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Effect of quasi-particle injection on retrapping current of Josephson junction

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Abstract

We report that the energy dissipation of Josephson junction can be controlled by quasi-particle injection. We fabricated two Josephson junctions on the narrow aluminum wire and controlled the energy dissipation of one junction by quasi-particle injection from the other. We observed the retrapping current increased as the quasi-particles were injected. We also studied the heating effect of our measurement.

Key words: Quasi-particle injection, Small Josephson junction, McCumber-Stewart parameter

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Macroscopic quantum tunneling is one of the most important issues in modern physics. Tunneling of macroscopic variables is expected to be significantly affected to the quantum friction associated with the tunneling [1]. First experimental study of controlled friction was done in single small Josephson junctions by implementing ohmic dissipaters at very vicinity of the junctions [2]. The ohmic dissipaters in the experiment were small strips of resistive alloy with fixed resistances. For further investigations of quantum friction, more controllable dissipater is desirable. In this paper we propose a method for manipulating the dissipation with quasi-particle injection. Dynamic characters of Josephson junction can be predicted by RSJ model which describes an actual Josephson junction as a equivalent electric circuit containing the capacitance and resistance. The resistance, the energy dissipation, stems from quasi-particle tunneling. In this study, we controlled the quasi-particle tunneling resistance by varying the quasi-particle density in the superconducting electrode with injection. Figure1 is a schematic diagram of the multi-terminal Al/AlO$_X$/Al junction device. Two junctions located 2μm apart share one of the electrodes. The junction area was 0.2μm × 0.2μm. We measured *I-V* characteristic of one junction while injecting quasi-particles from the other. The device was fabricated with the electron-beam lithography and the shadow evaporation. Mea-

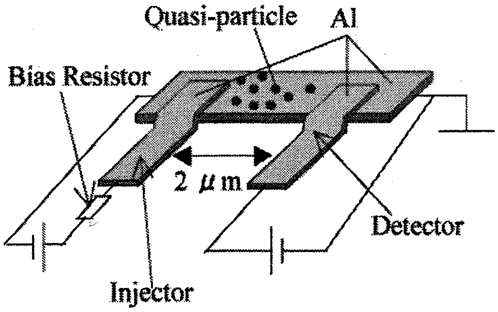

Fig. 1. Schematic drawing of a device structure.

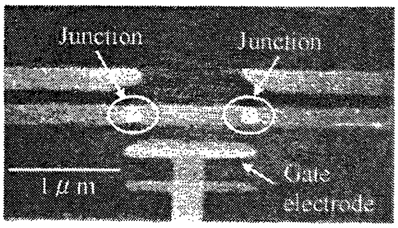

Fig. 1. A scanning electron micrograph of the fabricated SET transistor.

was 0.5 torr and excitation power was 200W. The junctions were quite stable that the resistance were approximately unchanged after leaving them in the atmosphere of air for one week.

We measured transport properties of the SET device at T=90mK with dilution refrigerator. Fig.2 shows voltage-current characteristics for different gate voltages V_g varied between 2.736mV and 2.832mV. For V_g=2.736mV. Coulomb gap was visible at vicinity of zero bias voltage. The total capacitance($C_\Sigma=2C+C_g$ C: junction capacitance, C_g: gate capacitance) of the sample was estimated to be 1.87fF from this Coulomb gap. In the figure, we could observe $V-I$ characteristics varying with V_g. Measurements of detailed behavior of tunneling current against the gate modulation is depicted in Fig.3. Constant voltages -0.047mV, -0.023mV, 0.024mV, 0.047mV and 0.071mV were applied to the source the drain. Periodic oscillations occured because the SET transistor switched on and off periodically as V_g was changed. Gate capacitance(C_g=e/Δ V_g) was estimated from period Δ V_g of Coulomb oscillation to be 0.80fF.

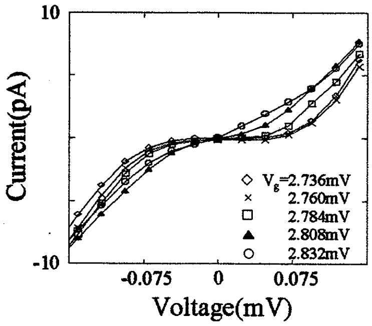

Fig. 2. $I-V$ characteristic of the chromium SET transistor for different gate voltages.

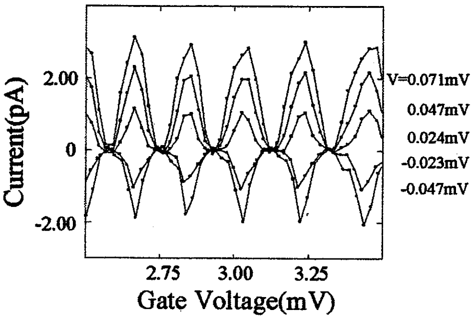

Fig. 3. Gate voltage dependence of tunnel current under fixed bias voltages.

Finally, we comment on the quality of the tunnel junctions. The zero bias resistance for the Coulomb blockade state was estimated to be about 440MOhm which was about 54 times larger than the tunnel resistance. The measured zero-bias resistance apploximately agreed with the theoretical estimation based on the orthodox theory using the appropriate temperature. This allowed us to estimate the quality of tunnel junction to be sufficient for the single electron device.

Acknowledgements

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