Silicon nanophotonic waveguide components

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1. Introduction

In the last decade, silicon photonics has become an ever more important technology to realize compact photonic integrated circuits. this is because silicon , and especially the silicon-on-insulator (SOI) material system, has exceptional waveguiding properties. The high refractive index contrast between silicon and its native oxide allows optical confinement in submicron waveguide cores. These co-called photonic wires (Fig. 1) also enable very sharp bends with bend radii of a few micrometers [1][2]. Compared to glass waveguide technologies, SOI photonic wires can therefore scale down the footprint of integrated optical components with 3 to 6 orders of magnitude. It is possible to make extremely compact passive components such as wavelength filters and (de)multiplexers [4][5] [7][8], but recently also several photodetectors and modulators have been demonstrated.

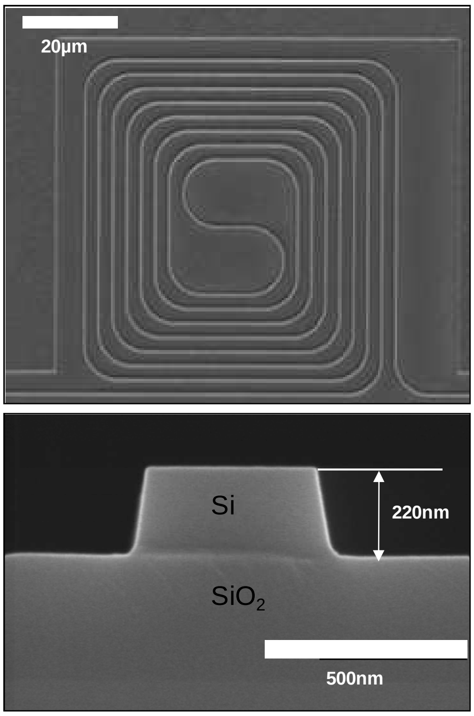

Fig.1: Photonic wire waveguides. Top: Spiral for loss measurements. Bottom: Cross section.

A second reason why silicon photonics has become so relevant is the possibility to fabricate the photonic structures with the same tool set as used for the mass-manufacturing of CMOS electronics. This provides a scaling route for volume production, which makes silicon photonics much more attractive for low-cost, mass-manufacturable applications, such as in access networks, or biosensors.

In this paper we will mainly focus on recent progress in passive waveguide components. These include a variety of wavelength filtering functions such as ring resonators [3][7], Mach-Zehnder filters [7], arrayed waveguide gratings (AWG)[4] and echelle diffraction gratings [5][8]. In addition, we will discuss essential components for larger waveguide circuits, including low-loss crossings and splitters, as well as fiber-chip coupling based on diffraction gratings.

2. Fabrication and experimental results

As already mentioned, silicon photonic waveguide circuits can be fabricated using CMOS fabrication tools. In the Interuniversity Microelectronics Center (IMEC), located in Leuven, Belgium, we can make use state-of-the-art clean-room facilities with industrial 200mm and 300mm tools, including high-end 193nm deep UV lithography.

The waveguides are made in a 220nm silicon layer on top of a 2µm thick oxide to shield the optical mode from the silicon substrate. These SOI wafers were commercially purchased from SOITEC. waveguides are defined using a deep etch of 220nm down to the buried oxide layer. In addition, we also define a shallow etched region (70nm deep). This is necessary to make efficient diffraction gratings for fiber coupling [6], such as shown in Fig.2, but it can also be used to locally reduce the lateral index contrast to tailor the mode behaviour of components where the high contrast is a drawback. Examples include waveguide crossings, as well as the interfaces between waveguides and slab areas [4][5][8].

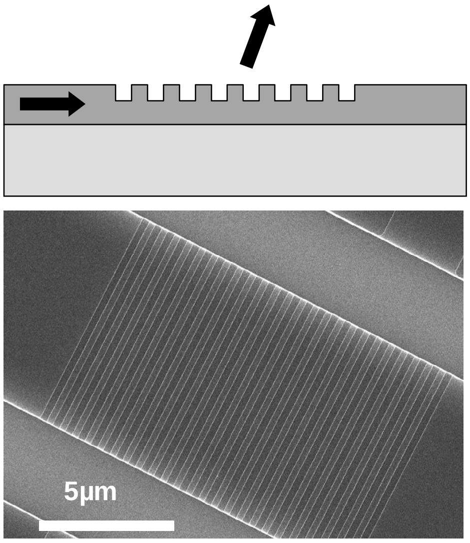

Fig.3: Grating fiber coupler with 70nm in 200nm silicon waveguide. Coupling efficiency is 30%.

The basic building block in a photonic integrated circuit is the optical waveguide. The propagation losses have to be sufficiently low to be useful for large-scale integration. We now have a routine process to make photonic wires with losses of 3dB/cm without sacrificing confinement and lateral contrast [4]. This low loss allows us to make compact ring resonators, with Q-values up to 25000 and a free spectral range of tens of nanometers.

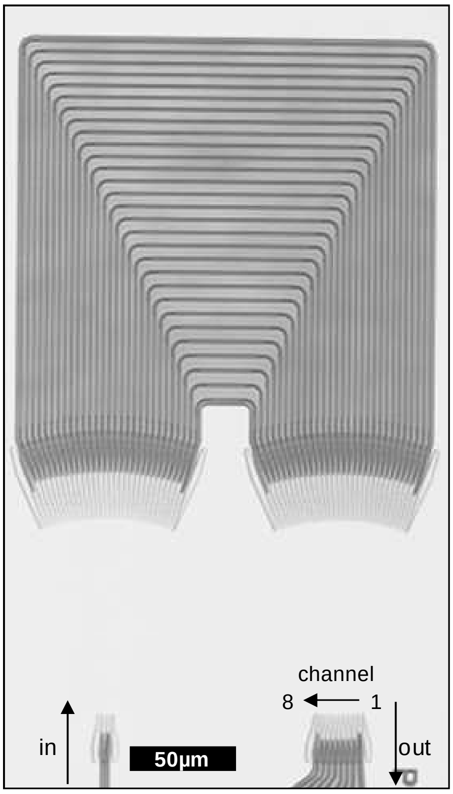

Fig.3: Arrayed waveguide grating with 8×400GHz wavelength channels.

Also, using the combination of deep and shallow etch, we can make crossings and splitters with an excess insertion loss of only -0.15dB, or 98% transmission.

Arrayed waveguide gratings (Fig.3) can be used to demultiplex several wavelength channels into different output waveguides. Because silicon photonic wires are small, but also have a large group index (strong dispersion) these AWGs can be very small. Also, the use of a local shallow etch reduces insertion loss and results in very low crosstalk levels down to -25dB.

3. Conclusion

We demonstrate a wide variety of passive silicon photonic components fabricated with industrial CMOs tools, with performance that is already suitable for different applications

Acknowledgements

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