Manufacturing SiN Bullseye Cavities and SOI Photonic Crystal Nanobeam Cavities

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Primary CNF Tools Used: JEOL 6300 & 9500, E-beam Spin Coaters, Olympus MX-50 Microscopes, Oxford 82, Oxford 100, PT770 RIE, Oxford Cobra ICP, Plasma-Therm Tikachi HDP-CVD, Oxford PECVD, Primaxx Vapor HF Etcher, Yes EcoClean Asher, Yes Asher, Filmetrics systems, Zeiss Ultra SEM, Zeiss SEM Supra, Veeco AFM, DISCO Dicer Saw

Abstract:

Our group is interested in quantum research on photonic platforms. Some topics we are currently exploring include: on-chip lasing and single-photon emission enhancement with circular Bragg gratings, and room temperature single phonon quantum sensing using phononic crystal enhanced optomechanical cavities. There have been recent reports of Purcell enhancement from circular Bragg cavities, as well as mechanical ground states being achieved at room temperature through use of well-designed phononic crystals.

Summary of Research:

Users have done diligent work to refine the fabrication process for the circular Bragg grating (CBG) cavity, colloquially referred to as a bullseye cavity. A deposition recipe was developed on the Oxford PECVD that achieves repeatable SiO_2 followed by SiN deposition thicknesses. Experimentation was completed on different gas pressures during inductively coupled plasma (ICP) etching of silicon nitride in order to achieve the high aspect ratio, anisotropic etches required for the silicon nitride (SiN) bullseye cavities.

Additionally, the group has created our first fabrication procedure for creating suspended structures like nanobeams and phononic crystals. Due to the fine transverse structures required to make photonic crystal cavities, experimentation has been done with e-beam resist type, thickness, and dosage applied in lithography machines to match designed requirements. Experimentation was also completed on applying a varied bias to different regions in pattern files in order to account for reactive ion etch lag (RIE lag) affecting the transverse dimensions of nanostructures differently than larger structures. Different chemistries have been attempted in the lab to create anisotropic silicon etches during pattern transfer with great successes being achieved with a hydrobromic acid (HBr) inductively coupled plasma (ICP) etch, instead of the sulfur hexafluoride and oxygen (SF_6/O_2) chemistry frequently seen in literature for silicon etches. Finally, experimentation was completed with vapor hydrogen fluoride (HF) etching to successfully create suspended structures without any stiction. This was successful for suspended features in the tested range of tens of microns.

Conclusions and Future Steps:

Correcting the critical dimension blur is the last step to successful bullseye fabrication. After that is verified the next steps for the bullseye cavities will be to optically characterize the cavity resonance in lab.

As the nanobeam and phononic crystal fabrication is still in its incipiency, many next steps need to be taken both in the lab at University of Rochester and in the lab at Cornell. The fabricated nanobeams also need to be optically characterized. Many nanobeams were created with varying biases and cavity lengths with the hopes of pin-pointing an optical resonance in a new optical setup at the University of Rochester. Experiments need to be done with the HF vapor etch of much larger suspended structures. Simulations indicate that more phononic crystal layers increase mechanical *Q*-factor, so experiments need to be completed to make sure large, suspended structures in the range of hundreds of microns can be fabricated successfully using the same HF vapor etch without issues of stiction. Great success was achieved with the anisotropic HBr pattern transfer etch. More experiments need to be completed on the replicability of these results.

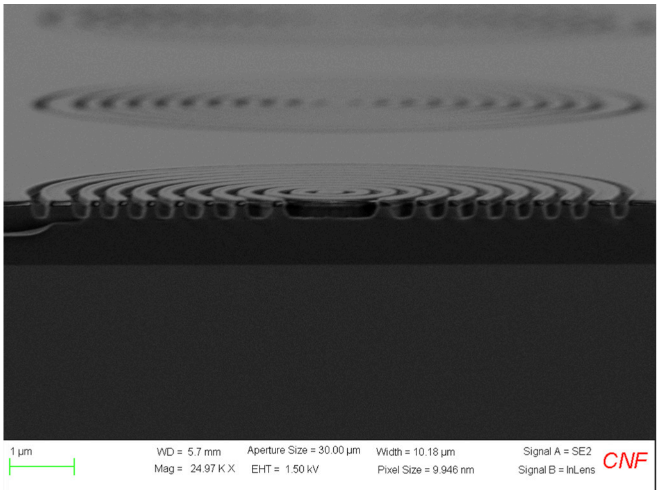

Figure 1: Cross-section of a bullseye cavity.

