A 77 K COMPUTER CONTROLLED MM WAVE SPECTRAL JOSEPHSON DETECTOR USING MICROSTRIP TECHNIQUE, PRELIMINARY RESULTS

M. Daginnus and J.H. Hinken

Institute of High-Frequency Engineering
Technical University of Braunschweig
P.O. Box 3329, D-3300 Braunschweig, F.R.G.

ABSTRACT

Superconducting granular bridges of Y-Ba-Cu-O show the ac Josephson effect. A spectral detector is built up with a granular bridge as the sensor, which is coupled to a microstrip line. The device is operated in the millimeter wave range (Ka-band) in liquid nitrogen at a temperature of 77 Kelvin.

INTRODUCTION

In superconducting electronics, Josephson point - contacts are well known for the application of very sensitive spectral detectors, especially in the millimeter wave range [1], [2]. The change of their dc V(I) characteristic on injection of a RF signal, contains information about the signal power P_1 and, in addition, allows a direct determination of the signal frequency f_1. A device with these features we call a spectral detector. Standard semiconductor devices need a separate local oscillator for the determination of the signal frequency. A Josephson spectral detector makes use of the first Shapiro step. The voltage V_1 of this first Shapiro step is derived from the second Josephson equation as

$$V_1 = hf_1/(2e) \qquad (1)$$

(h = Planck's constant; e = elementary charge).

Up to now any application as a Josephson detector was restricted to temperatures lower than 20 Kelvin, due to the available superconducting metals and alloys. Practical devices were operated at liquid helium temperature or even below.

During the last two years, several authors reported, that some devices of granular superconducting high-T_c material show V(I) characteristics with a behaviour, which is similar to Josephson point -contacts even up to temperatures above 77 Kelvin [3], [4]. Now they can be operated with inexpensive liquid nitrogen cooling. This work describes the operation of an experimental detector with one of these devices, a granular bridge of Y-Ba-Cu-O, as the sensor.

GRANULAR BRIDGES

We manufactured the granular bridge from a bar of bulk Y-Ba-Cu-O material of about 10 mm × 1 mm × 1 mm. Thin gold layers are evaporated on the contact areas, where thin dc-V and -I copper leads are connected by the use of silver paint. Protections are taken against mechanical breaking of the sample by gluing it to a ceramic substrate, see fig. 1, and then a cut is set to reduce the cross sectional area of the bar.

The quasi-twodimensional structure gives the possibility to integrate the granular bridge into a planar circuit, as we shall show below. Another advantage, compared to standard point-contact structures, which are made out of two pieces, is the renunciation of mechanical adjustment during operation.

The granular bridge is not to be confused with a microbridge or a VTB (Variable Thickness Bridge) [5]. All dimensions of this Y-Ba-Cu-O device are large compared to the coherence length of the material. A random network of intergrain boundary Josephson junctions is responsible for the appearance of Shapiro steps in the dc V(I) characteristic, if a RF signal is injected.

CH2725-0/89/0000-0631$01.00 © 1989 IEEE

1989 IEEE MTT-S Digest

PLANAR CIRCUIT OF THE DETECTOR

The planar circuit is shown in fig. 2. It consists of a broadband transition from Ka-band waveguide to microstrip line with low impedance. The granular bridge is mounted as a termination to the microstrip line. A final stub provides a short circuit at the plain of the reduced cross sectional area of the granular bridge, which is positioned over a narrow slot across the strip. The ends of the strips are contacted to the bridge by additional gold layer areas. All dc lines show high input impedances for high frequencies to avoid RF losses in the millimeter wave region.

THE MEASUREMENT SET-UP

The granular bridge and the planar circuit are mounted in a suitable housing with a Ka-band waveguide flange. This housing is immersed liquid nitrogen in a simple cryostat (see fig. 3). The RF signal is fed through a waveguide. Signal frequency and power can be varied and measured at the flange plain of the cryostat. The dc V(I) characteristic of the granular bridge is sampled by setting the dc current and measuring the dc voltage. Using a chopped millimeter wave generator, the voltage is measured without and with millimeter wave injection before setting a new bias point. A very sensitive preamplifier in connection with a low pass filter to reduce external noise is needed for an exact measurement of the voltage. The measurement procedure is controlled by the computer. The stored data will be used to calculate the signal power and the frequency.

