Photoacoustic infrared gas sensors based on mechanical resonators for environmental to diagnosis applications

A. Vicet[1], D. Ayache[1], J. Charensol[1], T. Seoudi[1], E. Kniazeva[1,2], E. Rosenkrantz[1] F. Gouzi[3], M. Bahriz[1]

1 IES, Univ. Montpellier, CNRS, Montpellier, France
[2]PolySense Lab, Università degli Studi di Bari Aldo Moro e Politecnico di Bari, Bari, Italy
3 PhyMedExp INSERM U1046 CNRS UMR 9214, Montpellier University, Department of Clinical Physiology Montpellier University Hospital, Montpellier France.
Aurore.vicet@umontpellier.fr

Abstract: We present in this paper a review of our works on resonators-based photoacoustic spectroscopy. We have worked on quartz enhanced photoacoustic spectroscopy (QEPAS) for many years, then developed in 2018 a new technique based on silicon mechanical resonator (MEMSPAS), dedicated to photoacoustic sensing. We will present some of the applications of these techniques, especially breath analysis by biomarkers detection for medical diagnosis.

Laser photoacoustic (PA) spectroscopy has been widely used as gas sensing technique in various applications. Improvements and large scale production of MEMS microphones made them affordable and very efficient, and several PA devices have been demonstrated and commercialized [1].

PA spectroscopy exploits mechanical resonators (cantilevers, MEMS, tuning forks…) in or out of their resonant mode to detect acoustic waves generated by photoacoustic effect. While MEMS microphones and cantilevers work in a broad frequency range out of their mechanical resonance, the sharp electro-mechanical characteristic of the quartz tuning fork (QTF) has been successfully exploited since 2002 in the development of quartz enhanced PA spectroscopy (QEPAS) [2]. Based on a low-cost, high Q-factor component, this technique is immune to ambient noises and have proved its efficiency in diverse applications. Many configurations were proposed to enhance the sensitivity of QEPAS [3] and some custom QTF with lower resonance frequencies and bigger prongs spacing were developed as standard QTFs are not perfectly designed to fit photoacoustic excitation.

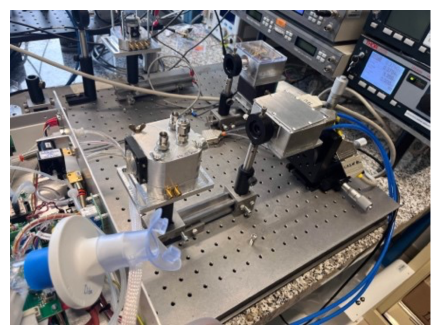

Figure 1. QEPAS setup for breath analysis.

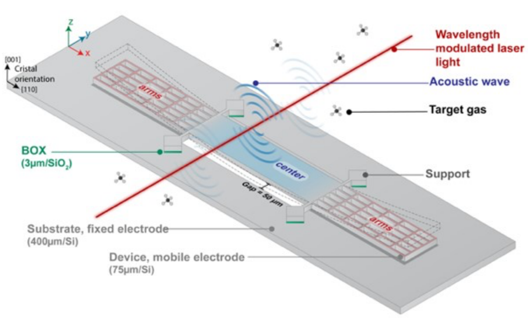

Figure 2- Deflection of a MEMS-type mechanical resonator under photoacoustic excitation. The resonator is made up of two parts: the central part collects the photoacoustic energy, and the arms transform it into a signal proportional to the concentration of the targeted pollutant.

In this talk we will present the development that we made on QEPAS in an off-beam configuration with 3d-printed acoustic resonators and its applications in many setups, from the industrial (gas pollutants) [4] to the clinical field (breath analysis) (figure 1) [5]. Then we will describe an innovative approach that we propose using resonant silicon-based MEMS (figure 2) specially designed for PA sensing. The measurement is based on capacitive detection which allows simple fabrication and detection scheme as well. These resonators, with optimized coupling to the acoustic wave, show very promising results in terms of detectivity (Normalized Noise Equivalent Absorption) [6,7], integration (Silicon material) and can also be coupled to an acoustic resonator to improve their detection limit.

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