Zeitschrift: Helvetica Physica Acta
Band: 65 (1992)
Heft: 2-3

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DOI: https://doi.org/10.5169/seals-116441

The Effects of Inherent Bond Disorder on the rf Properties of SNS Josephson Junction Arrays

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Abstract. Bond disorder in SNS arrays can arise from non-identical junction lengths. This disorder disrupts the global phase coherence, responsible for the observed giant Shapiro steps, and results in finite step slopes and step rounding. We compare our experimental results with numerical simulations.

Introduction

Recently, integer giant Shapiro steps were observed in two-dimensional (2D) NxN arrays of SNS junctions[1],[2]. Numerical simulations [3] suggest that coherent motion of rf current induced phase slips are responsible for these giant steps. For an array of ideal junctions, at T=0, the step slopes are infinite; however, in experiments, the slopes are all finite indicating that complete phase coherence is being disrupted. Sample fabrication processes of SNS arrays result in varying junction lengths; thus, inherent bond disorder cannot be avoided and is a likely cause for the observed rounding and finite slopes.

Experiments

Figure 1 shows the giant Shapiro steps in the dc IV characteristic for a 300x300 array at T=4.2K with ν_{rf}=90MHz. These steps occur at voltages $V=Nn(h\nu_{rf}/2e)$, where $n(h\nu_{rf}/2e)$, n=1, 2,... , are the Shapiro steps voltages of a single junction. Non-identical junction lengths result in different critical currents I_c, normal state resistances R_n, and thus different characteristic frequencies, $\nu_c=2eR_nI_c/h$, and time-dependent voltage drops, for each junction in the array. Therefore, coherent phase locking will occur for a range of voltages , resulting in a finite step slopes and rounding.

Numerical Simulations

Simulations were performed on an M x N lattice of superconducting crosses with methods similar to that described elsewhere [3]. A uniform distribution of the junction lengths, out to some maximum value σ, were used. The critical current, normal state resistance, and ν_c were, thus, different for each junction. The junctions were randomly arranged on the array.

Figure 2 shows an IV characteristic of a 15x4 array, with a uniform distribution for σ = 0.05. The step rounding and finite step slopes agree with experiment.

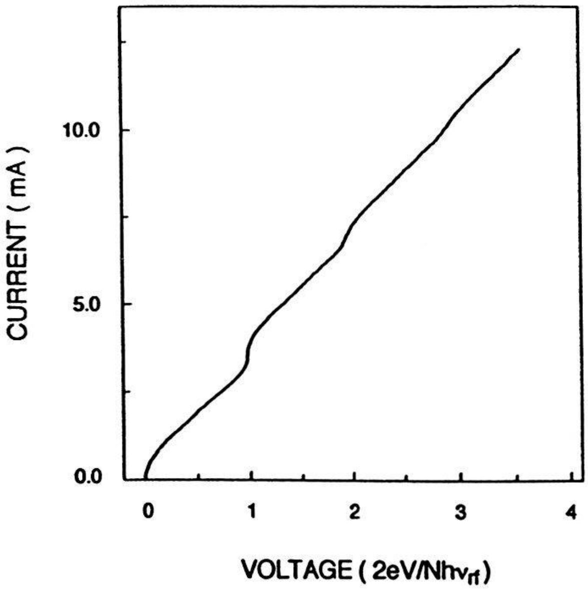

Fig. 1. Giant Step. The I-V characteristics in zero field at T=4.2K with ν_{rf}=90MHz and I_{rf}/I_c=2.1.

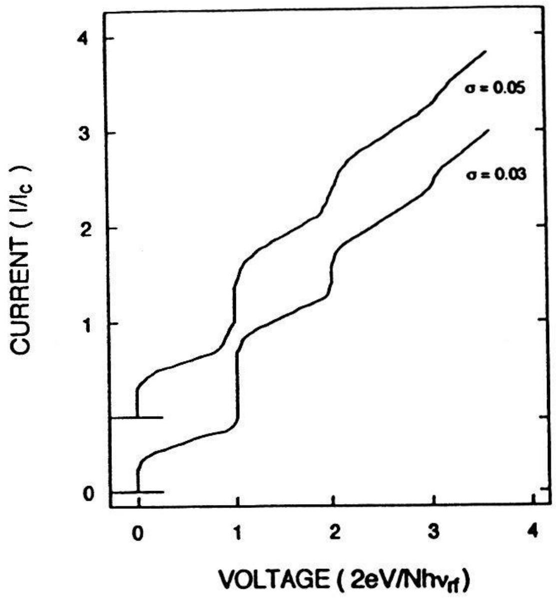

Fig. 2. Numerical simulation with uniform distribution of gap distances and periodic boundary conditions. Ω=1.0 and I_{rf}/I_c=2.0

Conclusions

We have shown, with experiments and numerical simulations, that inherent bond disorder (non-identical junction lengths) in 2D arrays of SNS Josephson junctions introduces finite step slopes and rounding in the integer giant Shapiro steps. The simulations are in good agreement with our experimental data in terms of the degree of step rounding and finite step slope.

The authors are indebted to D. C. Harris for fabricating and J. C. Garland for providing the arrays. This research was conducted with support from USAF Wright Laboratories, Materials Directorate through Aerotherm Corp.

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