Fabrication of superconducting qubits at CNF

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Primary CNF Tools Used: Angstrom-Q, JEOL 6300, Zeiss Ultra SEM, AJA-Q

Abstract:

We demonstrate fabrication of superconducting qubits using CNF tools. Josephson junctions of Dolan and Manhattan type are defined using shadow masks. Evaporation and in-situ oxidation are performed using the Angstrom Quantum evaporator.

Summary of Research:

The objective of this project is to demonstrate fabrication of state-of-the-art superconducting qubits at CNF. We fabricate transmon qubits on base layers of tantalum thin films on 100mm highly resistive silicon wafers. The fabrication of the tantalum base layer structures is covered in a separate report.

The main step in the fabrication of superconducting qubits is the deposition of Josephson junctions (JJs). The JJs are fabricated using shadow evaporation and liftoff. In a first step the shadow masks are defined using electron beam lithography (JEOL 6300) in a bilayer resist stack (MMA/PMMA). Using the JEOL6300 ebeam writer we perform lithography on 100mm wafers. The ebeam writer allows loading of two 100mm wafers for each writing session.

We demonstrate both Dolan-type JJs (Fig. 1) which use a suspended PMMA bride as well as Manhattan-type JJs without a suspended bridge (Fig. 2). Initially we used the AJA-Q evaporator for the deposition of Dolan-type JJs providing superconducting qubits with highly promising characteristics.

As part of the CNF-REU summer project we characterized the new Angstrom-Q tool, which is dedicated for the fabrication of Josephson junctions for superconducting qubits (REU student Gabriele Di Gianluca). The Angstrom-Q provides several benefits for the fabrication of JJs:

- fully programmable recipes, high degree of automation
- precise alignment of stage rotation and tilt, ideal for shadow deposition
- in-situ argon ion milling and oxygen plasma descum
- evaporation of ultra-clean aluminum films directly from the copper hearth, without graphite crucibles
- low base pressure p < 1e-8 torr after chamber baking and titanium gettering
- both static and dynamic in-situ oxidation with a tunable Ar/O2 pressure settings

After deposition the fabrication is finalized by a liftoff in a hot solvent. The JJs can be characterized at room temperature using a probe station. After optimization of the recipes in the REU project we obtain resistance variations as low as 2% over single dies. The JJs can be imaged using the Zeiss Ultra SEM , see images Fig. 1 and Fig. 2 below.

Acknowledgement:

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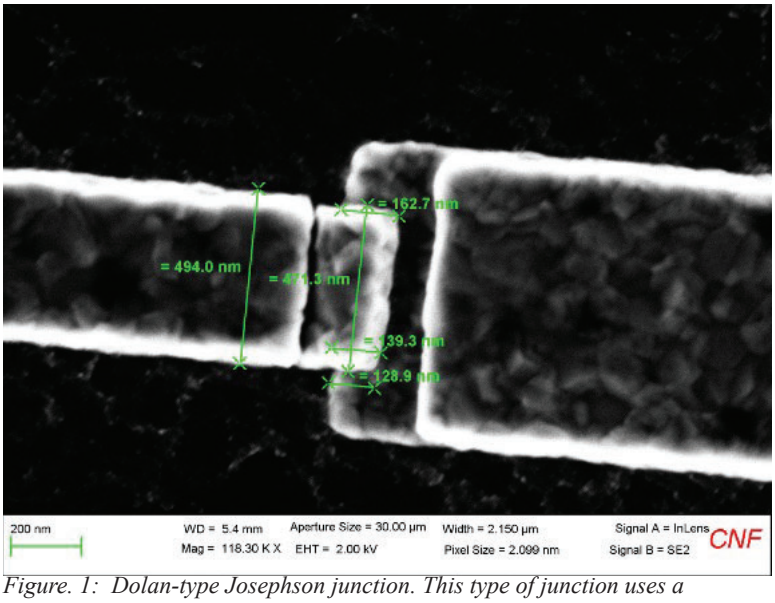

Figure. 1: Dolan-type Josephson junction. This type of junction uses a suspended bridge formed by electron beam lithorgaphy in MMA/PMMA resist. The evaporation of aluminum electrodes and in-situ oxidation is performed in the newly installed Angstrom-Q evaporator.

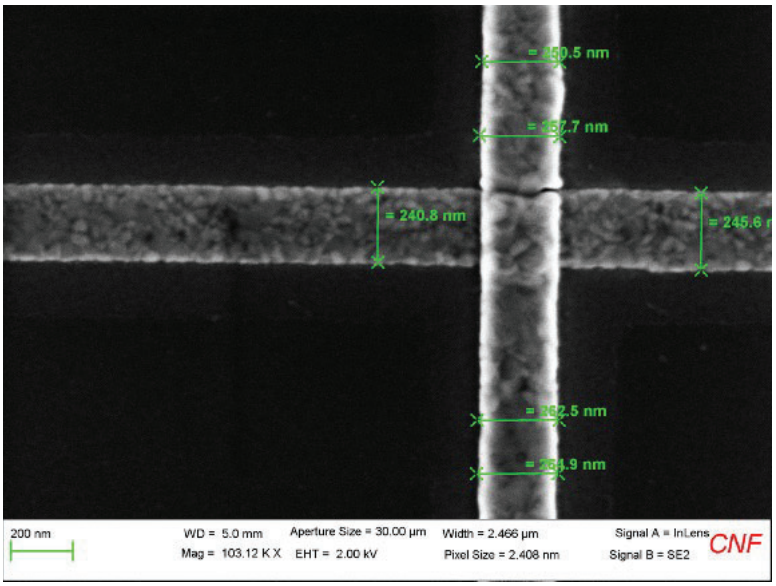

Figure. 2: Manhattan-type Josephson junction with an area of 250nm x 250nm. Lithography of the shadow mask is performed using the JEOL 6300 ebeam writer. The evaporation of aluminum electrodes and in-situ oxidation is performed in the newly installed Angstrom-Q evaporator.