Indium phosphide based membrane photodetector for optical interconnects on silicon

Citation for published version (APA):

DOI:
10.1109/LEOS.2008.4688610

Document status and date:
Published: 01/01/2008

Document Version:
Publisher’s PDF, also known as Version of Record (includes final page, issue and volume numbers)

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

Take down policy
If you believe that this document breaches copyright please contact us at:
openaccess@tue.nl
providing details and we will investigate your claim.

Download date: 14. Mar. 2019
Indium Phosphide based Membrane Photodetector for Optical Interconnects on Silicon


Abstract—We have designed, fabricated and characterized an InP-based membrane photodetector on an SOI wafer containing a Si photonic circuit. New results on RF characterization up to 20 GHz are presented. The detector fabrication is compatible with wafer scale processing steps, guaranteeing compatibility towards future generation electronic IC processing.

I. INTRODUCTION

For future generation electronic ICs, a bottleneck is expected at the interconnect level. The integration of optical sources, waveguides and detectors forming a photonic interconnect layer on top of the CMOS circuitry is a promising solution, providing bandwidth increase, immunity to EM noise and reduction in power consumption [1]. This solution is investigated within the European project PICMOS1. In that context, the interconnect layer is built as a passive Si photonic waveguide layer and the InP-based photonic sources and detectors are fabricated in a way compatible with wafer scale processing steps. This approach combines the advantages of high quality Si wires with the excellent properties of InP-based components for light generation and detection. The integration technique that is investigated here assures compatibility towards future generation electronic ICs and is based on a die-to-wafer molecular bonding technology [2]. Experimental results on a full optical link, including lasers and detectors, were reported in [3]. In this paper, we focus on the photodetector (PD): device design, fabrication and measurement results are presented, including device characterization up to 20 GHz.

II. DESIGN

In order to detect the light, it first has to be coupled from the Si waveguide into the PD structure. In our approach, that is realized by means of an InP membrane input waveguide on top of the SOI wafer containing the Si photonic wiring (see Fig. 1). The two waveguides act as a synchronous coupler that transfers the optical signal from the Si wire into the transparent InP waveguide, which guides it to the PD absorption region stacked on top of the transparent layer. The detector structure is built as an InGaAs absorption layer sandwiched between a highly p-doped InGaAs contact layer and a highly n-doped InP layer, which is also used for realizing the membrane waveguide, and has a footprint of 5 × 10 μm². We chose a total detector thickness of 1 μm in order to ease integration with the μ-disk lasers described in [3]. The thickness also results from a trade-off between device speed and efficiency: simulation results show that with our PD configuration, an internal quantum efficiency of > 70% and a 3-dB bandwidth of 25 GHz are expected, as we reported in [4]. The detector input InP coupler was designed with a cross section geometry of 0.25×1 μm² and a length of 14 μm to achieve mode matching with the Si photonic waveguide, which is 500 × 220 nm² [4]. Details about design, fabrication and characterization of the Si waveguides are extensively presented in [5].

III. FABRICATION

The PD layer stack was grown on a 2” InP wafer. It was sawn in dies that were then molecular-bonded upside down on an SOI wafer, in which the Si waveguides had been defined, and the InP substrate was removed from the dies by a combination of CMP and wet-chemical etching. Afterwards, the PD pattern was aligned on the Si structures by e-beam lithography and transferred to a SiO₂ hard mask.
Fig. 2. Picture of the chip. PDs are grouped in blocks (8 devices/block). RF pads and Si grating couplers are indicated. In the close-up box, a PD and the initial part of the Ground-Signal-Ground (GSG) RF metal pads are shown.

Fig. 3. Measured photocurrent for 0, 25 and 50 µW optical input power as a function of the detector applied bias voltage.

IV. EXPERIMENTAL RESULTS

The detector DC characterization was performed by using a tunable laser source (TLS) and a polarization controller to couple TE-polarized light through the grating coupler into the Si waveguide. A source-meter unit was used to reversely bias the PD and to read out the generated photocurrent. The photodiode generated photocurrent as a function of the applied bias voltage was measured for 0, 25 and 50 µW input powers (see Fig. 3). A dark current around 1.6 nA was registered at −4 V. The PD responsivity was calculated to be $R = 0.45$ A/W, which is a conservative value, as the grating coupler maximum efficiency was assumed (maximum 20% at 1575 nm). Such responsivity corresponds to a quantum efficiency of 35%, which includes the efficiency of the InP membrane coupler and the internal quantum efficiency of the pin-detector itself.

Dynamic measurements were performed in the range of 130 MHz to 20 GHz with an Agilent HP8703A lightwave component analyzer (LCA), used for small signal modulation of the input optical power from the TLS and for reading out the RF electrical signal generated by the PD. Results are presented in Fig. 4, which shows a rather flat frequency response up to 20 GHz, except for oscillations around 17 GHz, probably due to non-ideal de-embedding of the RF components used in the set-up, and around 2 GHz, caused by the optical module of our LCA, not working properly below that point.

V. CONCLUSION

We presented a 50 µm² InP-based photodetector fabricated on samples bonded to an SOI wafer containing Si waveguides, suitable for an optical interconnect layer on top of CMOS ICs. Measurements recorded a responsivity $R = 0.45$ A/W and a rather flat frequency response up to 20 GHz.

REFERENCES


Fig. 4. Detector frequency response.