Comparison of two NbTiN-nanowire patterning methods for fabrication of single-photon detectors

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Niobium-titanium nitride (NbTiN) is a superconducting material that is commonly used for superconducting nanowire single-photon detectors (SNSPDs). The core element of an SNSPD is a superconducting nanowire that is current biased just below its critical current and operated at a temperature well below its critical current[1]. The device design, nanowire geometry and material properties dictate the SNSPD performance. Thus, it is essential to pattern superconducting thin films into constriction-free nanowires. This project aims to produce the narrowest constriction-free nanowires to demonstrate efficient SNSPDs at the mid-infrared range.

Here, we present and compare two different NbTiN-nanowire patterning methods. In both ways, 8 nm-thick NbTiN thin films are deposited by DC magnetron sputtering from a NbTi (70/30% atomic weight) target in an atmosphere of argon and nitrogen on silicon-on-insulator substrates. The sputtering process was optimized following an empirical approach presented by Bos et al.[2]. The first patterning method is based on thin film deposition, spin coating of 50 nm-thick ZEP 520A resist, e-beam lithography to define the nanowires, development in ZED-N50 followed by deposition of 20 nm-thick alumina, used as a hard mask, and reactive ion etching with SF_6 and O_2. The second method is based on spin coating of bi-layer PMMA resist on a clean substrate, e-beam lithography to define the nanowires and development in 1:1 methyl isobutyl ketone (MIBK): IPA followed by thin film deposition and lift-off in acetone. The process flow is presented in figure 1. The lift-off approach has the advantage of minimal damage to the substrate and previous layers, making it suitable for integrating SNSPDs in outsourced chips. Nanowires with varying widths were fabricated following the two methods and characterized using a two-point probe to measure their superconducting properties that can inform their geometry, namely the critical current and critical temperature. The nanowires were inspected in a scanning electron microscope to extract their actual dimensions and estimate the critical current density. Figure 2 shows the normalized resistance as a function of temperature for the nanowires patterned following the first method (a) and the second method (b). The critical temperature of the nanowires based on the first method is constant and comparable to that of the thin film. In contrast, it is degraded for narrow nanowires based on the second method due to constrictions in the nanowires. However, this method would suit wide wires larger than 500 nm. Based on the first method, the critical current density of the narrowest nanowire is comparable to values reported in literature[3].

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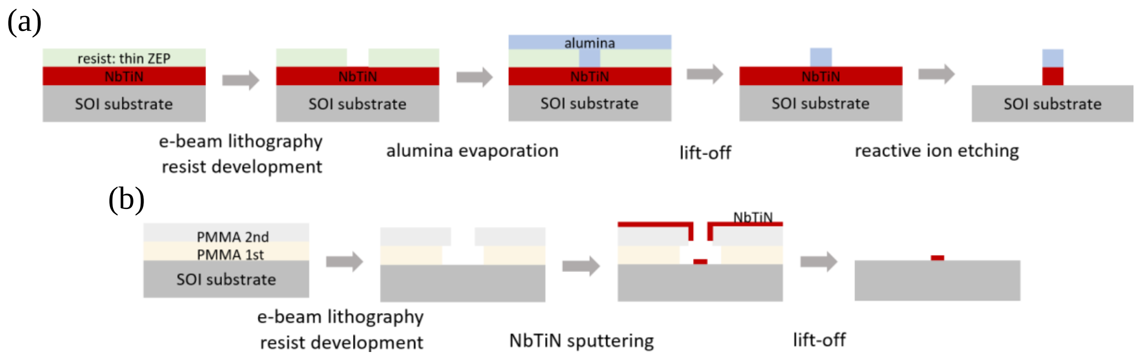

Figure 1: Process flow of the two NbTiN-nanowire patterning methods: (a) the first method: reactive ion etching (b) the second method: bi-layer PMMA resist and lift-off.

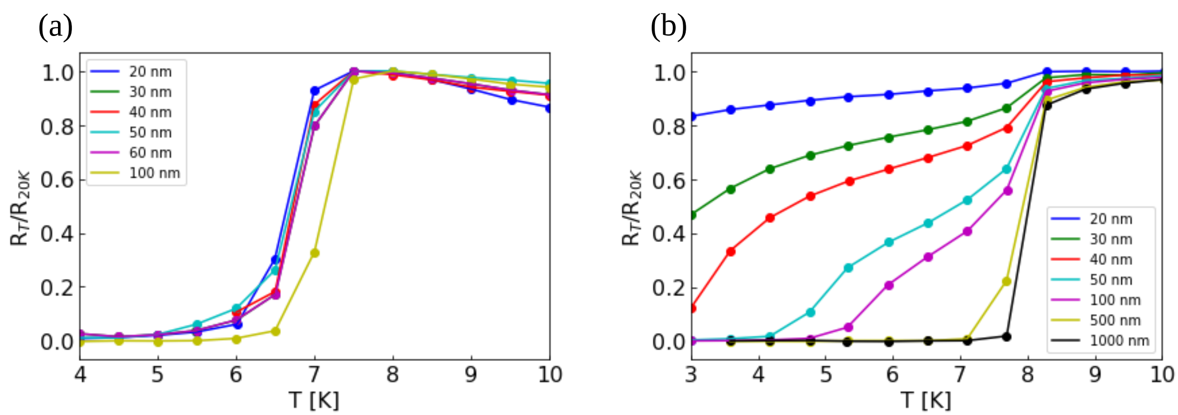

Figure 2: Normalized resistance as a function of the temperature of nanowires patterned through (a) reactive ion etching (2) bi-layer PMMA resist and lift-off.