

## Fabrication technology of a slot waveguide modulator in InP Membranes on Silicon (IMOS)

**Citation for published version (APA):**

Millan Mejia, A. J., Jiao, Y., van der Tol, J. J. G. M., & Smit, M. K. (2016). Fabrication technology of a slot waveguide modulator in InP Membranes on Silicon (IMOS). In *18th European Conference on Integrated Optics (ECIO 2016)*, 18-20 May 2016, Warsaw, Poland (pp. 223/224). [ECIO p-20]

**Document license:**  
Unspecified

**Document status and date:**  
Published: 21/05/2016

**Please check the document version of this publication:**

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

**General rights**

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

[www.tue.nl/taverne](http://www.tue.nl/taverne)

**Take down policy**

If you believe that this document breaches copyright please contact us at:

[openaccess@tue.nl](mailto:openaccess@tue.nl)

providing details and we will investigate your claim.

## Fabrication technology of a slot waveguide modulator in InP Membranes on Silicon (IMOS)

A.J. MILLAN-MEJIA\*, Y. JIAO, J.J.G.M. VAN DER TOL, M.K. SMIT

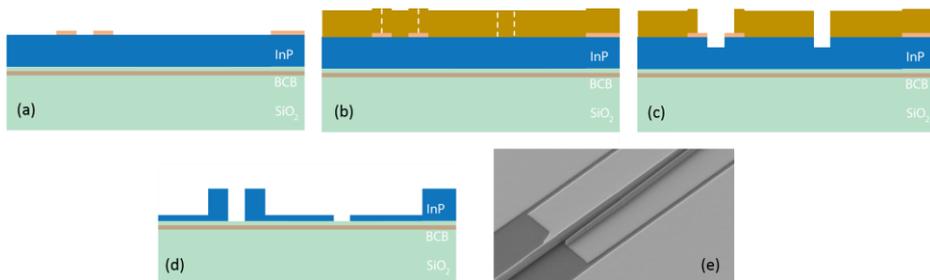
Photonic Integration Group (PhI), Dept. of Electrical Engineering, Technische Universiteit, Eindhoven, De Rondom 70, 5612AP, Eindhoven, The Netherlands

\* alonso.mlln@gmail.com

**Abstract:** For the InP Membranes On Silicon (IMOS) platform [1], we developed an electro-optic modulator based on a slot-waveguide with a high nonlinear polymer. A variety of fabrication techniques are used, including electron beam lithography (EBL), optical lithography (OL), dry etching and metallization. The fabrication of such modulator requires a complex fabrication process. In this work we present and discuss the most important fabrication steps.

It has become clear that in order to have a competitive photonic integration platform, high performance devices have to be included. A Mach-Zehnder interferometer structure with a phase modulator based on a slot waveguide with a highly nonlinear electro-optic polymer is a good candidate [2]. The high confinement of the optical electric field inside the low refractive index area in the slot waveguide, allows a high overlap with an electro optical polymer, letting to an effective phase modulation. We have predicted that this device working at  $V_{\pi} = 1.2 V$  and having a length of  $750 \mu m$  can have a  $V_{\pi} \times L = 0.7 Vmm$  and a bandwidth higher than 40GHz.

To fabricate this device we need five EBL steps and one OL step. The first two lithographic steps (E-beam) are the definition of the alignment marks and the grating couplers. A ZEP/C<sub>60</sub> resist in combination with a SiN<sub>x</sub> mask is used for this purpose. The etching of the semiconductor is performed with inductively coupled plasma (ICP) dry etching using a methane-hydrogen chemistry (CH<sub>4</sub>:H<sub>2</sub>). ZEP/C<sub>60</sub> resist was used because it gives better control of the dimensions and higher resolution of the structures than normal ZEP [3].

