DOI 10.5162/EUROSENSORSXXXVI/OT1.281

Preliminary Comparative Study of Different Materials to Reduce Humidity of Gas Samples

Ana Maria Tischer[1], Beatrice Julia Lotesoriere[1], Stefano Robbiani[2], Hamid Navid [1], Raffaele Dellacà[2], Laura Capelli[1]
[1] Politecnico di Milano, Department of Chemistry, Materials and Chemical Engineering "Giulio Natta", Piazza Leonardo da Vinci 32, Milan, Italy
[2] Politecnico di Milano, Department of Electronics, Information, and Bioengineering, Via Giuseppe Colombo 40, 20133 Milan, Italy

Corresponding email: stefano.robbiani@polimi.it

Summary:
Most of chemical gas sensors present cross-sensitivity towards humidity. In this study, we investigate the possibility to exploit water permeability of polymeric materials to develop a low-cost and scalable method for reducing the water content of gas samples for sensors analysis. Sampling bags should be disposable and thus minimize the risk of cross-contamination. A custom-made system for testing different polymeric materials has been implemented. Preliminary results prove the capability of some of the investigated materials to decrease the moisture content without losing VOC of interest for the purpose of the analysis.

Keywords: cross-sensitivity, moisture, polymeric materials, dehydration, MOX sensors

Background, Motivation and Objective

Nowadays gas sensing technologies are becoming of interest for several applications because of their versatility and relatively low-cost. Nevertheless, several challenges still need to be solved, as the cross-interference of sensors to several physical factors affecting their responses (e.g., humidity, temperature) [1]. From the literature, the presence of humidity is reported to result in a shift of the whole baseline of gas sensors or in a decrease of the sensors' sensitivity [2]. Over the years, different approaches have been adopted, especially when dealing with biological fluid samples: (1) software strategies focusing on algorithmic compensation and (2) hardware strategies focusing on a proper design of the sampling system. Despite the effectiveness of sorbents, desiccants and condensation systems in reducing the humidity level at the desired level directly on the sample gas line, such systems may introduce unavoidable and undesired risks of cross-contamination and reduction of target VOC concentration [2]. Another possibility that has proven effective, is the use of disposable containers (bags) for the gas samples, made of polymeric materials that are permeable to humidity [2,3]. For instance, Nalophan™, commonly used for olfactometric sampling (EN 13725:2022), is known to be highly prone to diffusion of small hydrophilic molecules (e.g., water, ammonia, or hydrogen sulphide). Previous work exploited Nalophan's capability to reduce the moisture content of biological samples by using the water vapor concentration gradient with the ambient air as driving force, requiring long times for conditioning (2 to 24h in ambient air) to get the desired conditions [3]. In this context, this work focuses on the design of a system to investigate and compare the capability of different polymeric materials, which can be used for the manufacturing of bags for the collection and storage of gas, to release water vapour in a possibly short time without losing the VOC of interest for the gas analysis.

Description of the New Method or System

To assess the dehumidification potential of different polymeric materials, comparative experiments are carried out considering first their permeability towards water and then, the loss of VOCs of interest when analysing urine samples. The reference benchmark is set by a Nafion membrane dryer (Permapure™, Inc., model MD-050-72S-1), extremely selective to water molecules, but very expensive and prone to cross-contamination, leading to a loss of performances over time. Four different polymeric materials with different wall thickness are tested building 2 L polymer-based bags: Nalophan™ 20 µm, high-density polyethylene (HDPE) 10 µm, low-density polyethylene (LDPE) 12 µm and biodegradable plastic (BIO) 15 µm. The system, installed inside a climatic chamber HPPeco (Memmert™) at

60°C, consists of two lines both dehydrating a saturated gaseous sample obtained by bubbling dry air in distilled water at 0.13 L/min for 15 min. The first line goes through the Nafion membrane reaching the target humidity level (i.e., 15% RH and 60°C) before being collected in the bag, while the second line goes directly into the polymer-based bag, which in turn is placed in a sealed box in which a dry air flow is flushed at 1 L/min to keep the moisture gradient through the bag enabling the diffusion process (Fig. 1). Inside each of the two bags, temperature (T) and relative humidity (RH) are monitored with a dedicated sensor (SHT40, Sensirion, Zurich, Switzerland). Further tests are carried out implementing an additional RH and T sensor inside the chamber without flushing dry air in the box to assess the quantity of water released by diffusion (vs adsorption) by making a mass balance of water inside and outside the bag. Finally, we decided to use urine as biological sample in order to carry out preliminary evaluations of VOCs losses by analysing the headspace sample with a PID Tiger 10.6 eV (ION Science limited, UK) and with a multi-sensor chamber (i.e., TGS2610, TGS2611, TGS2601, TGS2602, TGS2603, TGS2620, Figaro Inc., Osaka, Japan) equipped with a RH and T sensor. All the setup, considering sampling system and sensors chamber, is controlled by a LabVIEW interface.

