Digest of Tech. Papers *The 11th Conf. (1979 International) on Solid State Devices, Tokyo*

C—2—1 Experimental Integrated Microwave Circuits with Josephson Junction

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Josephson junctions are attractive in microwaves as signal sources, detectors or mixers due to their very wide available frequency range. When applying Josephson tunnel junctions, however, difficulties arise in matching the very low impedance junctions with the outer microwave circuit[1].

In this work we have studied the possibility of realizing the whole microwave circuit as an integrated thin film structure. One Josephson junction is operating as signal source and another as detector. The junctions are coupled to each other through a low impedance microstrip transmission line. The whole circuit is prepared on a single substrate in a combined vacuum process. The structure is depicted in Fig. 1. The junctions are sandwiches consisting of a niobium bottom film, a niobium oxide barrier, and a lead film prepared as described previously[2]. The microstrip is composed of the joint niobium electrode of the junctions and a separate lead strip insulated from the junctions by a silicon oxide film. The thickness of this film was chosen to match the characteristic impedance of the microstrip with the impedance of the junctions. Several circuits were prepared with junction dimensions varying from $0.25 \times 0.1\ \mathrm{mm}^2$ to $0.1 \times 0.03\ \mathrm{mm}^2$. The maximum Josephson current density was varied within the limits $0.2 \ldots 0.8\ \mathrm{A/mm}^2$ by varying the oxidation time.

The circuit enables a very simple measuring arrangement. The electromagnetic wave emitted by the signal junction produces changes in the current-voltage characteristics of the detector junction, Fig. 2. Because neither the signal source nor the detector is calibrated the magnitudes of the signal power and the coupling efficiency are obtained only approximatively.

Fig. 3 shows the relative detector current I/I_o as a function of the generator current I_g for junctions with a small current density. The great change in the maximum current occurring in the beginning of the curve ($I_g \approx 20\ \mu\mathrm{A}$) is probably caused by the plasma frequency radiation of the generator current. Biasing to this operating point was possible without using external magnetic field for adjusting the maximum current of the detector junction provided that the generator had trapped one flux quantum.

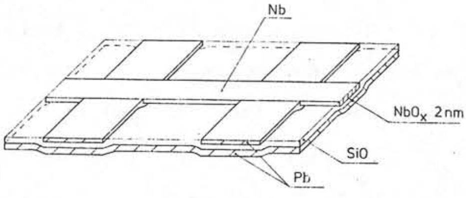
At the first current step, operating point b in Fig. 2, the maximum of the detector current was a linear function of the generator supercurrent. The coupling efficiency in this range was estimated to be 20 %.

In junctions with a high Josephson current the relationship between I/I_o and I_g was more complicated, Fig. 4. In this case the self field of the detector current causes additional complications in the characteristics. In these high current junctions the generator produced current steps in the detector up to the voltage 1.2 mV.

References

1. Sirkeinen Y., Somervuo P. and Wiik T.: Rev. Phys. Appl. 9 (1974), 131
2. Wiik T. and Stubb T.: J. of the Japan Soc. of Appl. Phys. 43 (1974)

Fig.1 The experimental circuit as seen through the substrate



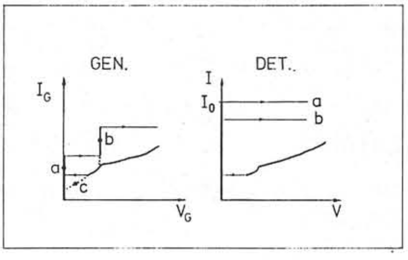


Fig. 2 The operation of the tunnel junctions as a generator and detector

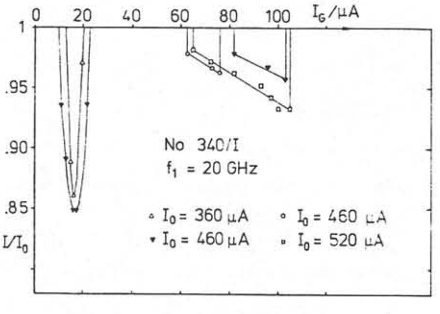


Fig. 3 The relative detector current vs generator current for small current junctions

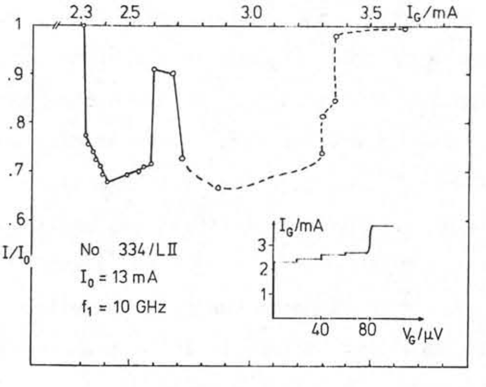


Fig. 4 The relative detector current vs generator current for a large current junction