A PROGRAMMABLE JOSEPHSON VOLTAGE STANDARD CHIP USING ARRAYS OF NbN/TiN/NbN/TiN/NbN DOUBLE-JUNCTION STACKS OPERATED AT 10K

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Abstract

A programmable Josephson voltage standard chip using arrays of NbN/TiN/NbN/TiN/NbN double-junction stacks was fabricated and operated at 10 K. The circuit with over 260 000 junctions showed constant voltage steps at +/- 6 V when driven at 11 GHz microwave bias. Further investigation is required to achieve 10 V operation at the desired design frequency of 19 GHz.

Introduction

A Programmable Josephson Voltage Standard (PJVS) was first demonstrated by Hamilton et al. in 1995 [1] and has some attractive features: (1) sub-millisecond voltage settling time, (2) large operating current range (>1 mA), and (3) inherent voltage stability against noise. We have been developing a PJVS system using NbN/TiN/NbN junction arrays that can be operated with a compact cryocooler [2]. NbN has a critical temperature of 16 K, and a chip consisting of NbN/TiN/NbN junctions can be operated at a temperature higher than that of liquid helium, which leads to a more compact, lower-power system. We have previously demonstrated operation of a PJVS chip with 1V output [2] and are developing chips with output voltages of 5 V and 10 V. Here we report the fabrication and electrical characteristics of a PJVS chip composed of arrays of NbN/TiN/NbN/TiN/NbN double-junction stacks.

Fabrication

Figure 1 shows the layout of metal layers in a PJVS chip designed for obtaining constant voltages of 5 V or 10 V. The edge of the square chip is 15 mm. First, we fabricated a chip using our NbN/TiN/NbN junction technology, which yielded step amplitudes of about 1 mA at the 5 V target voltage. To achieve a 10 V target output voltage in the present study, we use our stacked double-junction technology [3]. Figure 2 illustrates the equivalent circuit of a fabricated chip. Microwaves are fed to the chip at the coplanar waveguide launch at the top and delivered in parallel to 32 arrays of stacked double junctions through a 1:32 microwave distributor and 16 DC blocks. There are 8192 junctions and a 50 ohm termination resistor on each array. The microwave distributor consists of coplanar waveguide splitters, while interdigitated capacitors define the DC blocks. Bias currents are supplied to the junctions through quarter-wave low-pass filters at the 19 GHz design frequency. The circuits were fabricated on a Si wafer of 3-inch diameter.

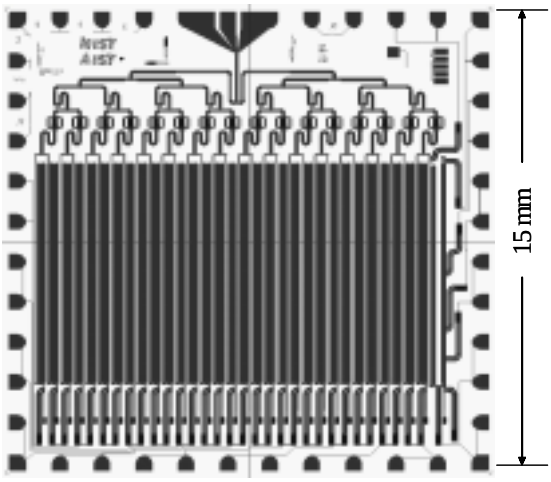

Fig.1. Layout of metal layers in a PJVS chip.

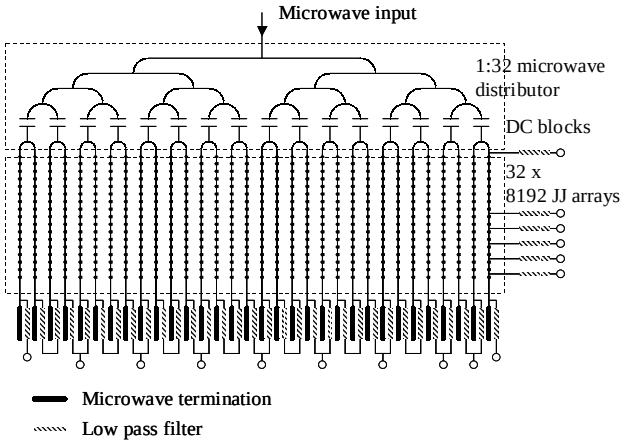

Fig.2. Equivalent circuit of a PJVS chip.

