Nucleation of superconducting domains in thin s-layers of S-F/N-sIS Josephson devices.

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Introduction

Josephson junctions containing normal (N) and ferromagnetic (F) materials in the weak link region are currently the subject of intense research. The interest in such structures is due to the possibility of using them as a new elements of superconductor memory compatible with the RSFQ logic. At present there are many implementations of such circuits. Among them, the tunnel structures containing single ferromagnetic layer in the weak link region, are of greatest interest. Anisotropy of their properties necessary for operation of the cell is achieved in an analogous way by complicating the structure of the weak-coupling area.

In this work we describe effect of nucleation of phase domains in superconducting films. They are induced with proximal fields through ferromagnetic and normal layers. We also consider possible applications of this phenomenon and propose some devices: Josephson lay and memory elements.

S - Domains

Pair Potential Δ

Pair amplitude and phase

Memory

Reading

Features

- Switching by Josephson currents
- Doesn’t require remagnetization of F-layer
- Scales in order of 100-200 nm

Basics

Numerical Solution

2D Boundary Problem:

Guided Equations

Self-consistent solution

We assume:

- Dirty limit in materials
- Neglect suppression in S-electrodes
- Structure is much smaller than Josephson penetration depth $\lambda_J \ll \lambda$

- Josephson energy $\Phi_0$ of junction $\Phi_J$

- Pairing energy of junctions with volume $\Phi_J$

Analytical Estimates

The relation between two component of phase energies:

$$\Delta E_{EM} = \frac{\Phi_0}{\lambda_J^2} (\lambda_J^2 + \Phi_J^2) \\ \Delta E_{EM} = \frac{\Phi_0}{\lambda_J^2} \Phi_J^2$$

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Josephson Key Device

Switching: Horizontal Current

Switching: Vertical Current

Reading of the states depends on the data stored in the cell before the reading. The data written into the current state of the junction is then transferred to the current state of the final state.

$$J_{SW} \approx 0.8 J_{CR}, J_{SW} = 4, E_{wall} = 0.4$$

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- Josephson energy $\Phi_0$ of junction $\Phi_J$

- Pairing energy of junctions with volume $\Phi_J$

- Domain wall energy $\Phi_J$

- Ewall: Domain wall energy $\Phi_J$

- Critical current $I_{CR}$

- Domain: Domain wall energy $\Phi_J$

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