FIRST MEASUREMENTS

An example of dc V(I) characteristics of a granular bridge is given in fig. 4, measured at 77 K. The curve on the right hand side is obtained without injected RF signal. The bridge shows a critical current of $I_c = 14.2$ mA. Rather small noise rounding is seen at the transition from the superconducting to the resistive part of the curve. The resistive part has a nearly constant differential resistance of $R_d = 13$ mΩ. It will not change for larger bias currents I, at least to the maximum measured value of I = 100 mA.

The other curves show the deformed characteristics by injection of a 35.5 GHz signal of different power levels to the detector. The left hand curve is obtained with the maximum injected power (0 dB), the other ones are due to attenuations of 0.3, 3, 6, and 10 dB.

With increasing the signal power, the first Shapiro step appears at a voltage $V_1 = 73.5$ μV and the width ΔI_1 of it grows. If more signal power is applied, ΔI_1 will decrease again, but the detection regime will not be extended to these power levels. Some of the curves in fig. 4 show the second Shapiro step at a voltage of $V_2 = 2\ V_1$. The decrease of the critical current I_c by the injection of the applied millimeter wave signal is not shown in the right scale. For better separation of the curves we gave a negative dc current offset to the characteristics with incident signal power. Signal injections at other frequencies result in corresponding curves.

The measurements of the described detector have not been finished yet. It will soon be characterised by the values of minimal detectable power, dynamic range and sensitivity.

CONCLUSION

After the first observation of the ac Josephson effect in granular devices with the new high-T_c superconductors about almost two years ago, an application for a Y-Ba-Cu-O granular bridge as a sensor for a millimeter wave spectral detector is presented here. It is supposed to be one possibility for the use of high-T_c superconductors in microwave and millimeter wave systems.

REFERENCES

[1] **Likharev, K.K.; Semenow, V.K.:** "The characteristics of a superconducting point contact Josephson detector. Selective mode of operation," Radio Eng. Electr. 18 (1973) 1892-1899

[2] **Rieger, M.:**
Mikrowellen-Detektion mit Josephson-Elementen. Dr.-Ing.-thesis, Technical University of Munich, F.R.G., 1988

[3] **Fan, Changxin et al.:**
"Observation of ac Josephson effect in Y-Ba-Cu-O devices at liquid nitrogen temperature," Solid State Communications, Vol. 64, No. 5, 1987, 689-690

[4] **Higashino, Y. et al.:**
"Observation of the Josephson effect in Y-Ba-Cu-O compound," Japanese Journal of Applied Physics, Vol. 26, No. 7, 1987, L1211-L1213

[5] **Hinken, J.H.:**
Supraleiter-Elektronik. Grundlagen und Anwendungen in der Mikrowellentechnik. Springer-Verlag Berlin Heidelberg New York London Paris Tokyo, 1988

ACKNOWLEDGEMENTS

The authors wish to thank Matthias Kuhn for his contribution to this work in the course of his diploma thesis. This work was supported in part by the Bundesminister for Forschung und Technologie (FKZ 13 N 5480) and by Hans Kolbe & Co. (FUBA Communication). The authors are responsible for the contents of this publication.

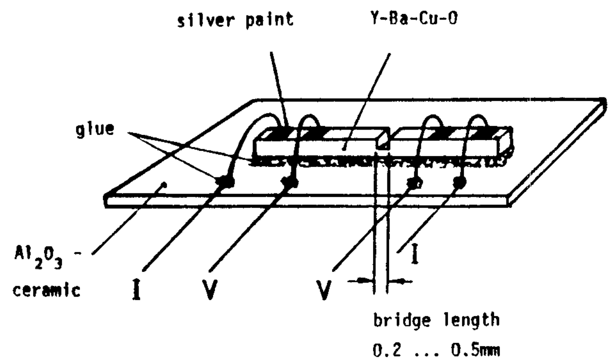

Fig. 1 Sketch of a granular bridge.

