Silicon-on-Insulator Bragg Gratings Fabricated by Deep UV Lithography

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Abstract: We demonstrate the design and performance of Bragg gratings on silicon-on-insulator waveguides. Two structures for achieving the modulation of the effective index of refraction are described. The grating fabrication is based on deep ultra-violet lithography using a single mask. The thermal tunability of the devices is demonstrated.

1. Introduction

Integrated Bragg gratings on the silicon-on-insulator (SOI) platform are expected to be an important component for achieving wavelength selective functions [1]. Several approaches have been reported to perturb the effective index of refraction in SOI waveguides, which fall into three categories: (1) using photorefractive effects via selective ion implantation to retain a planar surface [2]; (2) physically corrugating the waveguide, either on the sidewalls [3] or on the top surface [1,4]; and (3) placing periodic cylinders next to the waveguide [5]. Although the first approach can maintain a planar surface that may be useful for subsequent processing, the ion implantation makes the fabrication more expensive. For the second and third approaches, electron-beam lithography (EBL) was the workhorse for the fabrication. Unfortunately, this technique is not suitable for commercial application [6]. An alternative is to use deep ultra-violet (DUV) lithography, with high throughput and low-cost. Recently, the fabrication of SOI Bragg gratings based on DUV lithography was reported in [7]; however, the devices were top-surface corrugated, hence requiring double-exposure lithography and precise alignment.

In this work, we present Bragg gratings in SOI strip waveguides fabricated by a single DUV lithography step. Two structures were designed: one with sidewall-corrugations (named as structure A), and the other with an additional sidewall-corrugated waveguide parallel to the core waveguide (named as structure B).

2. Design and Fabrication

Fig. 1 shows the SEM micrographs of the fabricated Bragg gratings. The SOI strip waveguide consists of a thin silicon layer (220 nm thick) on top of a buried oxide layer (2 um thick) on a silicon wafer. The corrugated waveguide parallel to the core waveguide, and the corrugation effective index of refraction decreases, hence reducing the Bragg wavelength. The peak reflectivity and the coupling coefficient increases, leading to higher reflectivity and broader bandwidth. On the other hand, as the gap distance of structure B is increased, the coupling coefficient decreases, leading to lower reflectivity and narrower bandwidth. The thermal tuning characteristics is shown in Fig. 5, where a positive shift of 0.11 nm/K in the reflection peak was observed.

4. Conclusion

We have demonstrated Bragg gratings in SOI strip waveguides fabricated by a single DUV lithography step. A large extinction ratio of 20 dB with narrow bandwidth of about 3 nm was obtained for both designed structures. The thermal tunability of the devices was also investigated, showing a positive shift of 0.11 nm/K.

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References

Fig. 1. SEM views of Bragg gratings (a) with sidewall-corrugations and (b) with an additional sidewall-corrugated waveguide.

Fig. 2. Structure A: (a) transmission spectra, (b) peak reflected wavelength versus corrugation width.

Fig. 3. Structure B: (a) transmission spectra, (b) peak reflected wavelength versus gap distance.

Fig. 4. Measured peak reflectivity and bandwidth: (a) structure A versus corrugation width; (b) structure B versus gap distance.

Fig. 5. Measured peak reflected wavelength as a function of temperature.