A miniaturized breath analyzer based on NDIR spectroscopy

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CONTEXT

Exhaled breath contains plenty of **volatile organic compounds** and aerosol particles. Both represent biological information for disease diagnosis or intoxication screening. Breath analysis is one of the non-invasive methods with the possibility of a very quick patient diagnosis. **Olythe developed a miniaturized sensor based on infrared spectroscopy** for gaz analysis in exhaled air. OCIGO is an innovative, reliable, mobile and **compact infrared alcohol breathalyzer.**

BACKGROUND AND OBJECTIVES

Our objective was to design a sensor to quickly, accurately and reliably measure breath alcohol levels. For this purpose, we focused on the **miniaturized non-dispersive infrared spectroscopy (NDIR) technology**.

The exhaled air passes through a measuring cuvette crossed by an **infrared radiation** provided by an optical emitter. A part of the radiation is **absorbed by the alcohol present in the cuvette**, allowing to calculate precisely the alcohol concentration in the exhaled air thanks to the **Beer-Lambert law**.

Beer lamber law: $A = \varepsilon l C$

A: the absorbance, **ε:** the molar attenuation coefficient , **l:** the optical path length, **C:** the gas concentration

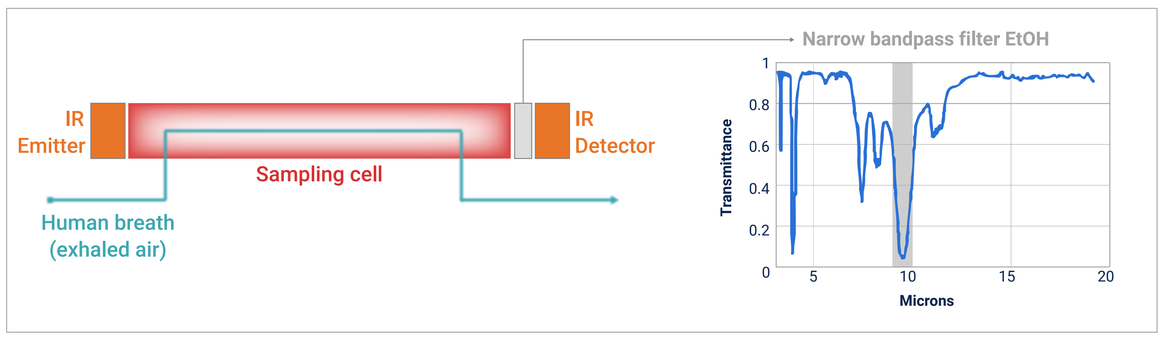


Figure 1 : NDIR technology principles

Technical challenges

To achieve miniaturization of a breath analysis sensor using infrared spectroscopy, some challenges had to be overcome:

- Thermal architecture and breath management
- Temperature compensated high sensitive detector
- Low electrical consumption & high emissivity emitter
- Optimized optical system with high reflectivity and high IR efficiency
- Signal processing with a dedicated algorithm on low power MCU

