Towards the Integration of an Ultrashort Polarization Converter on the Active-Passive InP-Membrane-on-Silicon Platform

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We propose and compare two integration strategies for including an ultrashort polarization converter on the InP-membrane-on-silicon (IMOS) platform. This technology can enable numerous devices and applications, e.g. polarization independent semiconductor optical amplifiers (SOAs) and Stokes vector (de)-modulators (SVMs).

Introduction

The ever-increasing growth of data traffic fuels the demand for higher bandwidth capabilities of optical fiber technologies. The most commonly used technique to date is wavelength division multiplexing (WDM), which allows for multiple data channels to be transmitted over a single fiber, using different wavelengths for each channel. With spatial division multiplexing, the number of channels is increased further by exploiting the spatial modes in for example few-mode and/or multicore fibers. Another degree of freedom that can be used to increase the bandwidth is the polarization state of the light. For the same wavelength, in a single mode fiber (SMF), two orthogonal polarization states can propagate independently: the EH and the HE modes. Furthermore, more complex modulation formats can be employed by integration of polarization diversity and active optical components, e.g. phase modulators and semiconductor optical amplifiers (SOAs). To achieve on-chip polarization diversity, an integrated polarization converter is of key importance. We propose two strategies for the integration of an ultrashort polarization converter on the InP-membrane-on-silicon (IMOS) twin-guide platform [1]. The IMOS platform [2] is a nanophotonic platform that provides miniaturization of components and tight optical confinement. The benefits and challenges of both integration strategies are studied, and the results are discussed in this paper.

InP-membrane-on-silicon platform

The IMOS platform consists of a thin, usually sub-micron thick, indium phosphide (InP) membrane adhesively bonded to a silicon carrier wafer by benzocyclobutene (BCB). The

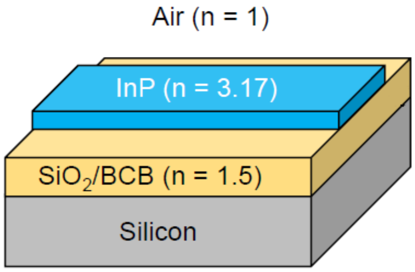


Figure 1 - Cross section of a typical waveguide on the IMOS platform.

cross section of a typical waveguide on a bonded IMOS wafer is shown in Figure 1. The thin membrane and high refractive index contrast enable small footprint devices and tight light confinement. An additional benefit of using a bonding process is the possibility of processing the InP wafer from both sides, which provides more flexibility in the process. Before the bonding process one side of the InP is processed, and after bonding and removing the substrate of the InP wafer the other side is processed.

Polarization converter

The basis for the integration of the polarization converter on the twin-guide IMOS platform is the device itself, which is shown in Figure 2. The device consists of two triangular sections connected by a short waveguide section to achieve full polarization conversion. As reported by Pello [3], the converter achieves a polarization conversion of >99% and a low insertion loss of 0.2 dB, measured on an all-passive chip. An extra lithographic step and wet etching is required to define where the triangular sections of the converters are placed, compared to the standard IMOS process flow. The triangular sections are higher than regular IMOS waveguides, therefore, the layer thicknesses of the triangular section is from the bottom up: 300 nm InP, 20 nm InGaAsP (etch-stop layer), and 140 nm InP, as shown in the cross-section in Figure 3 (a). Two integration methods are considered for integration, which will be discussed in the next section.

