DOI 10.5162/EUROSENSORSXXXVI/OT5.187

Development of a Photoacoustic Cell for Volatile Organic Compounds (VOCs) Detection

Mh. S. Moussa[1], R. Viard[2], J-F Lampin[1], V. Maurice[1], C. Ghouila-Houri[1], Sophie Eliet[1], A. Mazzamurro[1], O. Bou Matar[1], P. Pernod[1], A. Talbi[1]

[1] Centrale Lille institute, Univ. Lille, CNRS, Univ. Polytechnique Hauts-de-France, UMR 8520 IEMN, F-59000 Lille, France.

[2] Groupe Endress+Hauser, Fribourg-en-Brisgau, Allemagne.

Corresponding Author's e-mail address: mohand.moussa@centralelille.fr

Summary:

In this paper, we report the development and use of a photoacoustic cell designed for gas spectroscopy of volatile organic compounds (VOCs) used as biomarkers of breast cancer. The cell, composed of a PMMA Helmholtz resonator grafted to a finite size tube. A commercial microphone mounted on the Helmholtz enables the measurement of the system response at its resonance frequency. The system was successfully characterized using different concentrations of isopropanol (0.5 to 17 ppm) using tunable MIRCAT QCL laser with wavelength range of 8-11µm.

Keywords: Photoacoustic, gas spectroscopy, breast cancer biomarkers, volatile organic compounds.

Introduction

In the context of non-invasive medicine, volatile organic compounds (VOCs) can be used as biomarkers in various clinical applications, such as early detection of breast cancer, monitoring treatment efficacy, and detecting recurrences. These are created by human body cells when subjected to oxidative stress [1], then transformed by an enzyme, Cytochrome P-450 [2], which regulates the levels of chemical species in the human body. These VOCs can be found within the cells themselves and transmitted via the bloodstream to breath, sweat, urine, feces, saliva, etc. [3],[4].

Kure et al. published a study in 2021 [5] proposing a prediction model for breast cancer using only Isopropanol and 2-butanone as biomarkers with an efficacy rate of 90%. In this study, analysis was conducted on urine using mass spectrometry and gas chromatography. A healthy individual typically has an isopropanol level between 1 and 20 ppb, while a person with cancer has a concentration ranging from 10 to 100 ppb [6].

Experimental materials

In this study, we report the development and use of a photoacoustic cell entirely made of plexiglas (PMMA), see figure 1.b, for gas spectroscopy. The first design step focuses mainly on the design of high-performance photoacoustic cells. Isopropanol was the targeted gas for our analysis. A commercial microphone (TDK membrane microphone) was used in this study. The laser used is a MIRCAT QCL from Daylight solution laser emitting in the far-infrared [7], which is in the range of one of the absorption peaks of isopropanol at 8.73 µm (1144.47 cm^{-1}). Laser modulation is achieved using a mechanical chopper. The frequency of modulation is chosen close to the acoustic cavity resonance frequency. The acoustic cavity is composed of a Helmholtz resonator grafted to a finite size tube outside a pressure node as shown in Figure 1.a (COMSOL Multiphysics simulation).

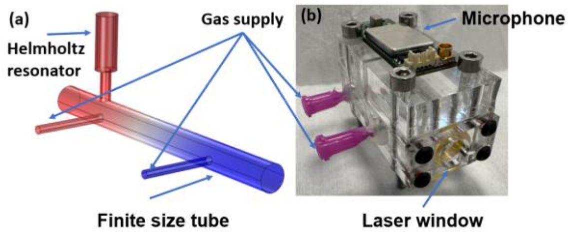

Fig. 1. Schematic of the photoacoustic cell and the pressure field at its resonance frequency (a). Picture of the Photoacoustic cell (b).