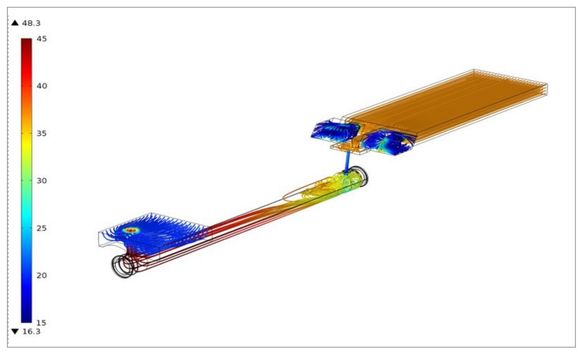


Figure 2: Aeraulic flow simulation

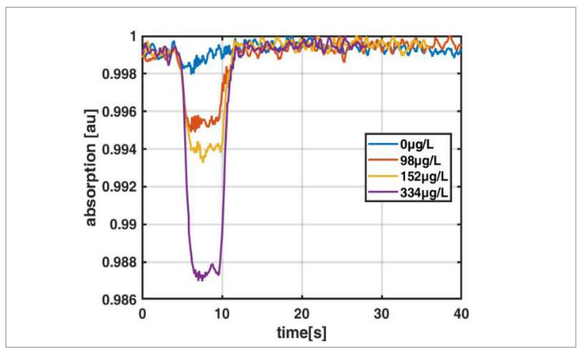
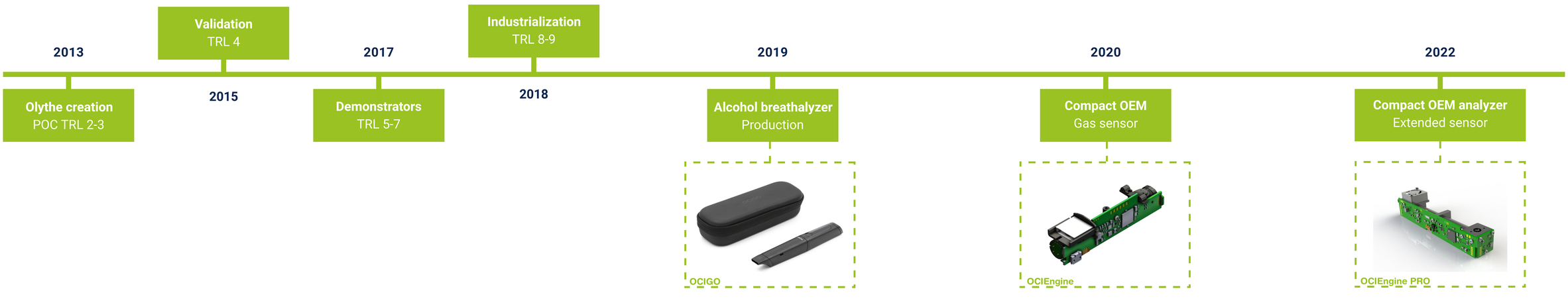


Figure 3: Optical absorption for different alcohol concentrations

DEVELOPMENT STAGES



RESULTS

Cuvette

Three major functions

- Heating: Patterned thin layer of a resistive material.
- Temperature measurement: thermistor effect.
- Optical reflexion: high reflective inner surface.

Sampling

- Optimized for breath analysis avoid condensation.
- Low thermal interference with ambiant air avoiding thermal disturbance.

Detector

- Thermal drift compensation
- High optical responsitvity
- Integrated amplification for high SNR

Infrared source

- Small radiative element footprint reducing power consumption.
- Dynamic PWM to optimize thermal stability and reduce start-up time.

Embedded electronic

- Optimized signal processing for high SNR.
- Algorithms for noise attenuation and short start-up time.
- Thermal feedback control for precise temperature.

Figure 4: Exploded view of the OCIEngine NDIR sensor

Table 1: OCIEngine and OCIEngine Pro sensors specifications

TECHNICAL SECIFICATIONS	OCIENGINE NDIR SENSOR	OCIENGINE PRO NDIR SENSOR
Measurement range	From 25 ppm to 2000 ppm	From 5 to 500 ppm
Measurement accuracy (max error)	± 10 ppm @ 50 ppm ± 30 ppm @ 300 ppm *Conditions:* *– ambient temperature: 23°C (± 3°C)* *– wet air inlet (>95% RH, 23°C): ethanol gas*	± 8,5 ppm @ 50 ppm ± 11 ppm @ 300 ppm *Conditions:* *– ambient temperature: 23°C (± 3°C)* *– wet air inlet (>95% RH, 23°C): ethanol gas*
Dimensions	21 x 21 x 80 mm	150 x 71 x 54 mm
Response time	1s (τ=63%), at a flow rate of 0,5L/min	1s (τ=63%), at a flow rate of 1L/min
Start-up time	< 1 min	5 minutes (30 minutes at full spec)
Time between two measurements	< 45 s	< 45 s