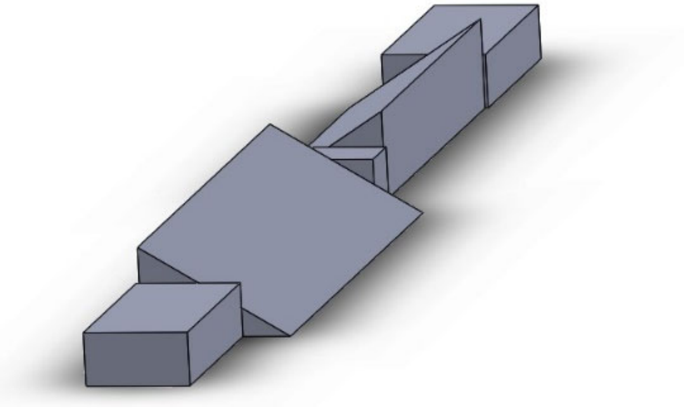
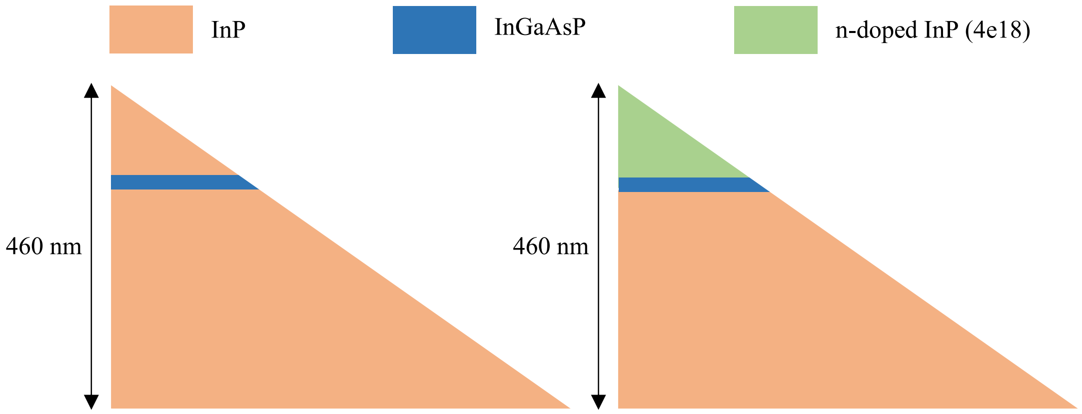


Figure 2 - 3D cartoon of the polarization converter and waveguide sections.



(a) (b)

Figure 3 - Cross section of triangular section for: (a) option 1; (b) option 2.

Integration strategy

For the integration of the polarization converter with the twin-guide IMOS platform two strategies are considered. For the first approach, the InGaAsP layer and top part of the triangular section can be added to the original twin-guide layer stack. The benefit of this approach is that the design of the polarization converter is identical to the prototypes which were demonstrated previously in all-passive chips. The challenge lies in the processing, especially in the wet chemical etching of the sloped side of the triangular sections. In Figure 4, the twin-guide platform cross section is shown with the strategy for this integration strategy (option 1). This implies the wet chemical etching of the sloped side can only be done after bonding, which means extra care should be taken in protecting the underlying active layers from the consecutive wet etches.

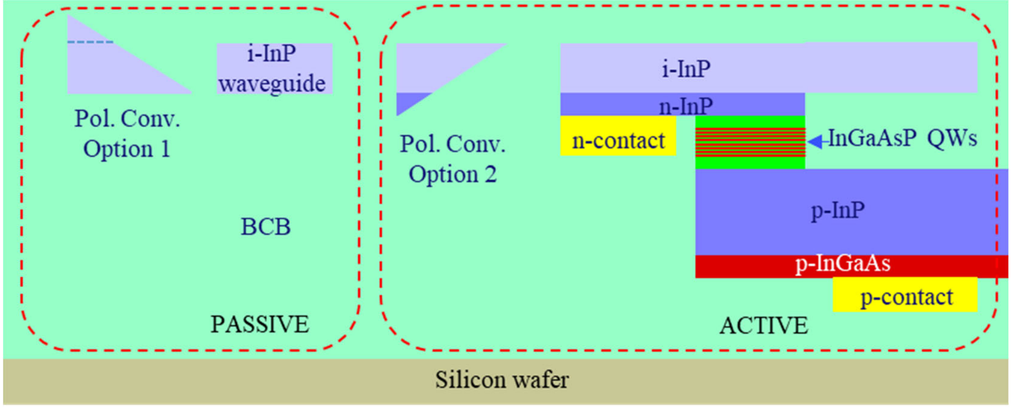


Figure 4 - Schematic cross-section of the investigated integration strategies.

For the second approach, no additional layers are required to integrate the polarization converter on the platform. However, the original thickness of the n-doped InP layer (the layer just below the intrinsic InP waveguiding layer) has to be increased to accommodate for the height of the triangular section. The benefit of this option, compared to the previously described one, is that no extra layers need to be added to the original stack. The drawback is the requirement of a slightly thicker (140 nm instead of 80 nm) n-doped InP layer, which may have implications for both electrical and optical performance of the devices.