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Figure 3 shows the cross section of a fabricated chip. First, a MgO etch-stop and NbN base wiring films were rf-sputtered. Stacked double junctions were fabricated by sequentially depositing a NbN lower electrode, a TiN lower barrier, a NbN middle electrode, a TiN upper barrier, and a NbN upper electrode. The first and second insulation layers were made by sequentially depositing films of SiO_2, Si, and SiO_2. Pd resistors are rf-sputtered and patterned using a lift-off method. Via-holes in the insulation layers were patterned with reactive ion etching in a mixture of CF_4 and H_2 gases. Finally, two NbN films were deposited for the wiring layer. A chemical-mechanical-polishing process planarized the first wiring layer. All the NbN and TiN layers were defined by reactive ion etching in CF_4 gas.

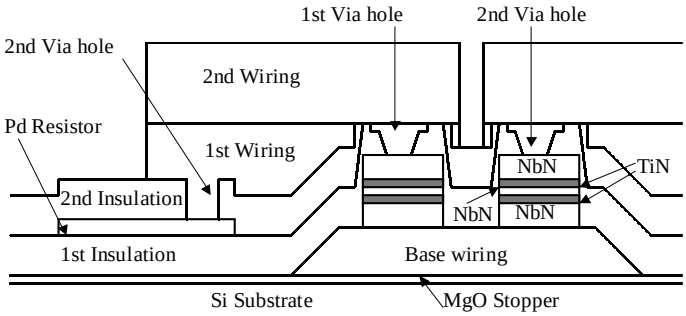

Fig.3. Cross section of a PJVS chip.

Current-Voltage Characteristics

Figure 4 depicts a fabricated voltage standard chip that is wire-bonded to a chip carrier. Microwaves are launched to the chip through the carrier using a semi-rigid coax. The chip and the chip carrier are shielded with a mu-metal box and cooled to 10 K in the vapor of a liquid helium dewar. Unfortunately, the circuit does not produce large flat steps at the 19 GHz design frequency, probably due either to resonances in the microwave distribution circuit or circuit heating due to inadequate cooling in the helium vapor. However, it did operate well at 11 GHz. Figure 5 shows the measured current-voltage characteristics at 10 K with 11 GHz applied microwave irradiation. Constant voltage steps are observed at +/- 6 V and appear flat over a 2 mA current range within the 2mV resolution on the 10 V scale of a 12-bit ADC. This indicates good yield for the 260 000 junctions on this chip.

Summary

A voltage standard chip with more than 260 000 junctions was fabricated using a stacked double-junction technology. The fabricated chip showed constant voltage steps with a current-range of approximately 2 mA at +/- 6V when driven with 11 GHz microwaves and operated at 10 K.

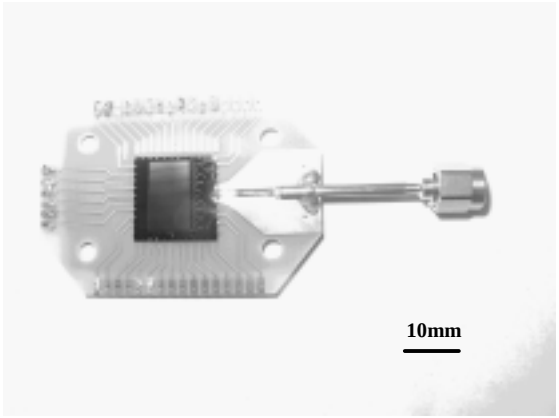

Fig.4. A PJVS chip mounted on a chip carrier and a coaxial cable for microwave irradiation.

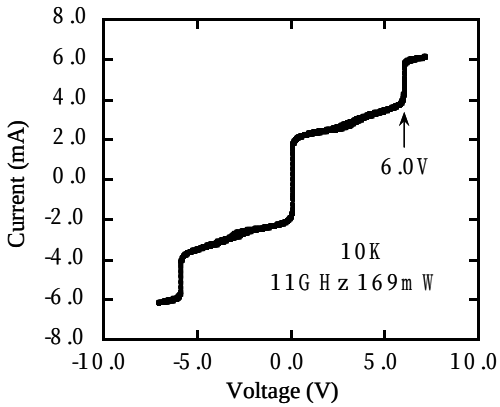

Fig.5. *I-V* curve for the array of 262 144 junctions on a PJVS chip irradiated by 11GHz microwaves.

References

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