Results

Figure 2 shown the schematic of the experimental setup of measurements, composed of the acoustic cavity, QCL tunable laser, chopper for laser beam modulation and high resolution acquisition systeme. Figure 3 display the results for the measured signal at different concentrations of isopropanol. Accurate acquisition system is used for this purpose (200kHz sampling frequency with 24bits resolution). The root square of the PSD is plotted in linear scale showing high SNR. In pure air the level of the signal is extremely low, we also test the excitation at different laser wavelength showing a good agreement with isopropanol absorption spectrum (result not shone here). The linearity of the system was evaluated and the results is shown figure 4.b. The sensitivity is estimated to be around 50mV/ppm. According to this preliminary results, resolution close to few ppb can be achieved with this design. Ongoing works on the design optimization are very promising.

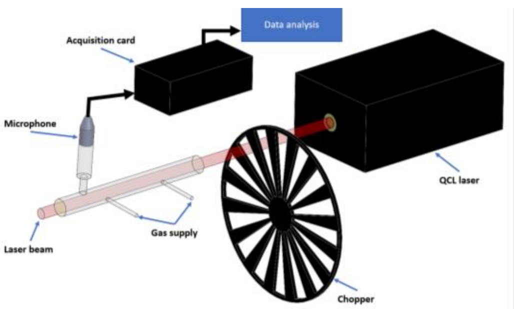

Fig. 2. Schematic of the experimental setup.

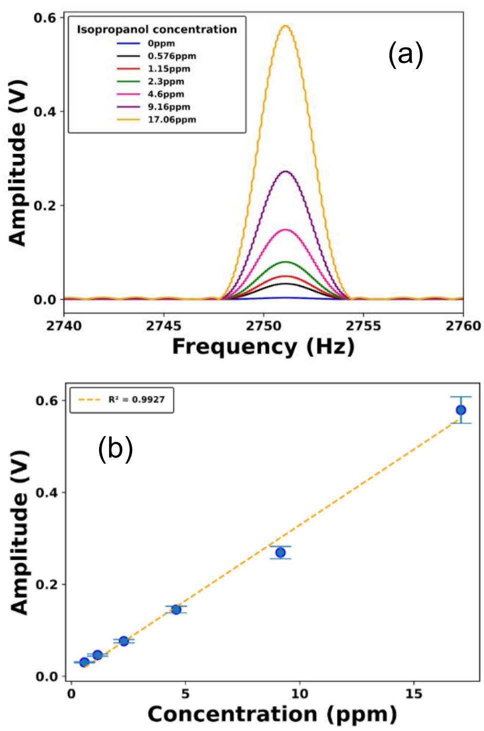

Fig. 3. Photoacoustic signal for different concentration of isopropanol (a). Linearity between the amplitude's signal and the concentration of isopropanol (b).

References

[1] A. Jezierska-Drutel et al., « Role of oxidative stress and the microenvironment in breast cancer development and progression », Adv. Cancer Res., vol. 119, p. 107-125, 2013, doi: 10.1016/B978-0-12-407190-2.00003-4.

[2] F. P. Guengerich et al., « Role of human cytochrome P-450 IIE1 in the oxidation of many low molecular weight cancer suspects », Chem. Res. Toxicol., vol. 4, no 2, Art. no 2, mars 1991, doi: 10.1021/tx00020a008.

[3] A. Amann et al., « The human volatilome: volatile organic compounds (VOCs) in exhaled breath, skin emanations, urine, feces and saliva », J. Breath Res., vol. 8, no 3, Art. no 3, juin 2014, doi: 10.1088/1752-7155/8/3/034001.

[4] Y. Y. Broza et al., « Hybrid volatolomics and disease detection », Angew. Chem. Int. Ed Engl., vol. 54, no 38, Art. no 38, sept. 2015, doi: 10.1002/anie.201500153.

[5] S. Kure et al., « A prediction model using 2-propanol and 2-butanone in urine distinguishes breast cancer », Sci. Rep., vol. 11, p. 19801, oct. 2021, doi: 10.1038/s41598-021-99396-5.

[6] Y. Adiguzel et al., « Breath sensors for lung cancer diagnosis », Biosens. Bioelectron., vol. 65, p. 121-138, mars 2015, doi: 10.1016/j.bios.2014.10.023.

[7] « MIRcatTM Mid-IR Laser: Tune 1000 cm-1 at 1000s cm-1/s | High-Speed Tuning », Daylight Solutions. https://www.daylightsolutions.com/products/mircat/