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Design of a chamber for the characterization of gas sensors in dynamic flow

Diseño de una cámara para la caracterización de sensores de gas en flujo dinámico

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Abstract

In the present work, the description of a design is presented, as a proposal, for the evaluation or characterization of gas sensors. The proposed design allows the introduction of gas into a chamber at one end and its exhaust at the other, so that a flow of this is generated during the evaluation of the sensors. The gas to be evaluated in the first instance is ethanol. On the other hand, the use of peltiers was contemplated to heat the chamber at different temperatures, with a series of heatsinks and fans for its regulation, for which the use of a temperature sensor and a humidity sensor were incorporated. In total, eight gas sensors manufactured specifically with QCM crystals and an ethyl-cellulose film are contemplated. So, also, the corresponding electronic circuit is shown. Finally, the results of the simulation, in Abaqus, of the temperature distribution inside the chamber for a certain value in the peltiers and the variation of the gas flow along the duct inside the chamber are shown.

Gas, Dynamic flow, Sensors, Design, Peltiers

Resumen

En el presente trabajo se presenta la descripción de un diseño, como propuesta, para la evaluación o caracterización de sensores de gas. El diseño propuesto permite la introducción del gas a una cámara por un extremo y su escape por el otro, por lo que se genera un flujo de este durante la evaluación de los sensores. El gas a evaluar en primera instancia es el etanol. Por otro lado, se contempló el uso de peltiers para el calentamiento de la cámara a diferentes temperaturas, con una serie de disipadores y ventiladores para su regulación, por lo cual se incorporó el uso de un sensor de temperatura y otro de humedad. En total se tienen contemplados ocho sensores de gas fabricados exprofeso con cristales QCM y una película de etil-celulosa. Por lo que, también, se muestra el circuito electrónico correspondiente. Finalmente, se muestran los resultados de la simulación, en Abaqus, de la distribución de temperatura dentro de la cámara para un determinado valor en los peltiers y la variación del flujo del gas a lo largo del conducto dentro de la cámara.

Gas, Flujo dinámico, Sensores, Diseño, Peltiers

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Introduction

During the history of humanity, we have faced great changes and within those changes is the use of several gases, which are very useful in different industrial sectors. However, their management must be adequate, since many are toxic and flammable, so there is interest in having detection mechanisms for the different types of gases to react on time in case of leaks or gas excess in a closed space, due to this necessity arise the term of Electronic Nose.

Electronic noses can be defined (Busto O., 2002) as an instrument equipped with chemical sensors and a chemometric pattern recognition program that is capable to recognize and compare individual or complex odors of substances.

In this work, the information that is intended to obtain with this instrument is both quantitative and qualitative, or, in other words, its objective is to analyze and recognize the olfactory traces of ethanol gas, assessing the volatile compounds of the sample as a whole to analyze or classify, thus imitating the human olfactory system.

The quantitative composition of the aroma can be performed using instrumental analysis techniques such as gas chromatography (GC), particularly the one in which the instrumental detection is performed in parallel with an olfactometer that allows determining the odor of each compound. Another investigation (Biedman et al., 2004) consisted of taking a sample of 32 cheeses, where two variables are presented, the state of maturation and the maturation temperature, with Tin Oxide sensors and Figaro Sensors, these have great amplitude. of designs and compounds that are used for different applications. On the other hand, in a study (Osorio-Arrieta et al., 2018) the use of QCM sensors coated with an ethyl cellulose sensor film was introduced to detect ethanol, a volatile organic compound that is frequently found in beverages or flavors and that is suitable for conducting this type of study due to its low toxicity. The operating principle of the QCM gas sensor is based on the interaction of gas molecules with the detection film deposited on the electrodes of the gas sensor. When the mass attached on the sensing film increases, the resonance frequency decreases due to the mass charge effect.

There are several techniques used to make these sensors, however, something important to analyze the response of these sensors are the different devices using measurement chamber, which are responsible for housing the gas that will be introduced into it, the sensors that will generate the detection of the sampling inside it and in strategic places.

It is similar for the case of the research performed in the sampling of cheeses (Biedman et al., 2004) in which a measurement chamber with semiconductor chemical sensors is also used, for the analysis of the Tin Oxide sensors, with controlled temperatures.

