Removal of Humidity by Ionic Liquid Filter to Protect Gas Sensors

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Thèmes – *Environnement - Électronique*

Résumé –*Air quality has become a hot issue of common concern, particularly BTEX gases (Benzene, Toluene, Ethylbenzene and Xylene). They often cause serious environmental problems and have negative effect on human health even at very low concentration. Gas sensors have been in use for monitoring flammable as well as toxic gases. Since a few years, metal oxide gas sensor are also used to the control and monitor the air quality The detection of gaseous pollutants under real conditions requires working in a humid environment. It is well known that the humidity reduces the performances of gas sensors, particularly in terms of sensitivity. In this work, we demonstrated the possibility to reduce the humidity impact on a metal oxide sensor by using ionic liquid-based filter, without modification of the sensor sensitivity.*

Mots-Clés – *ionic liquid based filter, VOCs gas sensor, humidity removal.*

1 Introduction

With the development of society and the advancement of technology, human demand on the environment has gradually gone beyond the bearing capacity of the environment. Air quality has become a hot issue of common concern, particularly BTEX gases (Benzene, Toluene, Ethylbenzene and Xylene). They often cause serious environmental problems and have negative effect on human health even at very low concentration. Since a few years, mental oxide gas sensors are used to control and monitor the air quality. It is well known the performance of metal oxide gas sensors is influenced by relative humidity [1]. In this work, we demonstrated the possibility to reduce the humidity impact on a metal oxide sensor using an ionic liquid-based filter, without modification of the sensor sensitivity.

2 Materials and Methods

2.1 Ionic liquid based filter

Ionic liquids (ILs) are salts which form liquid phase at room temperature. More importantly, these are endowed with excellent solvating ability and can be recycled [2]. In this study, the 1-butyl-3-methylimidazolium bromide ($[Bmim^+][Br^-]$) [3] is selected as absorbent due to its high viscosity hygroscopic properties and availability. The innovation of this filter is to capture the water vapor from a mix of gases without impacting the target gases [4].

2.2 Gas Sensor

The gas sensor is composed of a sensitive layer of tungsten trioxide (WO_3) thin film (50 nm) deposited by reactive RF magnetron sputtering on a transducer developed in IM2NP laboratory [5].

The WO_3 is a n-type metal oxide with a large gap and oxygen vacancies and its conductivity depends on the composition of the surrounding gas atmosphere.

The sensor response under BTEX vapors was calculated using the relation (1):

$$\text{Sensor response (\%)} = \left(\frac{R_{air} - R_{gas}}{R_{gas}}\right) \times 100 \quad (1)$$

With R_{air}, the sensor's resistance under air and R_{gas}, the sensor's resistance under BTEX vapors.

2.3 Test bench for electrical characterization under target gases and humidity

We used a fully automated test bench specially designed for the BTEX gases detection in the pressure of different humidity levels. It is composed of a gas dilution and humidification system that generates an output mixture at very low concentrations (1 to 500 ppb) with a variable humidity (0 to 90%), an integrated test cell and an acquisition system to characterize the electrical responses of the sensor.

3 Results and Discussion

3.1 Influence of humidity on sensor response

To study the humidity influence on the sensor response, the gas sensor was exposed at 500 ppb of BTEX under dry air and wet air (relative humidity 50%). With the figure 1 shown, under dry air, the sensor response is 24%. When the introduction of 50% relative humidity in mixture gas, the sensor response is reduced to 12%. As some studies reported that humidity leads to a decrease of the sensor response [6, 7].

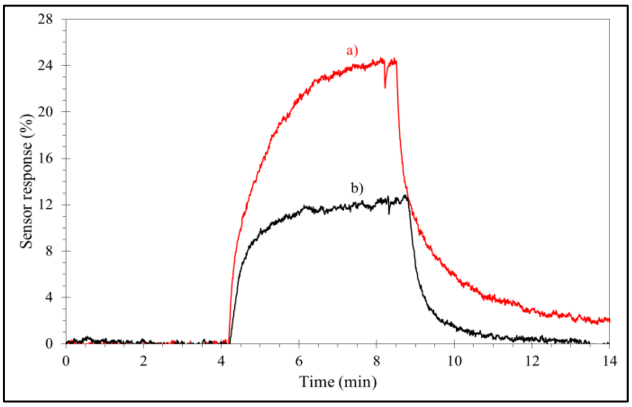

Figure 1 - Sensors response to 500 ppb of BETX, a) in dry air (0 %), b) in wet air (50 % RH)

3.2 Influence of filters to sensor under dry air

It is important that the addition of a filter upstream of the sensor does not disturb its response. We therefore studied the sensor response under identical conditions (HR 0%, BTEX: 500ppb) initially without filter and then with filter.