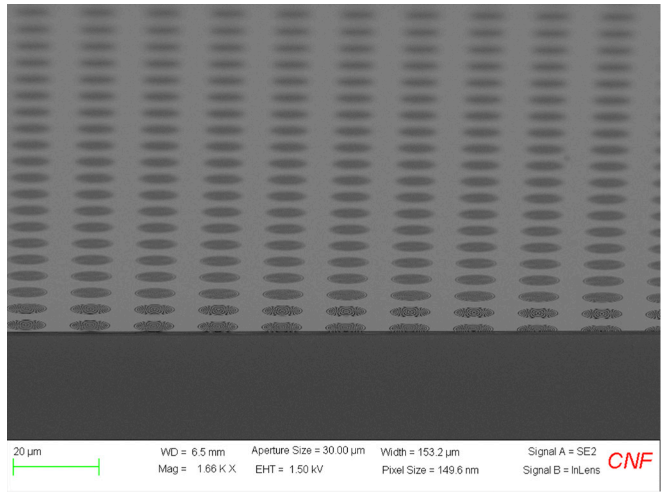

Figure 2: Array of bullseye cavities.

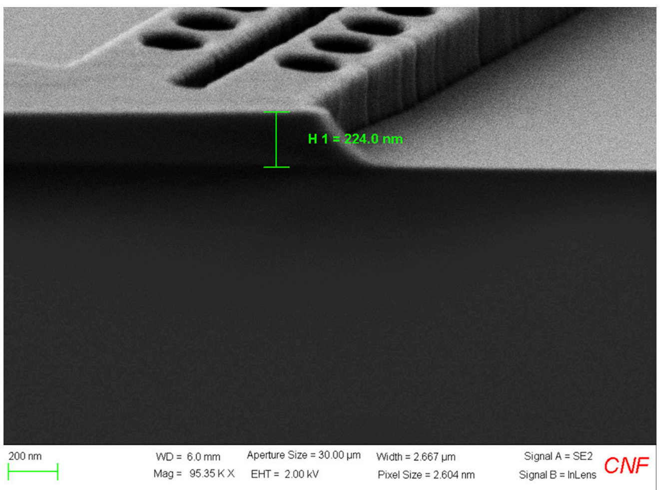

Figure 3: Cross section of nanobeams before release showing the device layer and pattern still with resist taken with the Zeiss SEM Ultra.

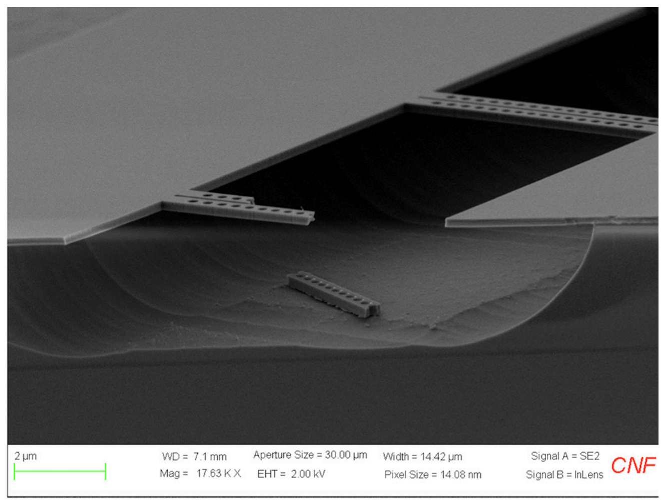

Figure 4: Nanobeam intentionally broken to show fully etched photonic crystal holes with intact suspended nanobeams in the background, taken with the Zeiss SEM Ultra.

References:

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