**Preparation of Silicon Based Photonic Materials**

*CNF Project # 810-99*

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**Abstract:**
By forming a lattice of macroscopic dielectric media, an optical analogy of a crystal can be fabricated, called a photonic crystal. This investigation seeks to use silicon fabrication techniques to construct photonic bandgap structures with the capability of manipulating light for potential all-optical silicon based optoelectronic circuits. The electrical properties of silicon nanocrystals are also being investigated as potential light emitters in these photonic structures.

To achieve these goals, various thin-film deposition, etching, annealing, and photolithographic processes were performed at CNF. Equipment used in this project includes the MOS dry oxide and nitride LPCVD furnace, the Applied Materials RIEX etcher, JEOL e-beam writer, Plasmatherm 770 chlorine silicon etcher, HTG System III-HR Contact Aligner, Hitachi S-4700 SEM, Oxford PlasmaLab 80+ RIE, GaSonics Aura 1000 Asher, Heidelberg DWL 66 Laser Pattern Generator, Plasmatherm 720 Aluminum etcher, GSI PECVD nitride deposition, CAD tools, and the GCA PG3600F optical pattern generator.

**Summary:**
We use two distinct approaches for fabrication of the silicon based photonic materials.

In the first approach, we define a variety of photonic crystal resonators/waveguides on SOI wafers by e-beam lithography and fabricated by RIE. All coupling facets are polished after fabrication. In Figure 1, a 2-D PBG cavity, which is a “defect” lattice in the matrix and a photonic crystal waveguide, which is a string of “defects” are connected by side coupling. In Figure 2 a microcavity is placed inside a ridge waveguide by lining up 9 holes with the center one as the “defect”. We have also fabricated resonators of other geometries, like ring resonator [1, 2], and the preliminary measurement shows their discrete resonance peaks.

The second approach is to use electrochemical etching of silicon to define photonic structures. Etching of silicon will occur when current is passed through an electrochemical cell containing a hydrofluoric acid electrolyte [1]. By controlling the current density through the cell and the duration of the etch, porous layers with reproducible structure can be fabricated. This technique can also be used to etch arrays of deep holes into a substrate at positions determined by a prepatterned surface [2].

The formation of one-dimensional and two-dimensional porous silicon based photonic bandgap (PBG) structures continues to be investigated. PBG structures have a periodically varying index of refraction, which determines how light propagates in the medium. If the perfect periodicity of the dielectric function is broken, a defect in the PBG is created. 1-D PBG microcavities with Q-factors greater than 200 and 2-D PBG structures have been fabricated for active tuning. Tunable PBG structures have been achieved by infiltrating liquid crystals throughout the porous silicon structures [3-5]. Mesa structures in which the porous layer has been selectively removed in order to allow in-plane transmission measurements were fabricated by reactive-ion etching as well as wet chemical etching. Interdigitated electrodes are being fabricated for potential electric field modulation.

**References:**
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Figure 1, top right:
2-D photonic bandgap microresonator defined by the
electron-beam lithography and RIE.

Figure 2, below left:
1-D microcavity integrated in a silicon ridge
waveguide on the surface of silicon dioxide cladding.

Figure 3, below right:
2-D PBG membrane defined by anisotropic chemical
etching to enable for transmission measurements.