

## Application of a micro-machined electronic nose to detect *Escherichia coli* in human urine samples

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### Introduction

The analysis of volatile organic compounds (VOCs) as disease biomarkers released by the urine, it permits an early and non-invasive diagnosis of Urinary Tract Infections (UTI) [1]. For this purpose, an instrumental method like the electronic nose composed by micromachined metal oxide gas sensors has been taken under consideration. *Escherichia coli* (E.coli) is the pathogenic microorganism responsible for up to 80% of the UTI and it is here chosen as benchmark bacterium [2]. The purpose of this research work is to test the capability of the electronic nose approach to recognise the presence of E.coli, indicative of a possible UTI disturb [3], in urine samples.

### Materials and Methods

In the research's work, a device named miniMOx (JLM Innovation) has been involved. It is equipped with two micromachined metal oxide gas sensors (MOX): TGS8100 (Figaro) and CSS801 (CCMOSS). The MOX are capable to work with custom temperature modulation protocols controlled through their embedded heaters. This modulation periodically activates and freezes the interaction between gaseous molecules and the metal oxide surface, producing a periodic resistance vs. time curve as a response. In particular, a square wave of a 20 seconds period was applied. A warm semi-period was settled at voltage of  $V_{heaters}$ : 2.31 V for 10 seconds while the cold one at the voltage of  $V_{heater} = 1.65$  V for the same amount of time. The resistance vs. time curves obtained were described through the  $\Delta R_{cold-hot}$ ,  $\Delta R_{cold}$  and  $\Delta R_{hot}$  parameters. The  $\Delta R_{cold-hot}$  represents the subtraction between the sensor's resistance measured at the end of the cold period and the resistance measured at the start of the warm period after 0.2 seconds.  $\Delta R_{cold}$  signifies the difference between the sensor's resistance measured at the end of the cold period and after 0.2 seconds or at the beginning to the same period.  $\Delta R_{hot}$  respects the warm period. In the end, a Principal Component Analysis algorithm (PCA function on Matlab) was used to elaborate the data acquired with the described parameters. Three representative samples were taken under consideration: urine, urine contaminated with a pathogenic microorganism (*Escherichia coli*) and sterilized water as a control. The analysis' procedure provided to place in contact the miniMOx for a time of 5 minutes with the head-space released from the samples, interspersed with 10 minutes for the sensors' recovery in ambient air. In parallel, bacterial counts were performed to monitor the *Escherichia coli* concentration during the whole analysis.

### Results and Discussion

The resistance vs. time curves was acquired with the two micromachined metal oxide gas sensors during the exposition at the VOCs released by uncontaminated urine and urine inoculated with *E. coli* at the initial concentration of 10<sup>4</sup> CFU/ml. The resistance values are lower during the warm semi-period (200-300K $\Omega$  with urine samples contaminated by *E.coli*, 100-200K $\Omega$  with urine samples uncontaminated) and larger during the semi-cold one (600-1000K $\Omega$ , with urine samples contaminated by *E.coli*, 250-650K $\Omega$  with urine samples uncontaminated), mainly due to thermal effect on the MOX semiconductor. The shape of these curves is sensitive to the surrounding atmosphere, with differences that can be properly resumed in terms of  $\Delta R_{cold-hot}$  and  $\Delta R_{cold}$ . PCA algorithm applied to the parameters explained before. The PCA Score Plot represents a scenario with three separated cluster, each one representative for sterilized water, urine and urine contaminated with *Escherichia coli*. Therefore, there is a separation between the two urine's samples. Since the difference between the two urine's samples is the *E. coli* presence, potentially the pathogenic microorganism is the responsible to the separation itself.

### Conclusion

The custom measurement protocol developed with the commercial electronic nose miniMOx revealed suitable to discriminate between water, urine and urine with *E. coli* through the analysis of the VOCs released by them. Since *E. coli* causes different kind of diseases in the human body, an early detection of this pathogenic microorganism into the urine could prevent the illnesses development. In conclusion, the miniMOx could be an easy-to-use, low-cost device for the pre-screening diseases through the VOCs released by urine.

### References

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## Summary

**Primary author:** SOPRANI, Matteo (University of Brescia - National Institute of Optics, National Research Council (CNR-INO))

**Co-authors:** Dr ZAMBOTTI, Giulia (National Institute of Optics, National Research Council (CNR-INO) - University of Brescia); Prof. GOBBI, Emanuela (University of Brescia - National Institute of Optics, National Research Council (CNR-INO)); Dr PONZONI, Andrea (National Institute of Optics, National Research Council (CNR-INO) - University of Brescia)

**Presenter:** SOPRANI, Matteo (University of Brescia - National Institute of Optics, National Research Council (CNR-INO))

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