Properties of shallowly etched second order grating in silicon-on-insulator (SOI) waveguide

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The reflection, transmission and radiation spectra of the shallowly etched second order gratings in silicon-on-insulator (SOI) waveguide are simulated using the FDTD method. The influence of the grating duty cycle and the buried oxide layer are analyzed. The first order gratings are also calculated for comparison.

Introduction

Second order gratings have been widely used to design grating couplers, surface emitting lasers and distributed feedback (DFB) lasers [1-3]. The light propagating in the second order gratings can be diffracted into the top and bottom claddings, which provides a good approach to transmit light between waveguides and other optical devices, such as fibers and III-V semiconductor devices. In addition, the typical length scale of the second order grating is two times as large as that of the first order grating, which helps to reduce the fabrication difficulty. However, there are not many publications discussing the properties of the second order gratings [4-5]. We present here the simulation results of both the first and the second order gratings in silicon-on-insulator (SOI) waveguides.

Discussion

The reflection, transmission and radiation spectra of the gratings are simulated using the FDTD method, and perfectly matched layers are used to reduce the reflections on the simulation boundaries. The simulated structure is an SOI waveguide grating with a crystalline silicon waveguide layer of 220nm and a buried oxide layer of 2μm.The width of the waveguide is 450nm. Since the etch depth of the shallowly etched grating in the standard SOI devices provided by ePIXfab can only be 70nm, this value is not changed in the simulation. The number of the grating period is 60, and we choose air as the top cladding.

The properties of the second order gratings without considering the influence of the buried oxide layer are depicted in Fig.1. The grating period is 570nm, and the results for duty cycle of 0.25, 0.5, 0.75 are shown in Fig.1(a), Fig.1(b) and Fig.1(c) respectively.

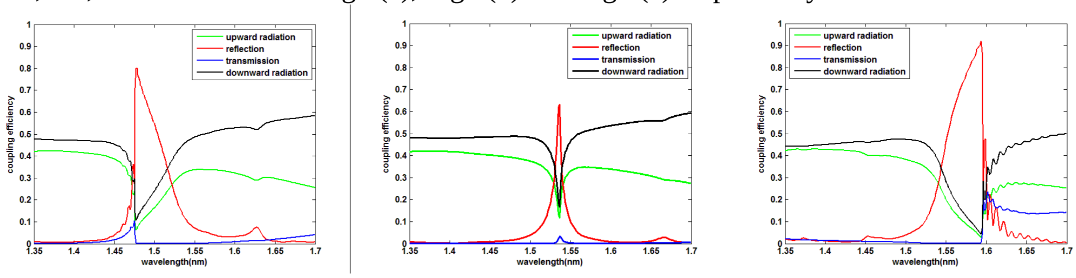

Fig. 1. The reflection, transmission and radiation spectra of the second order gratings without interface reflection: (a) for duty cycle of 0.25; (b) for duty cycle of 0.5; (c) for duty cycle of 0.75.

There is a reflection band in the spectrum, in which the radiation is low and most of the light is reflected. The transmission is low for all of the wavelengths, and the radiation dominants outside the reflection band. It is also shown that the grating duty cycle can affect the shape of the spectrum significantly. Theoretically, if the etched and the unetched regions of each period of the grating have the same optical distance for the guided light, the reflection of the second order grating with duty cycle of 0.5 should have no reflection at the second order Bragg wavelength. Considering the effective index difference between the etched and unetched regions, the duty cycle of the reflectionless grating is not but close to 0.5.

In addition, the spectrum would change due to the reflection on the interface between the buried oxide layer and the silicon substrate. To evaluate this influence, we simulated the second order gratings with the FDTD region extended to the substrate. The results are shown in Fig.2. It can be noted that a large envelop are formed due to the reflection on the interface. This envelop could change with the thickness of the buried oxide layer. Compared with these results, the radiation spectra without the influence of the interface reflection are almost flattened outside the reflection band.

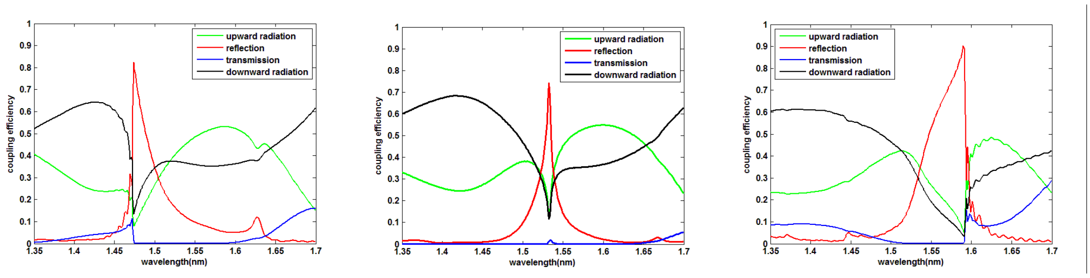

Fig. 2. The reflection, transmission and radiation spectra of the second order gratings with interface reflection: (a) for duty cycle of 0.25; (b) for duty cycle of 0.5; (c) for duty cycle of 0.75.

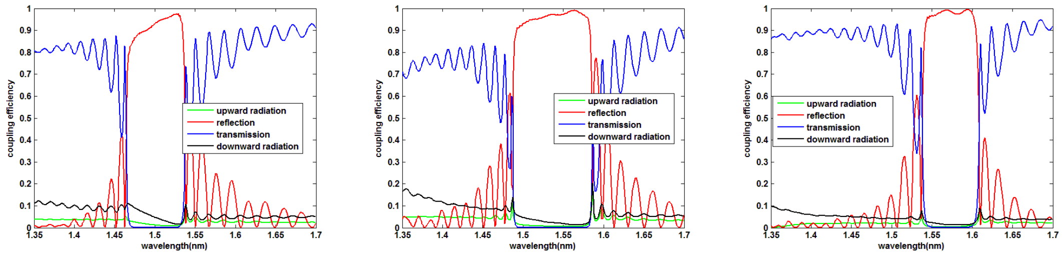

Fig. 3. The reflection, transmission and radiation spectra of the first order gratings without interface reflection: (a) for duty cycle of 0.25; (b) for duty cycle of 0.5; (c) for duty cycle of 0.75.

The spectra of the first order gratings are also calculated for comparison in Fig.3. The periods for the first order gratings are 285nm. They have broadband reflections with reflection ratios greater than 90%, and their radiation powers are low for the entire simulated band. There are significant differences between these gratings and the second order gratings, in which the reflection band is narrow and the radiation dominants outside the reflection band.

Conclusions

We have simulated the reflection, transmission and radiation spectra of the second order gratings in SOI waveguide using the FDTD method. The first order gratings are also assessed for comparison. The grating period, duty cycle, etch depth, and buried oxide layer can all influence the spectrum, but because of the limitation of the fabrication process, we just analyzed the influences of the duty cycle and of the buried oxide layer. These results are useful to design the second order gratings in grating couplers, surface emitting lasers, and DFB lasers.

References

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