as that the axis of the guide is normal to the film plane. The microwave source power injected into the sample is evaluated to be the order of 1 pW (10^{-15}– 10^{-14} $W/\mu m^2$).

DC 2 mV is induced without biasing by microwave irradiation. The maximum microwave-induced dc current flowing through the sample is observed to be about 2 μA.

Figure 1 shows a typical example of a current-voltage curve obtained using the four-terminal circuit. The load resistance is 10 kΩ. A distinct hysteresis loop,which is almost rectangular,appears in the curve. It has two stable voltage points at zero bias current. The voltage polarity skips oppositely when injection current exceeds 2 μA,which is just equal to the maximum induced dc supercurrent mentioned above. For simplicity,let's call the current required for the voltage skip the threshold current I_{th}. The skip between the two stable points occurs at I_{th}. Each voltage across the individual junction changes to the opposite polarity simultaneously. This behavior manifests the strong coupling among junctions.

Threshold currents for three samples of 6,12 and 24 μm in width in the same chip are shown in Fig.2 as a function of rf power. It is clear that the threshold current depends on the sample width in proportion as well as on rf power,as anticipated from the dependence of maximum Josephson current of a single Josephson junction on the width and rf power. While,microwave-induced dc voltage without biasing is observed to exhibit a tendency to be proportional to the width. Therefore,it is possible to design the hysteresis loop size by selecting sample length and width.

Figure 3 demonstrates voltage switching by the pulsed current injection between two voltage steps in the hysteresis loop shown in Fig.1. Current pulse height is 2.5 μA(about 60 A/cm^2) and pulse repetition rate is 1 kHz. It is clear that the voltage switching from 2 mV to -2 mV or vice versa can easily be realized by as low injection current as a few micro-amperes. The output voltage waveform is insensitive to the current pulse waveform distortion,because the hysteresis loop is almost rectangular.

In summary,the nearly rectangular hysteresis loop determined mainly by the microwave-induced dc high voltage and the maximum dc supercurrent appears in the current-voltage curve for the coherently coupled multi-junction array of $BaPb_{0.7}Bi_{0.3}O_3$ superconducting film. The hysteresis loop can be used effectively for voltage switching by slight current injection in future elements.

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Reference: (1) Y.Enomoto,M.Suzuki,T.Murakami,T.Inukai and T.Inamura:Japan.J.Appl. Phys.,20,9,L661,1981

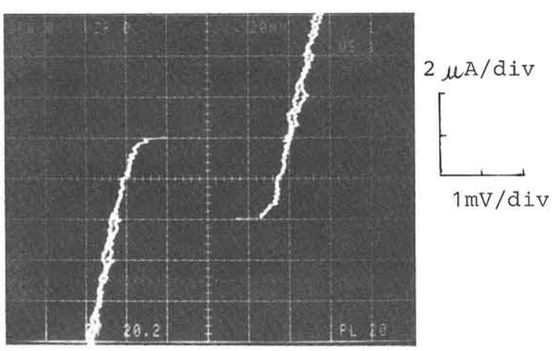

Fig.1 Hysteresis loop in I-V curve under microwave irradiation

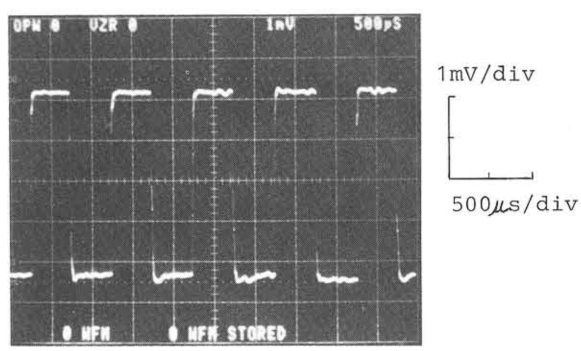

Fig.3 Voltage switching by ± 2.5 μA current injection

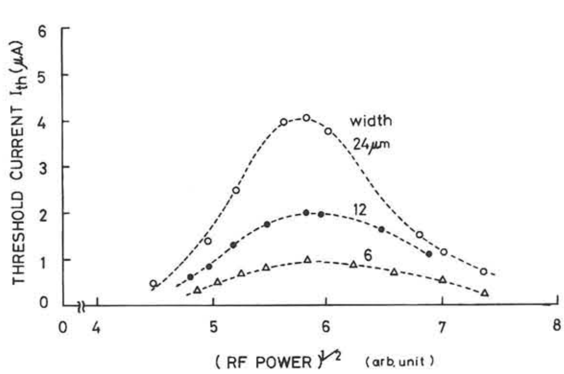

Fig.2 Threshold current for three samples with different widths. The evaluated rf power density is the order of 10^{-15}-10^{-14} W/μm^2.