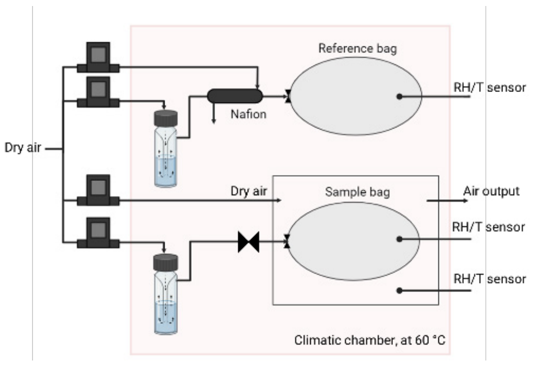

Fig. 1. Scheme of the experimental set-up

Results

Fig. 2 shows the drying time needed to reach the target humidity level within the different polymer-based sample bags tested. Overall, BIO bags present a particular behaviour, which may be explained by the affinity of water with biodegradable films. For all the tested materials, a competitive mechanism between adsorption and diffusion is observed (Fig. 2). Preliminary results prove that HDPE and LDPE may be considered the best candidates since they show lower drying times combined with reduced VOC losses. Moreover, sensors' responses to samples in HDPE bags are also comparable with the ones obtained using the Nafion membrane, which is our gold standard (Fig. 3). Further experiments are ongoing to better understand the permeability phenomena towards water and VOC, confirming such results.

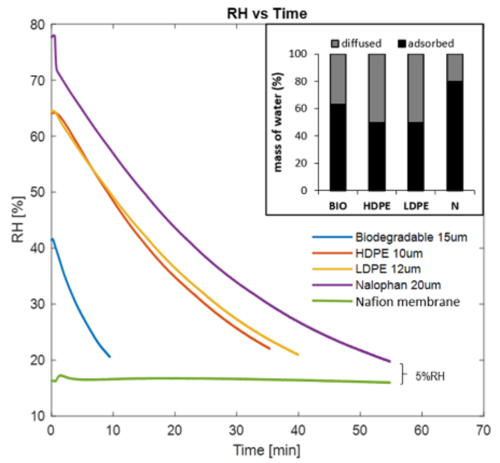

Fig. 2. RH vs drying time for different bag materials

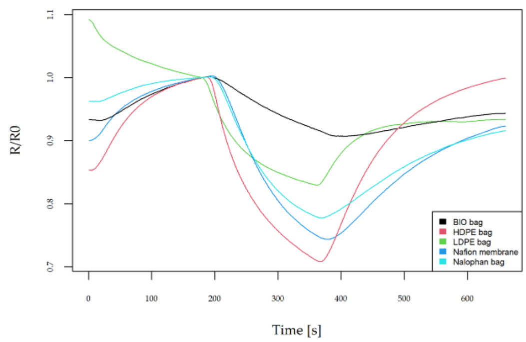

Fig. 3. Example of sensors' responses to urine headspace stored in different bags

Funding

This study was co-funded by the National Plan for NRRP Complementary Investments (PNC) - project n. PNC0000003 - AdvaNced Technologies for Human-centrEd Medicine (ANTHEM). This work reflects only the authors' views and opinions, neither the Ministry for University and Research nor the European Commission can be considered re-sponsible for them.

References

[1] J.A. Covington et al., Artificial Olfaction in the 21st Century, IEEE Sensors Journal 21, 11 (2021); doi: 10.1109/JSEN.2021.3076412

[2] S. Robbiani et al., Physical Confounding Factors Affecting Gas Sensors Response: A Review on Effects and Compensation Strategies for Electronic Nose Applications, *Chemosensors* 11, 10 (2023); doi: 10.3390/chemosensors11100514

[3] C. Bax et al., An Experimental Apparatus for E-Nose Breath Analysis in Respiratory Failure Patients, *Diagnostics* 12, 4 (2022); doi: 10.3390/diagnostics12040776