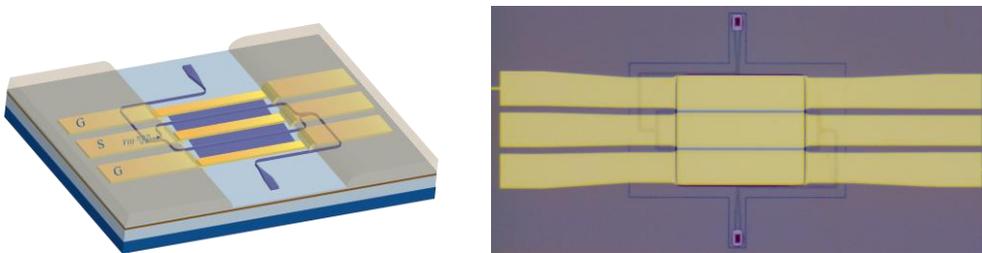


**Fig. 1. (a) Hard mask definition (SiN<sub>x</sub>). (b) Definition of the opening areas. (c) Etch of the opening areas. (d) Schematic of the final structure. (e) SEM picture of fabricated slot waveguide and the spot-size converter to normal stripe waveguide.**

The third and fourth EBL steps define two different height levels with a high resolution overlay exposure (a few nanometres tolerance). One level of footing which electrically connects the slot waveguide with the metal contacts (n-doped InP), and the second level which define the electric isolation section. A self-alignment technique is used to overcome the narrow tolerance. Fig. 1 illustrate this process. In the first step the slot waveguide is defined, as in the previous lithographic steps, with ZEP/C<sub>60</sub> resist in combination with a SiN<sub>x</sub>

mask. When the hard mask is defined. We remove the resist with an oxygen plasma (Fig. 1-a). The next step consists of depositing a new layer of ZEP/C<sub>60</sub> resist and exposing the areas where an electrical isolation is needed. Because the real definition of the waveguide is given by the hard mask already present, this exposure has a good tolerance to misalignment (Fig. 1-b). When we have developed the resist, we etch the sample with an ICP process with a depth for around 100nm, which will be enough to assure the electrical isolation (Fig. 1-c). Finally, we remove the ZEP/C<sub>60</sub> resist with an oxygen plasma process and we continue the etching with ICP until we reach the desired footing thickness (~50nm). We remove the hard mask with a reactive ion etching (RIE) process thereby obtaining our two level structures (Fig. 1-d).

The next step consists of the fabrication of the contacts. We need to have the contacts outside the MZ structure, to optimize the microwave properties and obtain good RF performance. This can be done with a two-level contacts scheme, as Fig 2(a) illustrates. To do so we start spinning a layer of polyimide of at least 1 $\mu$ m thick to avoid absorption when the metal cross the waveguide underneath. After the polyimide layer is deposited, we spin 2.5  $\mu$ m of negative photoresist (MaN 440). We define the areas where the metal will contact the semiconductor with optical lithography. When these areas are developed, we reflow the resist at 140°C to create a slope at the pattern edges. Using a polymer RIE process we transfer the slope from the photoresist to the polyimide. This is possible because they have the same etch rate. We remove the rest of the photoresist using acetone. Having created the slope, we define the metal contacts with an EBL step using PMMA photoresist and evaporate the metals (Ni(30nm):Ge(50nm):Au(250nm)). Finally we do a lift-off. Fig 2(b) illustrates a fabricated MZ device. The last step which has not yet be implemented is the deposit and poling of the electro optical polymer.



**Fig. 2. (a) Illustration of the MZ device where the two levels metal contacts are clearly seen. (b) Picture of the fabricated MZ modulator**

In conclusion we have shown a general overview of the processing technology to fabricate an electro-optic modulator based on slot waveguides in a Mach-Zehnder configuration. The most critical steps and their results have been presented and demonstrated. The fabrication is almost finished and it is ongoing. Acknowledgments: This work was supported by the ERC Project NOLIMITS and NANOLAB TU/Eindhoven

#### References

- [1] J. van der Tol *et al*, *Photonic integration in indium-phosphide membranes on silicon (IMOS)*, Integrated Optics: Devices, Materials, and Technologies XVIII, pp. 89880M-89880M-17, 2014
- [2] A. Millan-Mejia *et al*, *Design and simulation of a high bandwidth optical modulator for IMOS technology based on slot-waveguide with electro-optical polymer*, Proceedings Symposium IEEE Photonics Society Benelux, pp. 195-198, 2013
- [3] Jiao, Y. *et al*, *Fullerene-assisted electron-beam lithography for pattern improvement and loss reduction in InP membrane waveguide devices*. Optics Letters, 39(6), 1645-1648, 2014.