Currently there are chambers that have the capacity sense gases in a static system, as is the case of (Arenas L. N., 2015), who made a closed static chamber design, in order to evaluate the emissions of greenhouse gas flows. greenhouse in soils from the International Center for Tropical Agriculture (CIAT), obtained from different closed static chamber designs, using two sampling methodologies (Conventional and Gas Pooling). Another chamber, with a Dynamic design, was developed in studies by (Cueva-Rodríguez et al., 2004) for a soil respiration measurement system with closed dynamic chambers. Another chamber, with a Dynamic design, was developed in studies by (Cueva-Rodríguez et al., 2004) for a soil respiration measurement system with closed dynamic chambers. This leads us to understand that the generation of sensors for the detection of gases in the industry, establishments or houses is of the utmost importance, and the test methods that are performed on the elaborated sensors are by the use of measurement chambers in a static system or chambers using a dynamic flow, for this reason the Design of a Chamber for the Characterization of Gas Sensors in Dynamic Flow, with controlled temperature, is proposed.

Basic design conditions

The development and use of gas detector sensor arrays (commonly called "Electronic Noses" EN), has gained great importance in the field of scientific research due to the need to detect, recognize and discriminate gases or complex mixtures in the environment. This particular area is of great interest due to the enormous variety of gas sensors and the great diversity of materials that can be used as sensitive film.

Likewise, there is a wide range of applications for detection, recognition and discrimination systems, such as air quality monitoring, quality control in the food and beverage industry, cosmetology, biotechnology, etc.

QCM sensors, which will be exposed to ethanol samples, have a radius of 4.3 mm as we can see in figure number 1, will be covered with a sensing film on their surface that will react at different frequencies depending on the thickness of the film and/or the concentrated quantity of the gas within the controlled environment since these crystals are considered as piezoelectric sensors giving different response frequencies. The sensor dimension was taken as the basis for the creation of the conduit through which the ethanol will be applied, that is, the conductive channel must guarantee not only the gas flow, but also contain 8 QCM sensors with total hermeticity between the gas inlet and their respective output.

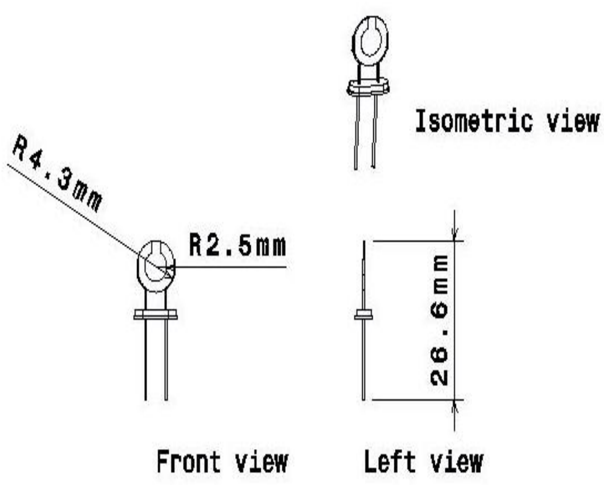

Figure 1 QCM gas sensor dimensions
Source: Own elaboration

The response frequencies are sent from the crystal thanks to the administered sample, since the principle of adsorption of the molecules of the sensing film.

Ethanol is a simple hydrocarbon, with a colorless and odorless gas nature that has a highly valuable and diversified use in the synthesis of ethylene. It occurs in nature as an odorless and colorless gas at standard pressures and temperatures (1 atm and 25°C).

Furthermore, is not affected by the exposure to acids or strong bases, ethanol's solubility is considerably low, increasing slightly when system pressure is raised. With a decrement in temperature beyond -183.2° C, its structure becomes monoclinic, increasing the stability of its molecule. The density of Ethanol is 0.789 g/cm^3, its melting point is -114°C, its boiling point is 78.4 °C.

To evaluate the presence of ethanol at different temperatures, the generation of heat in the chamber through electrical components called Peltier Cells, with a size of 5 by 5 cm, will be considered.

The innocuousness of the system must be guaranteed, therefore, materials that do not contaminate the samples must be chosen.

In this work, the challenge for the optimization of a system based on electronic nose is assumed, through a Dynamic Flow chamber that will contain the sensors and an ethanol flow will be injected.

In addition, with the developing of this design, it will be possible to have a piece of equipment that could be helpful in the performance tests of new sensors that can detect different types of gases and thus be able to distinguish the odors that have been registered in a series of samples.