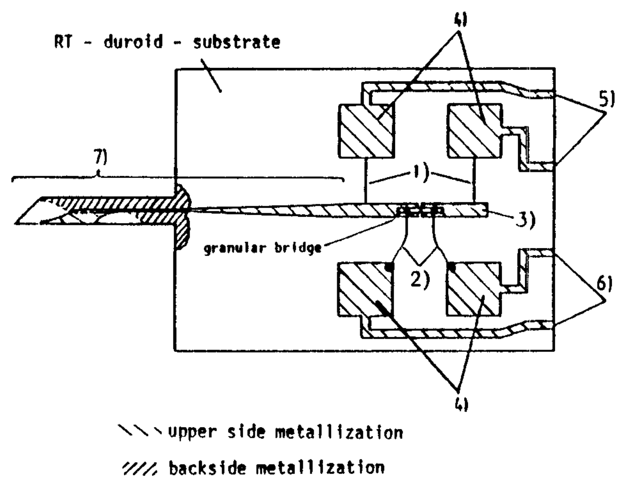

Fig. 2 Planar circuit of the detector.

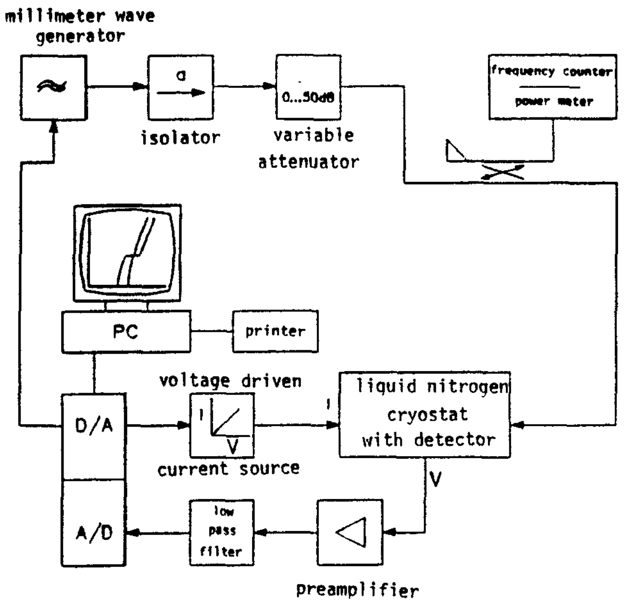

Fig. 3 Block scheme of the measurement set-up.

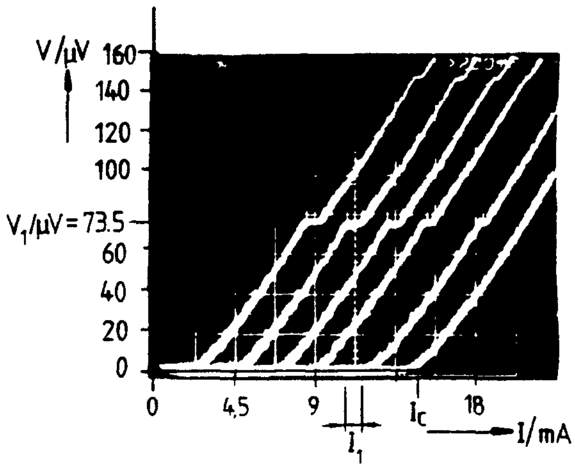

Fig. 4 dc V(I) characteristic of a granular bridge for a millimeter wave signal of f_1 = 35.5 GHz with various power levels, from the left hand curve to the right hand curve : max. power (0dB), -0.3dB, -3dB, -6dB, -10dB and -∞dB.