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Microwave power dependence of the $I - V$ characteristics of submicron and micron YBCO constrictions.

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Abstract. In this paper, the femtosecond laser technique was used to fabricate micron and submicron sized Josephson Junctions. The influence of an RF signal of frequency 19.5 GHz on the critical current of the micron sized Josephson junction of width 2.1 μm and the sub-micron sized Josephson junction of width 816 nm was analyzed. Both junctions showed the presence of Shapiro-like steps and critical current suppression due an increase in the RF Power. Critical current suppression occurs due to the varying magnetic field produced by the RF signal power.

Keywords. femtosecond laser, RF Power, Josephson junctions.

INTRODUCTION

Josephson's junctions (JJs) are used in superconducting devices, such as magnetic sensors and in other areas such as metrology [1-5]. Miniaturization of JJs to the submicron and nanoscale is necessary in qubit technology and in nano SQUIDS [6] because the smaller the nano constriction width the more sensitive the Josephson's junction is to the magnetic spin [6]. Several methods have been used for the fabrication (JJs) such as the focused ion beam [7-10], e-beam lithography [11-14], off-axis epitaxial fabrication [15-16] and laser etching methods [17]. In this case, the femtosecond laser technique was used in the fabrication of the micron and submicron sized Josephson junctions but not without its own imperfections [18].

EXPERIMENTAL DETAILS

The Josephson junctions on which the RF tests were done were fabricated using the femtosecond laser technique. The femtosecond laser was used as a lithography tool to cut "S"-shaped constrictions on the YBCO superconducting thin films based on LAO or MgO substrates. The resulting constrictions were patterned with 4-point gold contacts to facilitate $I-V$ measurements. The RF power signal of frequency of 19.5 GHz was introduced on one of the 4-point gold contacts. For $I-V$ measurements, DC current is passed through the sample across two of the gold point contacts. Then the resulting DC voltage is measured across the sample from the other two of the gold point contacts. This is done at same time as the RF signal is superimposed on the sample. The result being a plot of the $I-V$ curve with the RF power superimposed on the sample. Both junctions showed the presence of Shapiro steps. The micron-sized junction showed Shapiro steps at the following specifications, RF frequency 19.5 GHz, RF power level -12 dBm and the temperature was 25 K. The submicron sized junction showed shapiro steps with the RF frequency at 19.5GHz, the RF power setting at -30 dBm and the temperature at 8.5 K.

RESULTS

I-VC's at different levels of RF power and the Critical Current Vs RF power curve for the micron sized Josephson junction.

Figure 1 shows the $I-V$ curves for the micron sized Josephson junctions plotted at different RF power levels. The RF power level was varied on the $I-V$'s at a fixed temperature of 6 K. The RF power is increased from -40 dBm (0.0001 mW) to +5 dBm (3.16 mW) while the critical current reduces, (suppresses) from 774.2 μ A to 2.26 μ A. The critical current was measured at a voltage offset of 70.7 μ V for each value of the critical current. This proves that a Josephson junction is produced because the critical current responds to the presence of an RF signal by decreasing and getting suppressed [19] when the RF power is increased. For this micron junction Shapiro steps were achieved at a temperature of 25 K, power level of -12 dBm and a frequency of 19.5 GHz. The Shapiro steps showed a calculated step voltage of 40.5 μ V and measured step voltage of 40 μ V.