This system and its components will perform the analysis of the gas sample that will be injected to generate a dynamic flow, this sample will flood through the entire volume of the chamber designed to contain the gas sensors hermetically at a constant temperature, the sensors will be placed at equal distances and, thus, the sample will be taken in the system.

Once the chamber was designed, a series of computations with finite elements is carried out to verify the temperature distribution of the chamber and the gas flow in it.

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Operative description of the design proposal

In order to perform the chamber design (Figure 2), there is in the first instance the sealing plate, which will help to maintain hermeticity, it is manufactured using Teflon, which helps to prevent contamination of the samples, and by At the same time, it contains eight QCM sensors placed linearly and at equal distances between them.

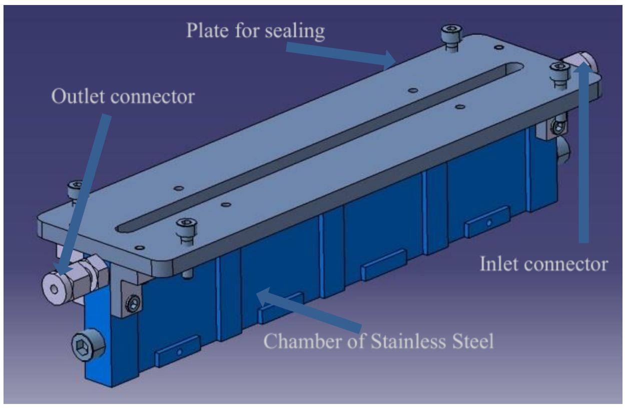

Figure 2 Stainless Steel Chamber, Seal Plate and Connectors
Source: Own

Below the Chamber cap, where the gas flow occurs inside. The Peltier cells (Figure 3) will be placed between this Chamber made of stainless steel, next to these, some aluminum heatsinks, four on one side and four on the other, in order to help regulate the temperature. Moreover, eight fans are added, one for each Peltier, which will serve as extractors on the heatsinks.

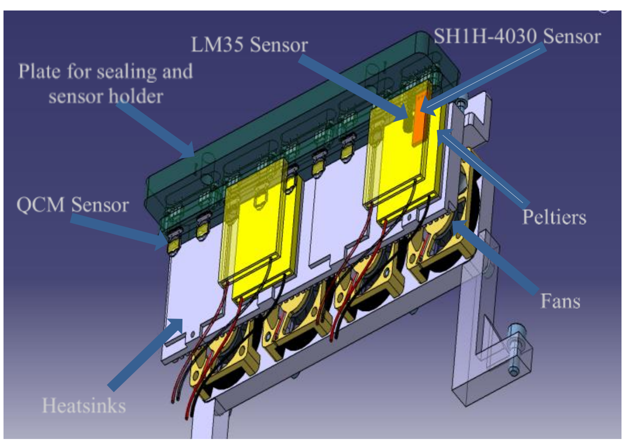

Figure 3 Components inside and out of the measurement chambe
Source: Own elaboration

The conical connectors for the gas inlet and outlet are screwed to both ends of the chamber. Specifically, the LM35 temperature sensor and the SH1H-4030 humidity sensor (Figures 3 and 4) are placed at the gas inlet. These sensors are fundamental devices for the correct operation of the equipment, with the aim of monitoring and thus regulate the temperature, and monitoring the internal humidity inside the chamber.

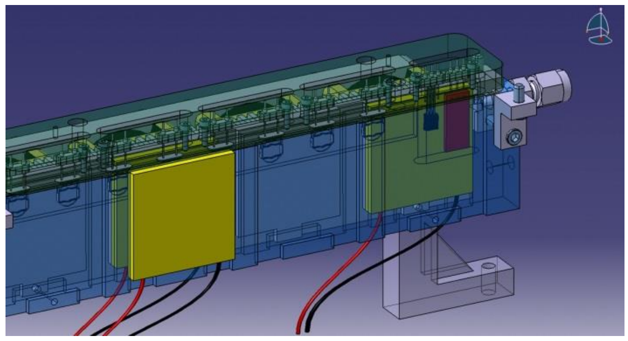

Figure 4 End with the inlet connector, followed by the temperature and humidity sensors
Source: Own elaboration

As previously mentioned, part of being able to estimate of the behavior of the measurement chamber, two simulations are performed, one of the temperature and another of the velocity of the gas, both inside the chamber, thus, the characteristics of the gas are set in the Simulia (Abaqus) CFD simulator, selecting only the basic elements of the chamber, the gas inlet and outlet, the hermeticity of the chamber and the heat sources of each of the Peltier cells.