We first designed a filter composed by a mixture of active carbon (AC) and ionic liquid (IL), to capture humidity. However, when we placed this filter upstream the sensor, sensor response decreased to 12% (fig.2a) compared to sensor response without filter (fig.2b).

It means that this filter has an influence on gas sensor response. In order to understand this problem, we renewed the experiment with a first filter based only on pure activated carbon and then with a second filter based only on ionic liquid. With the AC filter, the sensor response decreased to 12% (fig.2c), which is the same as the response of mixed IL-AC filter.

However, when only the IL filter was placed upstream the sensor, the response to 500 ppb of BTEX remains 25% (fig.2d). Based on this experiment we can conclude that the IL filter does not capture BTEX gases. For the next experiments we choose this filter configuration (IL filter only).

It is well known that AC can remove VOCs from a gas mixture, as already reported in the literature [8, 9]. Because of the overwhelming physical adsorption mechanisms, active carbon with large surface area and rich pore structure shows high adsorption capacity to VOCs. Furthermore, the presence of chemical functional groups on AC surfaces makes it a good adsorbent for VOCs through chemical adsorption mechanisms. When the $[Bmim^+][Br^-]$ was exposed on wet air, it was found that it caught water vapors because the anions of IL ($[Br^-]$) and water molecules form H-bonding [10].

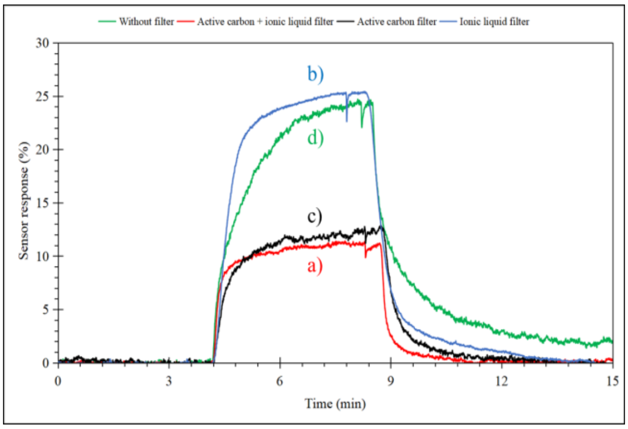

Figure 2 - Compared response to500 ppb of BETX with different filters under dry air (0 % HR, 100 sccm)

3.3 Influence of ionic liquid filter on sensor response under wet air

To reduce the humidity influence on the sensor response, according to last experiment, we placed an IL filter upstream the sensor, and the sensor was exposed to 500 ppb of BTEX with 50% relative humidity.

In figure 3, we can observe that with or without IL filter, the sensor response remains 25%. Hence, with this filter, the gas sensor keep its performances, even under 50% of relative humidity.

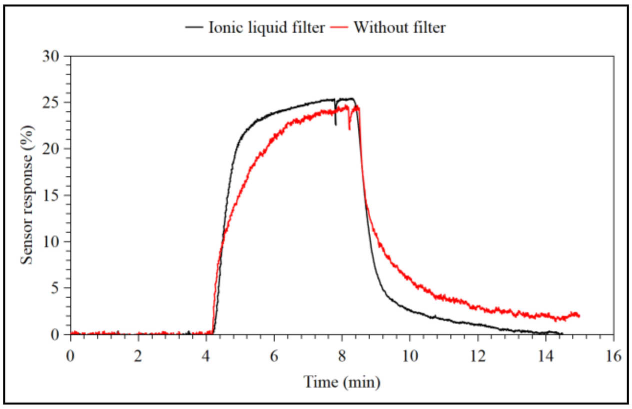

Figure 3 - Sensors response under 500 ppb of BTEX, a) in dry air (0 % RH), b) wet air (50 % RH) with ionic liquid filter

4 Conclusions

In this work, we proposed a new solution to protect gas sensors from humidity. We confirmed that with an IL filter, which is comprised by $[Bmim^+][Br^-]$, on upstream can reduce the influence on gas sensor. We also demonstrated that the ionic liquid filter does not disturb BTEX detection.

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