

Manufacturing SiN Bullseye Cavities & SOI Photonic Crystal Nanobeam Cavities

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Primary CNF Tools Used: JEOL 6300, JEOL 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. We have designed, fabricated, and tested Purcell enhanced Bragg cavities, as well as various photonic crystal optical nanocavities, and phononic crystal enhanced mechanical resonators.

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 SiO₂ 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 including: photonic crystal nanobeams, photonic crystal L and H cavities, and megahertz phononic crystal arrays. Due to the fine transverse structures required to make photonic crystal nanobeam cavities specifically, 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 (SF₆/O₂) chemistry frequently seen in literature for silicon etches. Finally, experimentation was completed with vapor hydrogen fluoride (HF) etching to successfully create suspended structures free of stiction. This was successful for suspended features in the tested range of tens to hundreds of microns. Photonic crystal cavities from these fabrications have been successfully tested and are undergoing further experiments.

Conclusions and Future Steps:

Optical characterization of bullseye cavities has been conducted with great success indicating that our fabrication process is adequate to achieve the desired sub 100nm dimensions required for our designed bullseyes cavities.

We are constantly modifying and improving our designs of the photonic crystal cavities for optomechanics. Many of these designs push the limits of transverse dimensions achievable these types of cavities. Next steps would include fabricating the modified photonic crystal cavities and testing the limits of transverse dimensions achievable in our transverse structures.

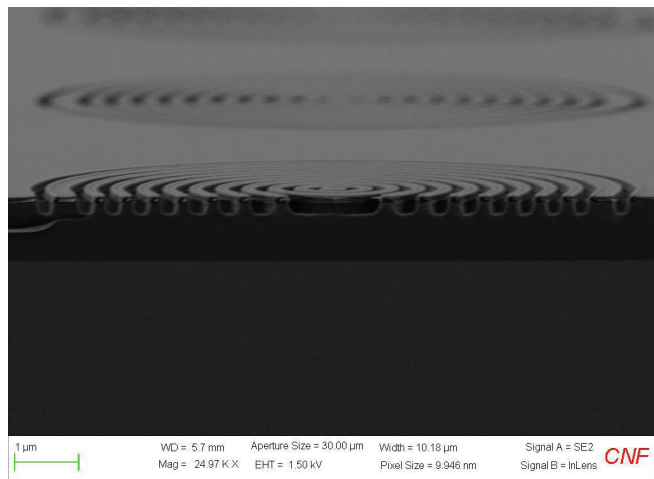


Figure 1: Cross-section of a bullseye cavity.

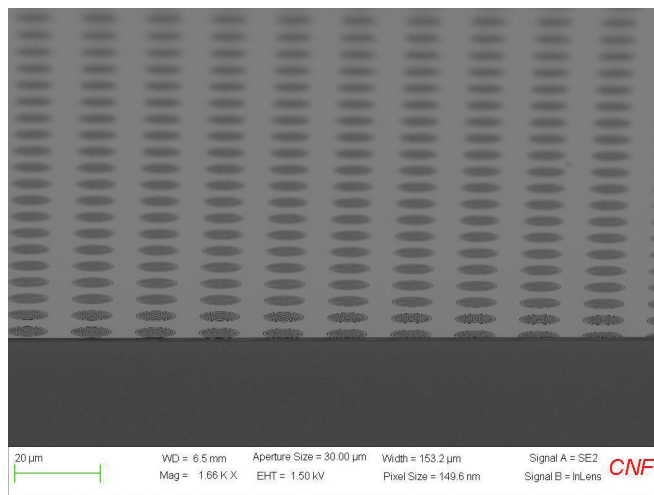


Figure 2: Array of bullseye cavities

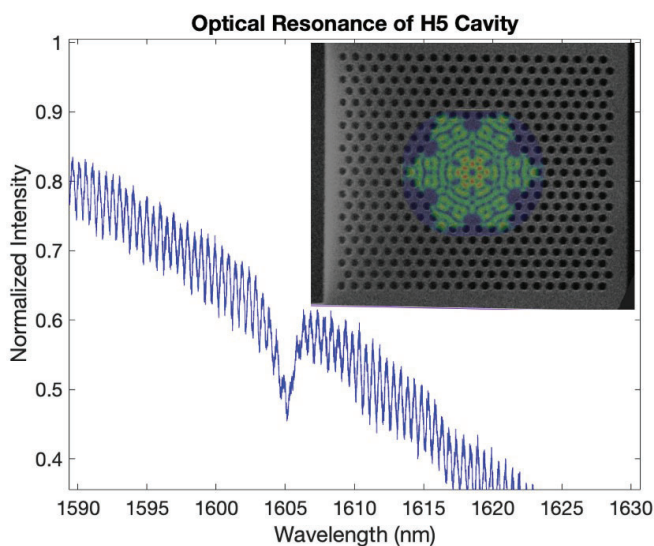


Figure 3: Resonant scatter spectrum plotted for measured photonic crystal H5 cavity, inset: microscope image of H5 cavity taken with Zeiss SEM Ultra, overlaid by simulated resonant mode profile of electromagnetic field norm.

References:

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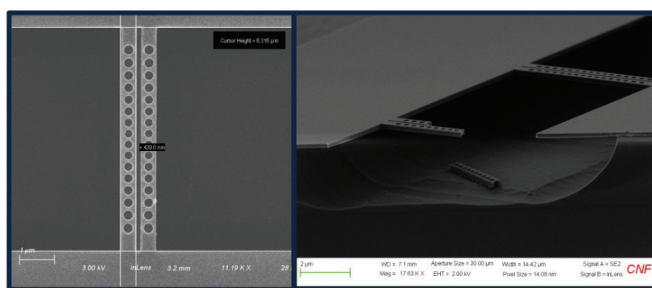


Figure 4: Microscope images taken with Zeiss SEM Ultra (left) image of dual nanobeams showing some transverse dimensions (right) dual nanobeams intentionally broken to show fully etched photonic crystal holes with intact suspended nanobeams in the background