In the first instance, the temperature distribution of the Stainless-Steel chamber is shown as shown in (Figure 5).

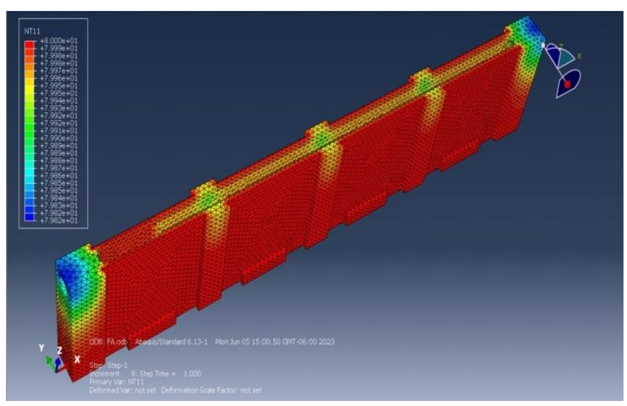

Figure 5 Temperature distribution of the measurement chamber
Source: Own elaboration

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Subsequently, the simulation of the velocity of the gas inside the measurement chamber performed as shown in Figure 6, setting the characteristics of the gas (Ethanol).

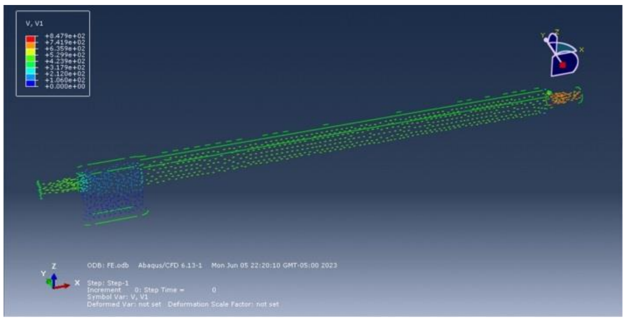

Figure 6 Abaqus simulation of the velocity of the gas inside the measurement chamber
Source: Own elaboration

With the development of these simulations, we realize that the design of the chamber is feasible since the temperature in the center of the measurement chamber remains uniform at an approximately constant temperature, the velocity of the gas stops once the injection begins due to the greater volume in the cavity for the sensors of temperature and humidity. However, it tends to stabilize such velocity maintaining a similar speed in each of the points where the QCM sensors are located until finding the exit of the chamber.

For the electronic configuration of the chamber, the power and control of the 8 QCM sensors, a LM35 temperature sensor, a SH1H-4030 humidity sensor and the TEC112710 cv-005 Peltier Cells are required, nominal voltage 12VDC, Qmáx 89W.

The functional operation of the circuit with a single Peltier Cell is described as follows (Figure 7): first the microcontroller sends a PWM signal (to control the power if Peltier Cells that will be paced on the sides of the stainless-steel chamber) the PWM signal travels through a transistor (VF547) to amplify the current, this signal passes to the Optocoupler (4N26) in order to isolate the power electronics from the microcontroller, Moreover, the microcontroller sends the polarity signals to the drivers (H bridge) to energize the Peltier plates. It is very important to recognize the polarity, because it determines if the measurement chamber is cooling or heating.

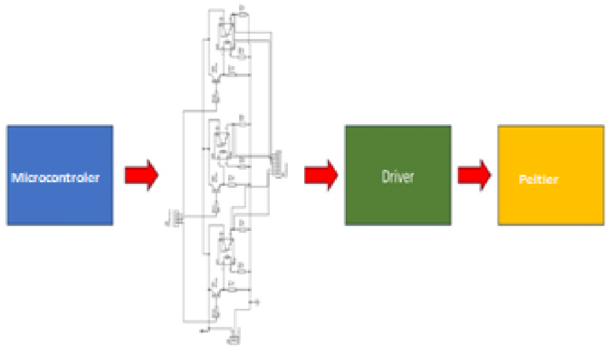

Figure 7 Block Diagram of the circuit connections
Source: Own elaboratrion

The development of this design will be a tool to contribute to the continuous development of chambers for gas detection of QCM sensors for different volatile organic compounds. This system is a prototype that allows the creation of necessary procedures that maximize the time necessary for leak detection. in closed room or continuous ventilation systems.

