

Study of vortex dynamics in Josephson junction arrays

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Primary CNF Tools Used: JEOL JBX-6300FS, Heidelberg MLA 150 Maskless Aligner, Angstrom E-Beam Evaporator, AJA sputter, Zeiss Ultra SEM, Zeiss Supra SEM, Glen 1000 Resist Strip

Abstract:

An array of superconducting islands deposited on a normal metal film forms the so-called Josephson junction arrays, providing a tunable platform for studying quantum critical phenomena. This system enables the investigation of competing vortex states and the phase transitions [1-4]. Here, we fabricate Nb-Au Josephson junction arrays and study vortex dynamics by combining electrical transport measurements and scanning superconducting quantum interference device microscopy. Our preliminary data shows the presence of periodic vortex lattice formed in the square and hexagonal arrays. Experiments on the vortex dynamics driven by an external current will be studied.

periodic vortex lattices [2]. We also performed scanning SQUID measurements to visualize the vortex lattices at different magnetic fields.

Conclusions and Future Steps:

We successfully fabricated Nb-Au JJAs with the critical temperatures ranging between 5 K and 7 K. Through electrical transport measurements and scanning SQUID microscopy, we detected the presence of vortex lattice in the JJAs, leading to enhancements of the critical currents at specific magnetic fields. We will visualize the motion of vortices driven by an external current for the understanding of the vortex dynamics [3, 4].

Summary of Research:

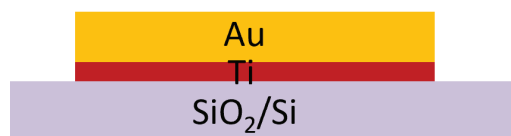
We fabricated Nb-Au Josephson junction arrays (JJA) and studied the formation of periodic Josephson vortex lattices using electrical transport measurements and scanning superconducting quantum interference device (SQUID) microscopy at low temperatures. Figure 1 illustrates the process to fabricate Nb-Au JJAs. First, we patterned Au/Ti (40/5 nm) films on Si substrates using optical lithography and electron-beam evaporations. Then we performed electron-beam lithography and sputtered Nb/Ti (70/2 nm) on the pre-patterned Au/Ti. Figure 2 shows an optical image of an exemplary Nb-Au square JJA device. The Nb islands are only connected by the underneath Au films, forming superconductor-normal metal-superconductor networks.

The JJAs were characterized by low-temperature transport measurements. We confirmed the JJAs are superconducting with the critical temperatures ranging between 5 K and 7 K. Furthermore, we observed maxima in the critical currents as a function of the external magnetic fields, indicating the formation of

References:

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- [2] N. Poccia, T. I. Baturina, F. Coneri, et al., Critical behavior at a dynamic vortex insulator-to-metal transition, *Science* 349, 1202 (2015).
- [3] C. Böttcher, F. Nichele, M. Kjaergaard, et al., Superconducting, insulating and anomalous metallic regimes in a gated two-dimensional semiconductor-superconductor array, *Nat. Phys.* 14, 1138–1144 (2018).
- [4] C. Böttcher, F. Nichele, J. Shabani, et al., Dynamical vortex transitions in a gate-tunable two-dimensional Josephson junction array, *Phys. Rev. B* 108, 134517 (2023)

1. E-beam deposit 40nm Au/5nm Ti



2. Sputter 70nm Nb/2nm Ti



Figure 1: Schematics of fabrication process of Nb-Au Josephson junction arrays.

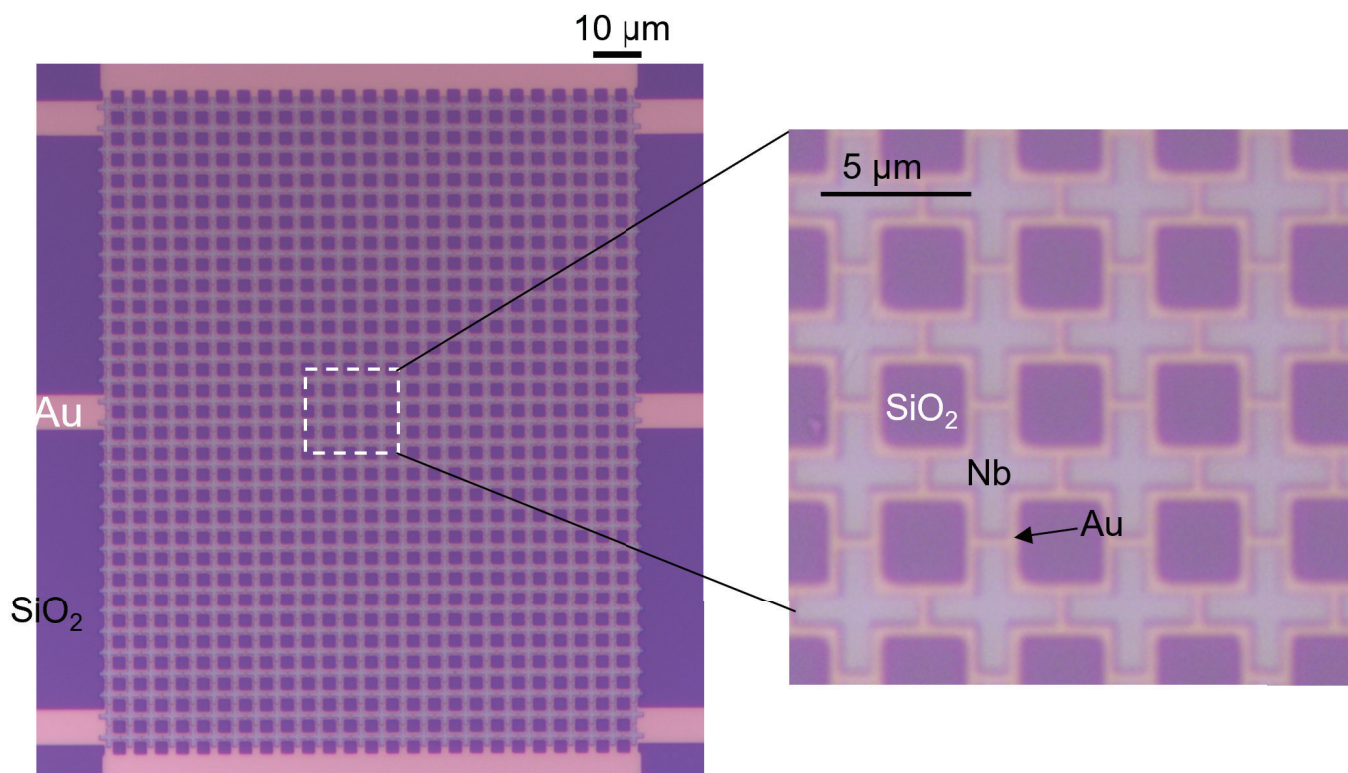


Figure 2: An optical image of an exemplary Nb-Au JJA device.