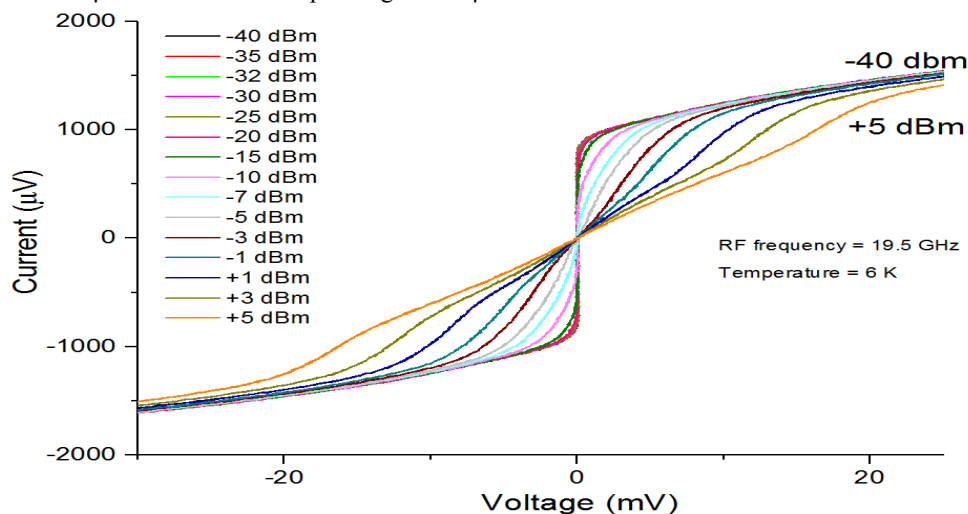


FIGURE 1. I-V curves at different levels of RF signal power for the micron sized Josephson junction, RF frequency 19.5 GHz and temperature of sample at 6 K.

I-VC's at different levels of RF power and the Critical Current Vs RF power curve for the sub-micron sized Josephson junction.

The sub-micron sized Josephson junction showed the $I-V$ curves in figure 2 when the RF signal was applied to the sample with varying power levels. The RF power was varied on the $I-V$'s of the sub-micron junction at a fixed temperature of 8.5 K. The RF power was increased from -40 dBm (0.0001 mW) to -14 dBm (0.0398 mW) while the critical current was suppressed from 86.96 μ A to 2.26 μ A. The critical current was measured at a voltage offset of 54.2 μ V for each $I-V$ curve in figure 2. The fact that the sample responds to the presence of an RF signal with the critical current being suppressed [19] when the RF power is increased proves that a Josephson junction is formed. The sub-micron sample showed Shapiro steps at a temperature of 8.5 K, RF power level of -30 dBm and a frequency of 19.5 GHz. At this frequency, the calculated Shapiro step voltage was 40.3 μ V while the measured step voltage was 42.6 μ V.

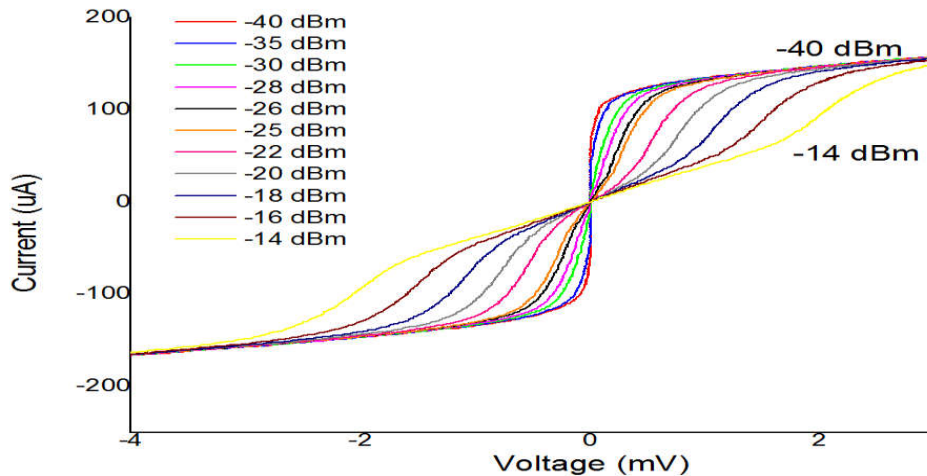


FIGURE 2. I-V curves at different levels of RF signal power for the sub-micron sized Josephson junction, RF Frequency 19.5 GHz and sample temperature at 8.5 K.

CONCLUSION

In conclusion two Josephson junctions were successfully fabricated, the first a micron sized junction and the second a sub-micron sized junction using the femtosecond laser technique. Both junctions responded to the presence of an RF power signal showing Shapiro steps and critical current suppression when the RF power level is increased which proves the AC Josephson Effect.

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