Conclusions

There is a complete design with a well-defined set of elements for its manufacture. Based on the aforementioned results obtained, future work will be the manufacture of the described proposal and the establishment of physical tests to perform the required adjustments and calibrations, in order to obtain the correct readings from the QCM sensors in the monitoring. of ethanol gas and other gases.

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References

Arenas L. N. (2015). *Diseño de cámara estática cerrada y medición de flujos de gases de efecto invernadero (GEI) en suelos*. Tesis. Universidad Nacional de Colombia. https://repositorio.unal.edu.co/handle/unal/56229

Biedman Perellón Óscar. (2004). *Diseño y Realización de una Nariz Electrónica para la Maduración de Quesos*. Tesis. Departamento de Enginyeria Electronic, Electrica i Automatica, Universitat Rovira i Virgili. http://deeea.urv.cat/public/PROPOSTES/pub/pdf/620pub.pdf

Busto Olga. (2002). *La nariz electrónica: una nueva herramienta para analizar el aroma*. Revista de enología científica y profesional. Dossier Enología Sensorial II. https://www.acenologia.com/ciencia60_2/

Correa Hernando E. C., Ortiz C., Ruiz-Altisent M., Robla Villalba J. I., Rodríguez, J. (2005). Establecimiento de las curvas de respuesta de una nariz electrónica QCM a distintas concentraciones de compuestos químicos conocidos. "AgroIngeniería 2005", 21 a 24 septiembre de 2005, León. ISBN 84-9773-208-1. https://oa.upm.es/9953/

Cueva-Rodríguez A., Yépez Enrico A., Garatuza-Payán J., Watts Christopher J., Rodríguez Julio C. (2012). *Diseño y uso de un Sistema Portátil para Medir la Respiración de Suelo en Ecosistemas*. Tierra Latinoamericana No. 30, Vol. 4. Pp. 327-336. <http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S0187-57792012000400327&lng=es&nrm=iso>. ISSN 2395-8030.

Muñoz-Aguirre S., Yoshino A., Nakamoto T., Moriizumi T. (2003). *Odor approximation of fruit flavors using a QCM odor sensing system*. Sensors and Actuators B: Chemical, Volume 123, Issue 2. Pp. 1101-1106. https://doi.org/10.1109/SENSOR.2003.1217028

Muñoz-Mata J. L., Muñoz-Aguirre S., González-Santos H., Beltrán-Pérez G., Castillo-Mixcóatl J. (2012). *Development and implementation of a system to measure the response of quartz crystal resonator based gas sensors using a field-programmable gate array*. Measurement Science and Technology, Volume 23, Number 5. DOI 10.1088/0957-0233/23/5/055104.

Nagle H.T., Gutiérrez-Osuna R., Schiffman S. S. (1998). *The how and why of electronic noses*. IEEE Spectrum (Volume: 35, Issue: 9). Pp. 22-31. https://doi.org/10.1109/6.715180

Osorio-Arrieta D. L., Muñoz-Mata J. L., Beltrán-Pérez G., Castillo-Mixcóat J., Mendoza-Barrera C. O., Altuzar-Aguilar V., Muñoz-Aguirre S. (2018). *Reduction of the Measurement Time by the Prediction of the Steady-State Response for Quartz Crystal Microbalance Gas Sensors*. Sensors, 18(8), 2475; https://doi.org/10.3390/s18082475.

Rayment M. B. (2000). *Closed chamber systems underestimate soil CO_2 efflux*. Eur. J. Soil Sci. 51: 107-110. https://doi.org/10.1046/j.1365-2389.2000.00283.x

Rayment M. B., P. G. Jarvis. (1997). *An improved open chamber system for measuring CO_2 effluxes in the field*. J. Geophys. Res. 102: 28779-28784. https://doi.org/10.1029/97JD01103

Rosales Hernández, Cruz Teresa y Reyes Galaviz, Orión Fausto. (2016). *Clasificación de Datos de Olor de Café provenientes de una Nariz Electrónica Utilizando Redes Neuronales*. Researchgate.net. Pp. 2-7. https://www.researchgate.net/publication/228513703_Clasificacion_de_Datos_de_Olor_de_Cafe_provenientes_de_una_Nariz_Electronica_Utilizando_Redes_Neuronales