Fabrication of Nanophotonic Optical Cavity Device from Inverse Design

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Principal Investigator(s): Gregory D. Fuchs[1]

User(s): Jialun Luo[2]

Affiliation(s): 1. School of Applied and Engineering Physics, 2. Department of Physics; Cornell University

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Contact: gdf9@cornell.edu, JL3562@cornell.edu

Website: http://fuchs.research.engineering.cornell.edu

Primary CNF Tools Used: AJA sputtering system, OEM Endeavor AlN sputtering system, JEOL 9500, PT770 etcher, P10 profilometer, GCA 5x stepper

Abstract:

On-demand polarized single-photons are essential in realizing many photon-based quantum communication protocols. We are developing and fabricating a nanophotonic cavity device from aluminum nitride (AlN) to serve as a platform for enhancing single-photon emission from isolated defects hosted in hexagonal boron nitride. The target structure is designed via numerical optimization known as the inverse design. We present an update on our work-in-progress on the fabrication of the device.

Summary of Research:

Hexagonal boron nitride (hBN) has drawn a lot of attention recently because of its bright emission of single photons [1]. The defect emission is stable at room temperature and appears in the visible spectrum [2]. Researchers have been able to find or create isolated defects, making these defects promising candidates for implementing single-photon emitters that are important for quantum communication protocols [3]. In this project, we aim to develop bright, on-demand single-photon emitters using hBN defects. To enhance the emissions we fabricate a nanophotonic cavity device based on inverse design techniques [4]. The structure is designed such that it resonates at frequencies of the emission of the single emitters with a small mode volume.

We take advantage of the similarity in the index of refraction of hBN and aluminum nitride (AlN). Starting from a fused silica wafer, we sputter a 300 nm thick AlN layer using the OEM Endeaver M1 AlN sputter system. In particular, the nanophotonic cavity design has a 600 nm mode that is strongly confined in the center of the structure, thus aiming to enhance the emission rate of isolated defects at that frequency.

The process flow is outlined as follows (Figure. 1). We use the AJA sputter system to deposit a thin layer (of 20 to 30 nm) of chromium (Cr) on top of AlN. The Cr layer serves as a hard mask for the etching AlN. The patterning is done with electron beam lithography (EBL) with the JEOL 9500 and reactive ion etching (RIE) with the PT770 etcher. We choose hydrogen silsesquioxane (HSQ) diluted into 3% solution as the EBL resist due to its sub-10 nm resolution. HSQ is spun on the wafer with a thickness of 10 to 15 nm, which implies an aspect ratio of 1:2 for the subsequent etching of Cr. To avoid charging artifacts on the HSQ resist during exposure, we spin a layer of water-soluble discharge polymer on top of the HSQ. We write the device structure with JEOL 9500. Next, we develop the exposed HSQ in MIF 300 for one minute, rinse with DI water, and then blow dry. The subsequent etching steps are carried out in the PT770 etcher. We etch the Cr layer with Cl_2/O_2 plasma and then the AlN layer with Cl_2 plasma. Lastly, the Cr layer is removed by wet chemical etch.

This project is a work-in-progress as we are debugging the etching step of the AlN layer. The SEM image of the Cr mask of the pattern is shown in Figure 2. The smallest feature size is of 10 nm.

Future Steps:

We will complete and refine the process parameters to fabricate the nanophotonic cavity devices. We will study the optical properties of the devices and characterize the Purcell enhancement of single emitters coupled to the devices.

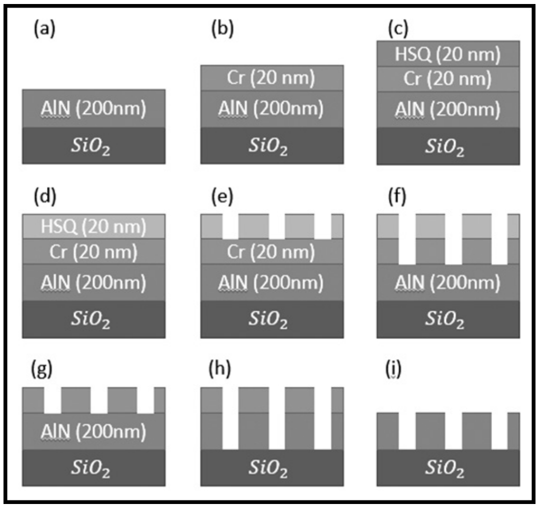

Figure 1: Outline of the process flow. (a-b) Sputtering of AlN and Cr on fused silica wafer, (c) deposition of HSQ, (d-e) EBL patterning on HSQ and development, (f) etching of Cr hard mask, (g) removal of HSQ, (h) etching of AlN, (i) removal of Cr mask.

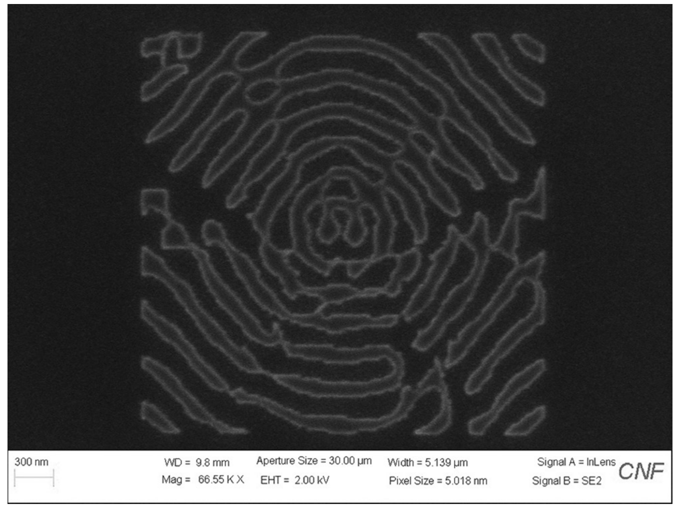

Figure 2: SEM image of the pattern after Cr etch.

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References:

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