Metal Grating Coupler for Silicon-on-Insulator

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Grating Couplers are a very elegant solution to the well-known coupling problem between single mode fibers and nanophotonic waveguides. In this paper, a novel type of grating coupler is introduced based on a metal grating. We discuss the design and, fabrication of metal grating couplers and present measurement results..

Introduction

Due to the large mismatch in mode size and shape between the fundamental mode of SOI waveguides and the mode of an optical fiber, coupling light efficiently from fiber to waveguide is rather challenging. Efficient and broadband grating couplers as compact as 10 μm x 10 μm have been proposed and demonstrated to solve this problem [1]. This device is based on etching a grating into the top silicon waveguide layer. In this paper, a different design is proposed and demonstrated. This novel type of grating coupler consists of a metal grating on top of the silicon waveguide layer.

Design

For the design of metal grating couplers and optimization, we use CAMFR, a two-dimensional fully vectorial simulation-tool based on eigenmode expansion and mode propagation with perfectly matched layer (PML) boundary conditions [2]. We consider 1-D gratings in 2-D simulations and concentrate on TE polarization (electric field parallel to the grating lines). With refractive index data for silver and gold taken from [3], the grating parameters (period, fill factor, height) were optimized to obtain high coupling efficiency. Another key parameter in the design of grating couplers is the buried oxide layer thickness. The result of this optimization is shown in Fig. 1, where the coupling efficiency is plotted as a function of buried oxide layer thickness for a silver grating with optimal grating parameters.

Fabrication and characterization

For the fabrication of prototype metal grating couplers, we had a few types of SOI wafers at our disposal. Based on the results of optimization discussed before, we choose to work with the SOI wafers with 2 micron buried oxide. Gold was chosen as the metal because of its inert chemical properties in contrast to silver which easily starts corroding after deposition. We studied two fabrication methods: (1) etching the grating in gold using a focused ion beam and (2) lift-off of gold after writing the grating in PMMA using e-beam lithography. Best results have been obtained using e-beam lithography. The main reason is that e-beam lithography does not require an intermediate protective layer as is the case for focused ion beam etching. As a proof-of-principle, a gold grating coupler was fabricated using e-beam lithography and lift-off on top of 10 μm wide SOI waveguides. They were characterized by fiber-to-fiber transmission measurements using the gold grating couplers to couple light in and out of the waveguide. A SEMimage of the fabricated gold grating coupler on top of a waveguide is shown in the inset of Fig. 2, where the measurement data are plotted. For this prototype, a coupling efficiency of 20 % has been measured.

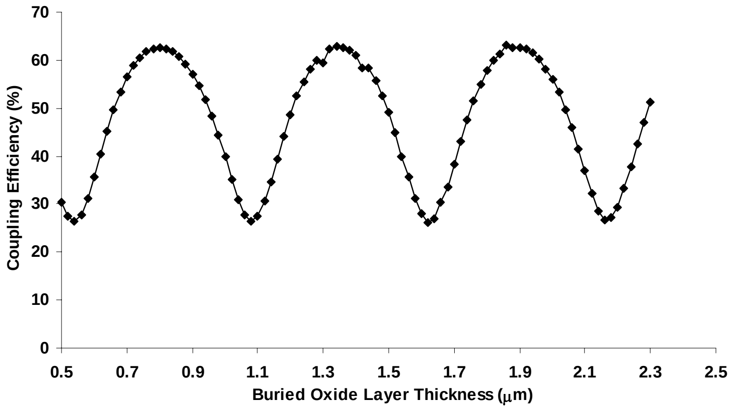

Fig. 1: Coupling efficiency of a silver grating coupler (period = 610 nm, fill factor = 30 %, height = 20 nm) as a function of buried oxide layer thickness.

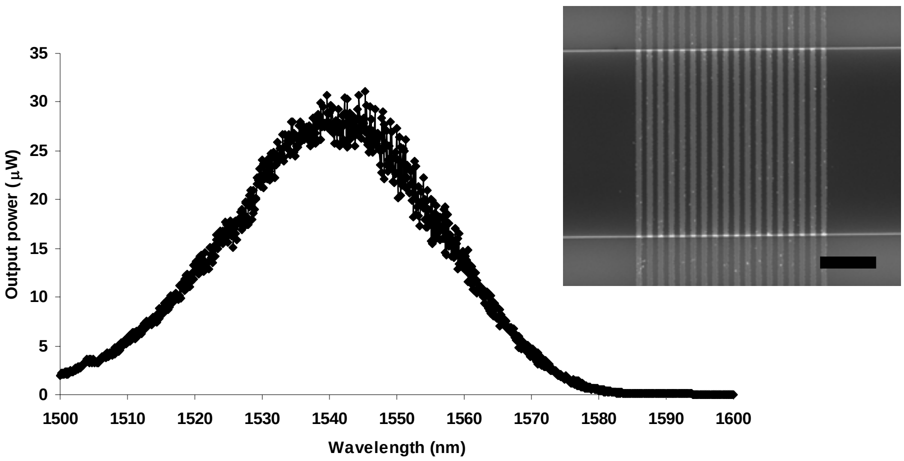

Fig. 2: Measurement data of fiber-to-fiber transmission via two gold grating couplers on top of a 10 μm wide SOI waveguide. Input power is set to 1 mW. Inset: SEM-picture of a gold grating coupler prototype. Bar length is 3 μm.

References

[1] D. Taillaert, F. Van Laere, M. Ayre, W. Bogaerts, D. Van Thourhout, P. Bienstman and R. Baets, "Grating couplers for coupling between optical fibers and nanophotonic waveguides," Jap. J. Appl. Phys. **45**, 6071-6077, 2006.

[2] P. Bienstman and R. Baets, "Optical modeling of photonic crystals and VCSEL's using eigenmode expansion and perfectly matched layers", Opt. Quantum Electron., **49**, 349-354, 2001.

[3] P.B. Johnson and R.W. Christy, "Optical Constants of the Noble Metals", Phys. Rev. B, **6 (12)**, 4370-4379, 1972