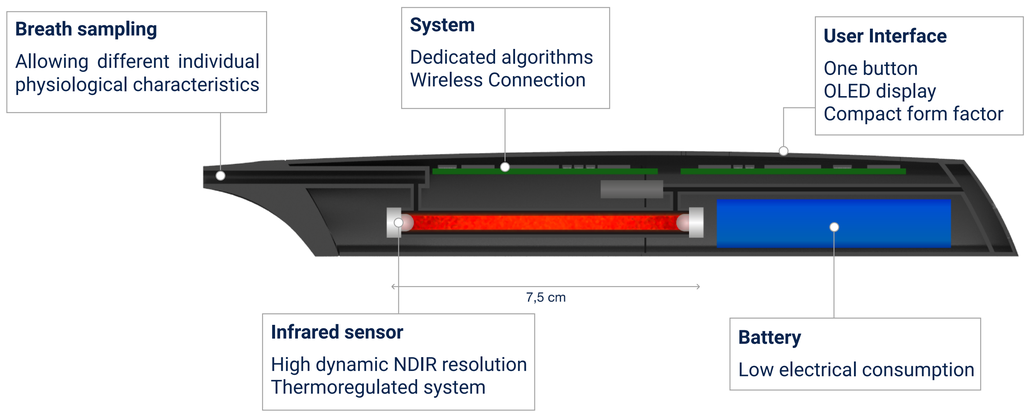


Figure 5 : Overview of the OCIGO breathalyzer composition

NEW CO2 GAS EXPLORATIVE RESULTS

Breath analysis can be classified into two groups: the first one is the **analysis of breath metabolites after drug or substrate administration** and the second one is the **analysis of endogenously produced breath compounds** due to a particular physiological state.

For example, **capnography measures the concentration of CO2 at the end of expiration** to analyze the causes of respiratory disorders and chronic obstructive pulmonary diseases. Also, the measurement of CO2 in the exhaled air can help to **determine the fertility period of a woman**. And finally, the CO2 level in the exhaled air allows to **know how the metabolism works**.

Due to the importance of the **CO2 gas**, we decided to adapt the OCIEngine sensor to monitor this biomarker in exhaled air. We obtained promising results to develop our sensor for this kind of applications.

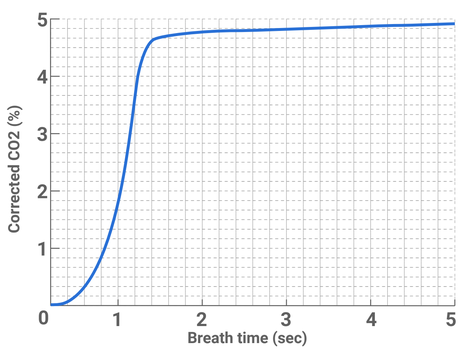


Figure 6: CO2 breath analysis during a 5 sec breath

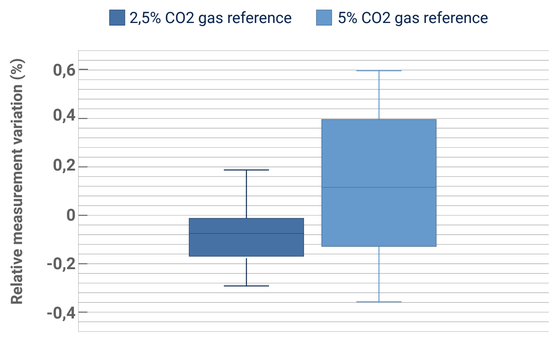


Figure 7: Distribution of CO2 measurements at 2,5% and 5%

CONCLUSION & PERSPECTIVES

Olythe has developed and commercializes **innovative systems** with **high sensitivity, specificity and reliability** to measure ethanol and carbon dioxide concentrations in exhaled air. Our perspective is to go further with the precision of OCIGO to detect and measure other volatile organic compounds in exhaled air, markers of several diseases and indicators of environmental pollution.

Figure 8: Overview of the next step in the development of the technology

To date, **some VOCs have already been established as biomarkers of specific diseases or metabolic disorders**:

Table 2: VOCs classified as disease biomarkers

Volatile organic coumpounds	Examples of diseases	References
CO2	Hypercapnia diseases	Patel S and al 2022
CH4	Obesity in patients with functional gastrointestinal disorders	Clive H Wilder-Smith and al 2018
Volatile Aldehyde: hexanal, octanal and nonanal concentration	Lung cancer	Patricia Fuchs and al 2009
CO	Chronic ob-structive pulmonary disease	Paolo Paredi and al 2000
Ethane		
NO		
C3H6O	Diabetes diseases and Diabetic ketoacidosis (DKA)	Valentine Saasa 1 and al 2019