SOI Nanophotonic Waveguide Structures Fabricated with Deep UV Lithography

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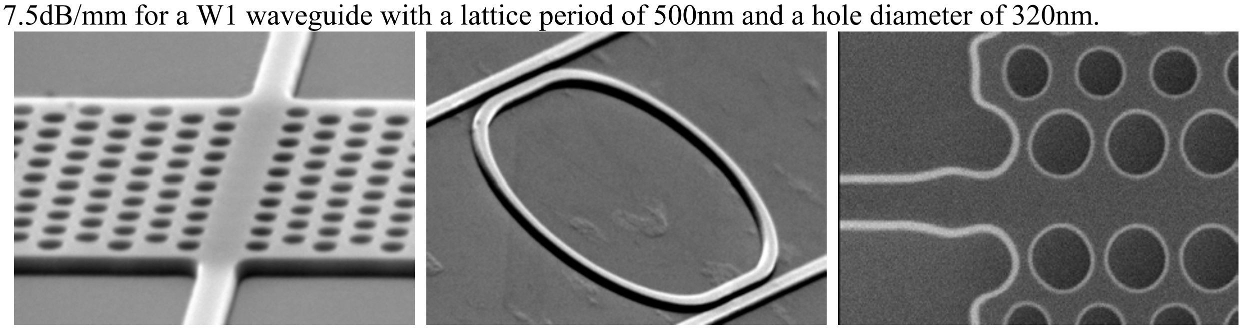
As is well known, nanophotonics promise a reduction in scale by orders of magnitude compared to contemporary commercial photonic components. This would allow the integration of many basic building blocks onto a photonic chip, an evolution reminiscent of electronic integration in the past decades.
Today, waveguides with weak confinement consume large fractions of photonic integrated circuits just for interconnections. Nanophotonic waveguides, which allow for sharp bends, will reduce this, but need a tight confinement and therefore a large refractive index contrast. This implies the use of semiconductors as base materials. Basically, there are two likely candidates for nanophotonic waveguides. Photonic wires are basically conventional waveguides with reduced dimensions and a high refractive index contrast between core and cladding. They allow for bend radii of the order of 2-3µm or even corner mirrors.
The alternative is to use photonic crystal slabs. Here, the light is confined by the photonic band gap effect [1]. By introducing a line defect, a waveguide is formed. However, it has proven less than straightforward to design and fabricate a photonic crystal waveguide with very low propagation losses.
To make nanophotonic circuits a viable product, a suitable mass-manufacturing technology is required. For research purposes, e-beam lithography delivers the required accuracy to make nanophotonic structures. However, it is a slow writing process and not useful for mass-fabrication. We have explored the use deep UV lithography at 248nm, as used in state-of-the-art CMOS fabrication, for making nanophotonic waveguides. Because we require a waveguide material compatible with CMOS processes, we used Silicon-on-Insulator (SOI), with a top Silicon layer of 220nm and an oxide buffer of 1µm, which is also a nery good nanophotonic waveguide substrate. After lithography, only the top Silicon layer is etched. The structure received no further treatment, like oxidation or removal of the oxide buffer. A detailed description of the fabrication process is given in [2,3].
As shown in the SEM pictures, the fabrication quality is very good, with very little sidewall roughness. This translates to low propagation losses. We have measured 500nm (single-mode) photonic wires with a propagation loss as low 0.24dB/mm. For photonic crystal waveguides the losses are still higher, with 7.5dB/mm for a W1 waveguide with a lattice period of 500nm and a hole diameter of 320nm.



[1] J. D. Joannopolous et al. Photonic Crystals - Molding the Flow of Light. Princeton University Press, Princeton, N.J., 1995.
[2] W. Bogaerts et al. Fabrication of photonic crystals in silicon-on-insulator using 248-nm deep uv lithography. IEEE J. Sel. Topics. Quant. Electron., 8(4):928–934, 2002.
[3] W. Bogaerts et al. Large-scale production techniques for photonic nanostructures. Proc. SPIE, 5225:101–112, 2003.