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Buffered Two-Dimensional Slab Photonic Crystals on a Silicon-on-Insulator Platform

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Microcavities in two-dimensional (2D) slab photonic crystals (PhCs), when fabricated in a free-standing membrane of high refractive index (*e.g.* Si or GaAs, see Fig. 1a), can achieve very high quality-factors (10^6 or even more) with a mode-volume on the order of λ^3 [1, 2]. This opens doors to a variety of novel, highly-compact devices in important areas such as telecommunication, on-chip optical interconnects and quantum information processing. However, practical devices, such as telecommunication-grade add-drop filters have not been demonstrated in such PhCs. Fig. 1a shows an important configuration for add-drop filtering, where a strip waveguide is placed in close proximity, but not attached, to two slab PhCs. Such a configuration is a general requirement as the strip waveguides provide the large transmission bandwidth and the slab 2D PhCs provide high-Q cavities, both are critical for many device applications [3]. Unfortunately, the lack of physical support for the membranes and strips makes it extremely difficult for them to hold their shapes and precise placement. If one places the slab directly on top of a substrate of lower index, the indices above and below the slab PhC and strip waveguide become different. This breaks the symmetry along the vertical direction upon which the low-loss propagation and extremely high-Q cavity modes are based.

We propose and demonstrate a buffered structure where two slabs of lower refractive index (*e.g.* SiO_2), yet with the same device pattern, are stacked above and below the slab PhC of higher index (*e.g.* Si, see Fig. 1b). The entire stack can now sit on a low-index substrate. We call this buffered slab photonic crystals (BSPCs). On a silicon-on-insulator (SOI) platform, the high index contrast between the middle slab and the buffers (3.45 for Si *vs* 1.45 for SiO_2) leads to strong confinement of light within the Si slab, thus the buffer layers can be fairly thin (200-300 nm for telecom wavelengths).

The fabrication steps are illustrated in Fig. 2a-d. We started with an SOI wafer with 250nm top Si layer and 3 μm of buried oxide. The PhCs and strip waveguides were patterned in a 600nm-thick negative e-beam resist, hydrogensilsesquioxane (HSQ). The high acceleration voltage of the Vistec VB6 e-beam lithography tool at Purdue's Birck Nanotechnology Center ensures complete exposure through such a thick resist layer. A rapid thermal annealing at 1000 °C was applied to fully convert the exposed HSQ into SiO_2. The pattern is then transferred into the Si layer via inductively coupled plasma RIE etch with Cl_2, which does not etch HSQ and stops at the buried oxide. Further etch into the buried oxide was achieve via RIE with a mixture of CF_4 and O_2. The top HSQ layer was also etched at roughly the same rate. Fig. 2e shows the fabricated structure.

Optical characterization of fabricated devices is currently underway and will be presented along with detailed fabrication parameters.

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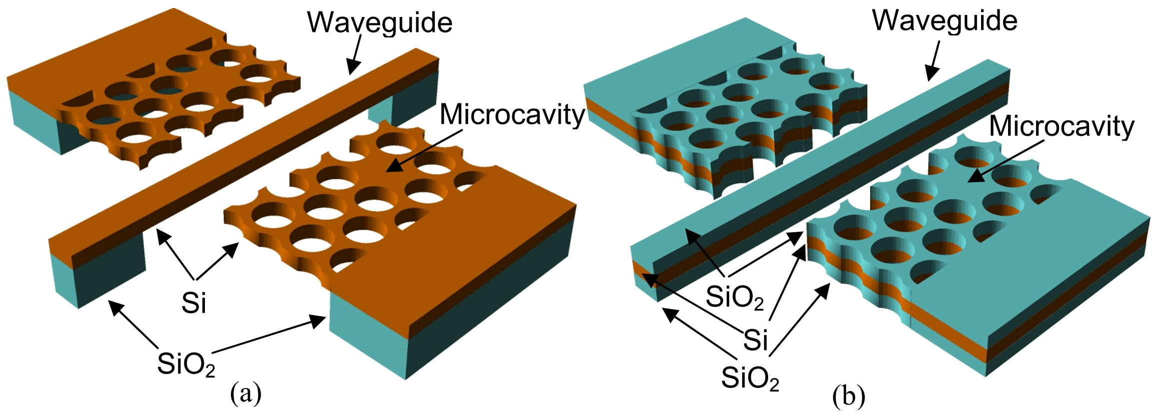

Fig. 1: (a) Schematic of a representative filtering device based on free-standing slab photonic crystals. Achieving structural robustness is very difficult without the support below the membranes and strip. (b) Schematic of proposed buffered slab photonic crystal, which has no free-standing structures.

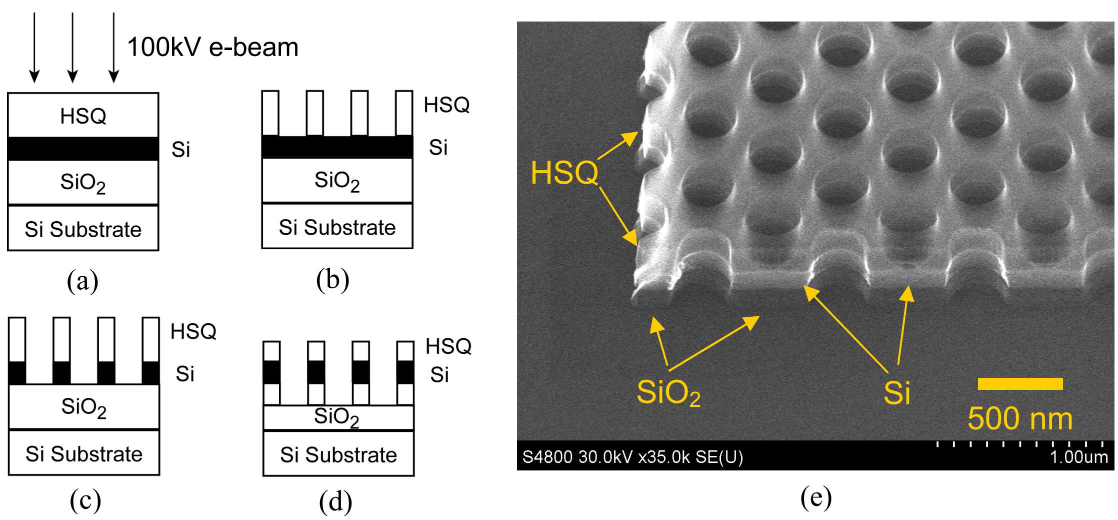

Fig. 2: Fabrication of buffered slab photonic crystals. (a) 600 nm of HSQ was spun on an SOI wafer for e-beam exposure. (b) HSQ was developed and annealed at 1000 °C. (c) Si was RIE etched with Cl_2. (d) Holes were further etched into SiO_2 in a plasma of mixed CF_4 and O_2 to yield a buffered structure. The etch rates for the buried SiO_2 and for HSQ are roughly the same. (e) A tilted SEM micrograph of a fabricated buffered slab photonic crystals. The total thickness of all three layers is 750 nm and each layer is roughly 250 nm thick.

References

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