Design and fabrication of a compact gas sensor integrating a polymer microresonator and a 850nm VCSEL source

Qingyue Li, Vincent Raimbault, Philippe Menini, Thierry Camps, Véronique Bardinal

Design and fabrication of a compact gas sensor integrating a polymer microresonator and a 850nm VCSEL source

Qingyue Li, Vincent Raimbault, Philippe Menini,
Thierry Camps and Veronique Bardinal.

Univ Toulouse, CNRS, LAAS,7 Ave Colonel Roche
F-31400, Toulouse, France
vraimbau@laas.fr

***Abstract*—A compact gas sensor integrating a polymer microresonator and a 850nm VCSEL source is designed for health and environmental applications. The overall system is optimized using simulation tools by considering cleanroom fabrication tolerances. First fabrication results on 3D printed lens for VCSEL collimation and 800nm period aluminum grating couplers are highlighted.**

Keywords—microring resonator; grating coupler; optical gas sensor; polymer; VCSEL; 2-photon lithography

I. Introduction

Major difficulties of miniaturized gas sensors are sensitivity and selectivity. In this context, optical sensors are relevant for ppb level detection. Following the development of nanofabrication techniques, microring resonators are gathering interest as passive label-free sensors for gas sensing [1]. They offer some numerous valuable features as Refractive Index (RI) sensing devices because of their high sensitivity, robustness, fast response time and compatibility with collective manufacturing cleanroom technologies. In this work, a system-based approach has been followed with the objective of an affordable, portable system in mind. Combination of SU-8 and CYTOP for the waveguide materials has been favored [2], as well as the use of aluminum to improve CYTOP wettability [3], and for grating couplers fabrication [4]. To further improve the system compactness, a 850nm VCSEL equipped with a 3D-printed collimation lens is associated to the grating coupler.

II. Sensor Design

The sensor operating principle is based on a sensitive layer covering the microresonator, which RI is influenced in the NIR range by the presence of the target gas molecules [5]. This leads to spectral shifts of the micro-resonator transmission peaks within the tuning range of the 850nm VCSEL source (max. 6nm with a thermal control). To guarantee single-mode operation, an optimal 400nm*1µm waveguide cross-section has been selected from both theoretical calculations (FDTD) and cleanroom fabrication limits. The aluminum grating period of the couplers has been fixed at 800nm, i.e. slightly above the resolution limit of our stepper lithography I-line equipment (365nm). An optimal coupling angle of 19° with a theoretical coupling efficiency of 17% has been retained, while the grating surface is 100µm by 100µm.

RENATECH and ANR-15-CE19-0012 DOCT-VCSEL

III. First Experiments

To obtain a VCSEL beam waist of ~60µm on the grating-coupler surface, a 130µm-high pedestal and a 80µm diameter polymer microlens have been designed using Zemax simulation tool. In this work, the pedestal and the microlens are fabricated in a single step, with 2-Photon Lithography (2PL), using IP-DIP resist. This new technique presents the advantage of being applicable on demand on VCSEL chips at a post-mounting stage and with a writing time of less than 10 minutes (fig1.b). The beam divergence at $1/e^2$ has been reduced from 14° to 3°, thus giving much more tolerance on the vertical positioning of the source. The fabrication process of the 800nm-period aluminum grating couplers on CYTOP bottom cladding has been carefully optimized. Our first tests indicate that this process can achieve good results in terms of period and with acceptable duty cycles (fig.1c).

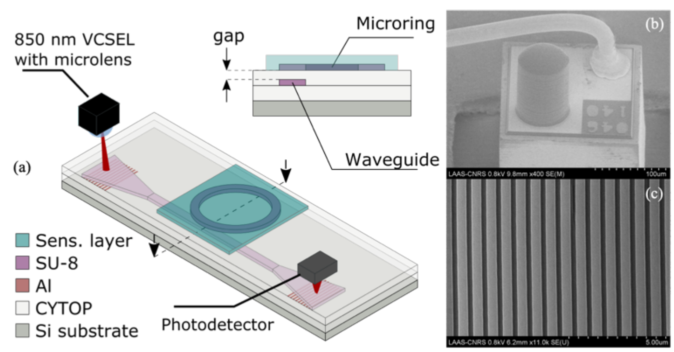

Fig. 1 (a) General view of sensor and waveguide design. Right: SEM images of the collimated VCSEL (b) and the metallic grating coupler (c).

IV. Conclusions

A compact optical gas sensor is designed based on the use of low-cost polymer materials, a collective lithography technique and a VCSEL source integrating a 3D-printed lens.

V. References

[1] G. Mi et al., *Opt. Express*, vol. 25, no. 14, p. 16250, 2017.
[2] C. Delezoide et al., *Proc. SPIE*, 2012, vol. 8264, pp. 826416-826416–13.
[3] B. Agnarsson, et al., *Microelectron. Eng.*, vol. 87, no. 1, pp. 56–61, Jan. 2010,
[4] C. A. Barrios et al., *Opt. Commun.*, vol. 382, pp. 477–484, 2017.
[5] S. Christie et al., *Sensors Actuators, B Chem.*, vol. 90, no. 1–3, pp. 163–169, 2003.