RESPONSE OF YBCO/PBCO/YBCO RAMP TYPE JOSEPHSON JUNCTIONS TO NEAR MM WAVE IRRADIATION.

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A high T_c Josephson device for high frequency detection applications is being developed, consisting of an YBCO/PBCO/YBCO ramp type junction and a broad band log-periodic antenna. In this contribution we present the response of such a device to (near) mm wave irradiation. Shapiro steps have been observed up to very high voltage values - nearly 4 mV at 10 K, at the maximum of the radiation power. The modulation of the step amplitudes shows very good resemblance with the predictions from the Resistively Shunted Junction model.

1. INTRODUCTION

High T_c Josephson junctions are very attractive for high frequency applications. To make a competitive device, the junctions must meet many requirements [1,2]. The first and most important one is a good response to (sub-) millimeter-wave radiation. Shapiro steps should be observable up to voltages of at least several mV and should modulate with radiation power according to the RSJ model.

We are developing a device for high frequency applications using YBCO/PBCO/YBCO ramp type junctions, placed between the terminals of a log-periodic antenna to improve the coupling to external radiation [1-3]. Design considerations, the fabrication process of the junctions, and their scaling and Josephson properties have been discussed in detail [1,2,4].

In this contribution we present the response of this type of junctions to near mm wave radiation.

The work at Twente was supported by the Foundation for Fundamental Research on Matter (FOM) and the Netherlands Technology Foundation (STW). The work at MIT was conducted under the auspices of the Consortium for Superconducting Electronics with full support by DARPA (contract MDA972-90-C-0021).

2. RESULTS

The presented measurements were performed on two devices, A and B. A has the described layout, with $T_c \approx 80$ K, $I_c \approx 280$ μ A at 10 K and a temperature independent $R_n \approx 3.5$ Ω . B was not equipped with an antenna; $T_c \approx 75$ K, $I_c \approx 100$ μ A at 7.5 K and $R_n \approx 2.5$ Ω . Both devices were fabricated on YSZ substrates, and had a PBCO barrier thickness of about 10 nm.

Irradiation of A with a mm wave signal causes the appearance of many Shapiro steps. Figure 1 shows the current-voltage characteristics (IVc's) at 10 K, 35 K and 65 K. The DC IVc's are shown, together with those for maximum applied 100 GHz power. At 10 K, the 19th step can still be observed at a bias voltage of 4 mV. This corresponds to the presence of AC Josephson oscillations with a frequency of 1.9 THz. At higher temperatures the number of observed steps decreases: 13 are present at 35 K, 5 at 65 K. At all temperatures steps are observed up to voltages far above the $I_c R_n$ product.

Device B, irradiated with a 176 GHz signal, also exhibits Shapiro steps up to high voltages: at 4.2 K, with maximum signal power, at least the 6th step is still observable at 2.2 mV, which corresponds to 1.05 THz AC Josephson oscillations [5].

Figure 1. Current voltage characteristics of device A at 10K, 35K and 65 K, both DC and with 100 GHz irradiation at the maximum power level.

Only few studies are present in literature that report high frequency response up to similar voltage values. Those results, however, were obtained with devices of a less controllable type, e.g. [6].

With increasing power the Shapiro steps demonstrate the proper oscillating behavior. Figure 2 shows for device B at 8K the normalized amplitudes of I_c and the first two Shapiro steps $I_{1,2}$ as a function of $2\alpha = C_{RF}P_{RF}^{1/2}$, where P_{RF} is the applied 176 GHz signal power. The measured data agree very well with a Bessel function behavior $I_n \sim J_n(2\alpha)$, which is expected for this high frequency [5]. C_{RF} was used as fitting parameter, in such a way that the first zero of $J_1(2\alpha)$ coincides with that of I_1 [5].

For device A, with 100 GHz irradiation, a similar good agreement was found between the measured amplitudes of I_c and $I_{1,2}$ and the predictions of the RSJ model [2] at several temperatures.

3. CONCLUSIONS

The presented results show that ramp type YBCO/PBCO/YBCO Josephson junctions have a very high degree of phase locking, up to voltages of at least 4mV, despite the strong reduction of the $I_c R_n$ product. In addition, the amplitudes of I_c and the Shapiro steps are well described by the RSJ model.

All these results indicate that these junctions are

Figure 2. Measured normalized amplitudes of I_c and $I_{1,2}$ of device B as a function of $2\alpha \sim P_{RF}^{1/2}$ at 176 GHz near 8 K. The solid lines are Bessel functions.

very suitable for (sub-) mm-wave applications.

What the limiting frequency for such applications is, and to what extent it is limited by the specific transport properties of the junctions is under investigation.

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