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Highly-Efficient Subwavelength Engineered Grating Couplers for Silicon-on-Insulator Waveguides

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Abstract: We present experimental results of efficient subwavelength index engineered surface grating couplers, developed in a standard 220-nm SOI substrate. Grating couplers are fabricated using a single full etch or a dual etch process (full etch and 70nm shallow etch). The measured efficiency of -2.2 dB, -2.5 dB, and -0.7 dB are reported for single-etch couplers without and with metal reflector in the near-IR wavelengths. We demonstrate a peak coupling efficiency of -1.3 dB for a novel and flexible dual-etch grating coupler with interleaved deep and shallow etched trenches.

Introduction: Grating couplers are an effective approach to couple light to or from integrated circuits, enabling flexible placing of the interface on the chip surface and automated wafer scale testing [1-4]. In these structures, the directionality, i.e. the amount of power coupled towards an optical fibre, is an important parameter that determines the overall coupling efficiency. Grating directionality strongly depends on the thickness of the silicon and the buried oxide (BOX) layers. Thicker Si waveguides yield higher directionality [2], while the 220 nm Si thickness is usually used in silicon photonics foundry offerings [3]. The directionality can also be improved by specialized gratings, at the expense of a more complex fabrication [1-5].

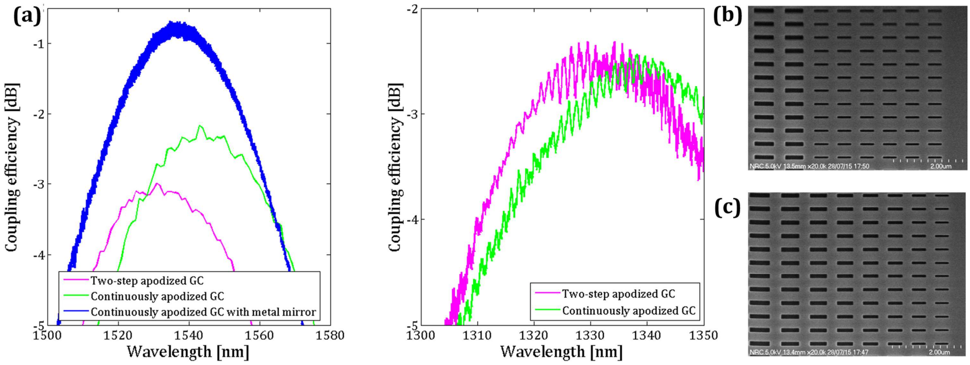

Fig. 18. (a) Measured coupling efficiency of single-etch subwavelength engineered grating couplers near 1.55 µm and 1.3 µm wavelengths. SEM images of fabricated devices: (b) two-step and (c) continuously apodized grating couplers.

Single-etch grating couplers: We recently designed and fabricated a series of efficient single-etch grating couplers for a standard 220-nm-thick Si layer over 3-µm and 2-µm thick BOX layers [6-8]. We found that the directionality, can be improved by optimizing the radiation angle. Specifically, we demonstrated that the thin film interference from the bottom oxide layer is maximized for a coupling angles of 27° (3-µm BOX, near 1.55

µm) and 33° (2-µm BOX, near 1.3 µm) off normal incidence. The high-directionality grating geometries are apodized using subwavelength grating (SWG) refractive index engineering [5-8]. This allows single-etch fabrication and enhanced coupling performance. Fig. 1(a) shows measured coupling efficiencies of apodized grating couplers, with peaks of -2.2 dB and -2.5 dB in the respective spectral bands. Figs. 1(b) and (c) show scanning electron microscope (SEM) images of fabricated structures. In addition, by utilizing the CMOS-compatible process of backside engineering and metal layer deposition, we reported the first sub-decibel coupling efficiency of -0.7 dB in 220-nm SOIs and single-etch fabrication [7].

Dual-etch grating couplers: We also developed a grating coupler with an ultra-high intrinsic directionality of 95% [9]. The structure comprises interleaved deep and shallow etched trenches. The vertical schematic and SEM image are shown in Fig. 2(a) and (b). An important practical benefit is that high-directionality is achieved independently on the BOX thickness [9,10]. The coupler also includes short SWG impedance-matching section (see Fig. (b)) to reduce back-reflections at the junction between the access waveguide and the grating. The coupler was fabricated in a 220-nm-thick SOI with 3-µm-thick BOX layer, with a measured efficiency of -1.3 dB at 1.55 µm, as shown in Fig. 2(c).

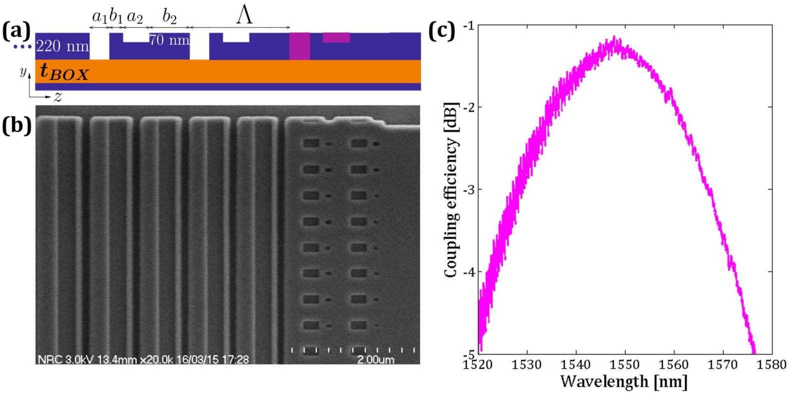

Fig. 2. (a) Schematic of dual-etch grating coupler with interleaved deep and shallow etched trenches. (b) SEM images of the fabricated structure. (c) Measured coupling efficiency.

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