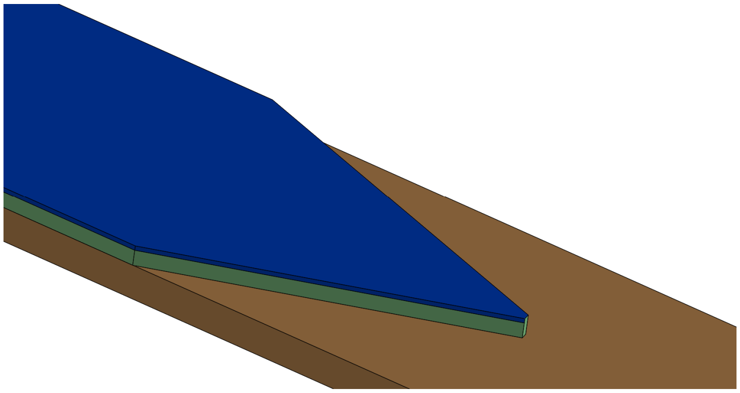


Figure 5 - Taper design, bottom layer is InP waveguiding core, middle layer (green) is n-doped InP, and top layer (blue) is InGaAsP.

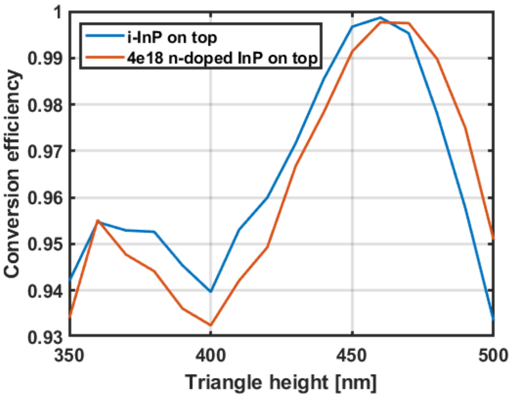


Figure 6 - Simulated conversion efficiency against triangle height.

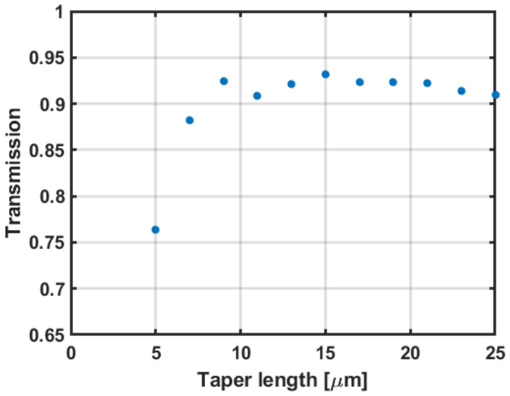


Figure 7 - Simulated transmission for various taper lengths.

A Finite-Difference Eigenmode (FDE) and solver was used to simulate devices with both cross-sections shown previously. These simulations show that the use of n-doped InP for the top of the triangular section compared to intrinsic InP has negligible impact on the performance of the device. The transmission of both devices is shown in Figure 6. The insertion loss of the full device is increased by less than 0.02 dB, and the effective refractive index difference of the hybrid modes changes by less than 0.01. The electrical performance of the device will be slightly improved by choosing a thicker layer of n-InP, since the metal is placed on the same side as the active core, as shown in Figure 4, and hence the resistance will decrease.

Taper design

Another challenge that is implied by opting for the second option, is the increased distance between the active core and the waveguiding layer. This requires changes to the taper that is used for transitions between the active core and the passive waveguides. Simulations are performed to determine the optimal taper design for high transmission and low reflections. The taper is designed for a 2 µm wide waveguide, as shown in Figure 5, and is made symmetric to prevent the excitation of the first order mode. The simulated transmission and reflection of the taper are shown Figure 7. The optimal taper length is around 15 µm, with a transmission over 93% and reflections well below -40 dB.

Conclusion

The challenges of integration of an ultrashort polarization converter on the IMOS twinguide platform are identified and discussed. Two integration options are presented and a new taper design is proposed, supported by results of 3D finite-difference time-domain simulations.

References

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