# Application of nanophotonic biosensors for the detection of traces of DMMP

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## Abstract

Label free measurement systems are developed for the implementation of more sensitive and reliable solutions for detection purposes. The specific detection of some chemical compounds is specially challenging due to the small size of the target molecules. In this work it is shown the detection of chemicals with interest in defence and security applications. By means of a photonic refractive index sensor coated with biospecific bovine odorant binding protieins (b-OBP) direct measurements of ultra low concentrations (20 ppb) of DMMP has been achieved.

## Introduction

The detection of traces and ultra-traces of toxic and harmful compounds in air by using networks of small sensors like MEMS (Micro Electro Mechanical Systems) or Lab-on-Chip devices, has led to a challenging research in these last years. Developments in biosensing solutions seek for the implementation of faster, more reliable sensing solutions with an ever increasing sensibility and at the same time easiness in the operation. These general features are valid for a big variety of fields in which the biosensors can be applied such as the medicine, veterinary or industrial applications. The molecular recognition approaches show outstanding performances with big biospecificity and are the ones with bigger expansion in commercial applications. Some of the most spread techniques, such as the well known ELISA (Enzyme-linked immunoSorbent assay) or ELFA (Enzyme-linked fluorescent assay), rely on the use of labelling molecules in the process of detection. These approaches require a labelling process that increases the complexity of the measurement. When the target of the sensing application consists of small chemical molecules these techniques fail due to the existence of only a single antigenic determinant. Therefore these kinds of techniques are no more valid for detection of chemicals with very small sizes.

Optical technology is one of the solutions widely used for implementation of transduction systems to monitor the sensing of a pollutant. Coupled to bio-recognition, nanoscale photonic Lab-on Chip systems permit both (i) the integration in one single device of several parts such as the probe, the transduction and the sampling system; and (ii) the development of a powerful detection and analysis tool with advantages of low cost and portability. Label free photonic biosensors have vast applications, especially in environmental and industrial monitoring.

This work, carried in under the project of the EDA JIP-ICET NANOCAP, deals with the detection of Dimethyl methylphosphonate (DMMP) as a stimulant of Sarin Gas for defence and security sensing applications.

## Experiment and results

The sensing structure employed in the measurements consists of photonic integrated

circuits [1] implemented with $Si_3N_4$ strip waveguides with a cross section of 0.3x1.1µm. The transduction is implemented with a ring resonator (RR) structure with a total length of 654 µm. SEM micrographs of the fabricated RR are shown in Fig.1. The $Si_3N_4$ layer was deposited using low pressure chemical vapor deposition (LPCVD) and was patterned using i-line photolithography and dry etching. The ring resonator was functionalized with bovine odorant binding proteins (b-OBP) whose amino acid sequence was modified to selectively bind DMMP [2].

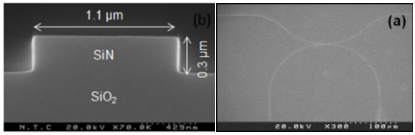


**Figure 1:** SEM images of the cross section of the SiN waveguide (left) and the ring resonator structure employed for the transduction of the biochemical binding (rigth).

A constant flow of 200 mL/min of $N_2$ is employed in the measurement for transporting the traces of DMMP. First the sensor is stabilized with the $N_2$ flow and then injections of 20 ppb of DMMP are performed to test the sensor. To demonstrate the selectivity binding of the b-OBP and check that there is no inespecific adsorption, the experiment was implemented in three different chips: one functionalized for DMMP with the b-OBP, a second raw chip without functionalization and finally a chip with a functionalization with other proteins. Results from the experiments are shown in Fig. 2 a, b and c respectively.

As it is shown in the graphs of Fig. 2 the flow of DMMP leads initially to a transient drift in the wavelength in the three cases but only the chip functionalized for detection of DMMP shows a stable signal (wavelength shift of ~20pm) due to the binding. The absence of a signal in the raw chip and in the one functionalized with proteins shows that there is no unspecific adsorption to the chip and neither to the proteins. In all the experiments all the conduction tubes and the measuring cell where heated up to 80 ºC to prevent the adsorption.

## Conclusion

In this work it is shown the capabilities of nanophotonic biosensros for the detection of traces of DMMP (20 ppb) in gas medium. The implementation of a direct measurement without labelling process permits the direct detection of small molecules with a single epitope. The technique shows high sensitivity but at the same time simplicity since it measures the target DMMP directly in gas phase without the need of preconcentration systems and the transportation to liquid phase.

These are key features for the implementation of defence and security applications in the surveillance of environmental conditions.

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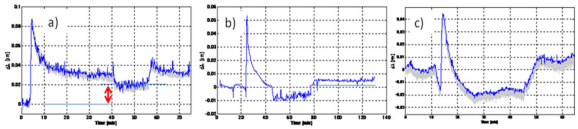


**Figure 2:** SEM images of the cross section of the SiN waveguide (left) and the ring resonator structure employed for the transduction of the biochemical binding (rigth).