Photoacoustic sensing based on resonant mechanical transducers: application to diagnosis in breath

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Abstract

In this paper we will illustrate our studies on photoacoustic spectroscopy based on mechanical resonators (Quartz tuning forks and MEMS) and their application on breath analysis.

We will describe a several-months measurement campaign at Montpellier Hospital, which focused on diagnosing chronic heart failure using Quartz Enhanced Photoacoustic Spectroscopy (QEPAS).

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Future medicine needs point of care diagnosis tools dedicated to fast, non-invasive and in situ measurements on patients, potentially at a long distance from any hospital, far from any specialist intervention, to be able to provide adapted treatments and chronic diseases follow up.

Breath analysis might play a substantial role in the future's medicine. It can give access to very simple sample extractions needing neither complex examination nor invasive examination. Breath biomarkers analysis opens the way to various applications from emergency diagnosis to long term follow up of several diseases, from respiratory affections to gastric malabsorptions, intoxications and even cancers [1].

We present here our latest works concerning photoacoustic sensing setups, based on resonant mechanical transducers and their developments on breath sensing. We will describe our last multigas sensing setup based on off-beam QEPAS [2]. QEPAS [3] has acquired a sufficient maturity to reach in situ demonstrations in various fields, such as pollution and environmental sensing [4], or clinical approaches [5].

MEMS photoacoustic spectroscopy is now a real challenger, and progresses were made that position this technique as sensitive as bare QEPAS [6], and its high potential in terms of miniaturisation and integration is a big advantage for future perspectives. We will show our latest developments on silicon-based MEMS designs, fabrication and photoacoustic sensing.

Then, we will present our latest demonstrations on QEPAS to detect several species of medical interest, particularly for chronic heart failure diseases. The setup will be used to investigate four cardiovascular diseases (CVD) biomarkers found in exhaled breath: Carbon Monoxide (CO), Nitric Oxide (NO), isoprene, and acetone, using four different infrared lasers (4.6 μm, 5.2 μm, 11 μm and 8.2 μm). The high resolution and real-time concentration measurements of these biomarkers using QEPAS sensors are combined with the flow rate and capnography provided by a breath sampler used at Montpellier hospital in pulmonary tests. It enables the reconstruction of the complete expirogram for the biomarker and allows tracing their concentration in each compartment of the respiratory system.

Eventually, we will discuss about the observations of this clinical study conducted in Montpellier hospital on both healthy individuals and patients diagnosed with cardiovascular diseases.

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