VOCs detection by microwave transduction using zeolites as sensitive material.

B. de Fonseca, J. Rossignol, I. Bezverkhyy, J.P. Bellat, D. Stuerga, P. Pribetich

*GERM Dpt. Nanosciences, Laboratoire Interdisciplinaire Carnot de Bourgogne UMR CNRS 6303, Dijon, France

ASP Dpt. OMR, Laboratoire Interdisciplinaire Carnot de Bourgogne UMR CNRS 6303, Dijon, France

Abstract

The gas sensing is an environmental topic representing a strong interest for this century. Whatever the purpose: industrial emissions control or indoor quality air supervision, the challenge remains to produce effective low costs detection systems adapted to the atmospheric conditions. This study focuses on the estimation of the microwaves transduction technique viability for the toluene detection by the implementation of sensors based on zeolites layers, deposited on coplanar structures adapted to the microwave frequency range. We shall apply to explain the principles of the microwave transduction before approaching the conception of the sensors, the measurement protocol and the obtained results.

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Peer-review under responsibility of the scientific committee of Eurosensors 2014

Keywords: gaz sensor, microwave transduction, zeolites, coplanar antenna, toluene.

* Corresponding author. Tel.: +33.380.395.936; fax: +33.380.396.132.
E-mail address: brice.de-fonseca@u-bourgogne.fr
1. Introduction

Most of the commercialized gas sensors are based on a conductimetric transduction using non-stoichiometric metal oxides as sensitive materials [1]. They are mainly sensitive to redox active species that can accept or give electrons, which induce a variation of the density of charge carriers [2]. They are also sensitive to species able to modify the mobility of these carriers, and more generally the transport properties in sensing materials [3].

In our case, this study highlights an innovative transduction method, working at room temperature, based on the microwave propagation through zeolites as sensitive materials. This transduction technique estimates the evolution of the permittivity [4, 5] of the sensitive material, at frequencies in the microwave range, consecutive to the adsorption of molecules on the surface of the sensitive layer at room temperature.

2. Microwave transduction method

The microwave transduction is based on the phenomena of propagation and reflection of an incident electromagnetic wave in a material in the range of microwave. (between 2 GHz and 10 GHz). By using a VNA (Vector Network Analyser), microwaves, are transmitted to a sensor made up of a coplanar structure covered by the sensitive material. The response of the microwave sensor leads to the obtention of a reflection coefficient at each frequency. This one is a complex number representing the ratio between the incident electromagnetic wave at the input of the circuit and the reflected wave [1, 6].

This transduction brings several advantages: the measurements are performed at room temperature [6] (without energy supply to the sensitive material) and allow the obtention of a couple of values (imaginary and real part of the response) for each frequency which gives a specific signature of the gas-material interaction on the whole scanned frequency spectrum.

3. Experimental section

3.1. Sensitive materials

We selected three different zeolites recognized as good VOC’s adsorbents [7] to produce this work experiments: hydrophobic dealuminated faujasite DAY, Silicalite-1 and hydrophilic faujasite NaX. Colloidal suspensions involving the same zeolite concentrations have been prepared with ethanol as solvent. The obtained solutions have been deposited on identical coplanar structures by spin coating to obtain reproducible layers.

3.2. Measurement method and devices

To expose the sensor to toluene, a Controlled Evaporation and Mixing system (CEM) from Bronkhorst is used to evaporate toluene in an argon flow regulated by two mass flow meters (Fig. 1).
Exposition to toluene concentration of 50, 100, 200 and 500 ppm are implemented according to the diagram presented in Fig. 2.

The exploited signals are the real and imaginary parts of the difference of the reflected coefficient between the presence of the pollutant and without pollutant for each concentration, which can be traduced by the equation (1):
\[ \Delta \Gamma = \Gamma(Ar + \text{pollutant}) - \Gamma(Ar) \]  \hspace{1cm} (1)

4. Results

Results obtained with the use of DAY zeolite as sensitive material are submitted on Fig. 3. They present the evolution of the real and imaginary parts of the reflection coefficient at 3.9 GHz as a function of the time exposure for each toluene concentration. Several items can be noticed: through this transduction technique the toluene expositions are quantifiable and the obtained measurements are reproducible.

![Fig.3. Representation at 3.9GHz of the imaginary and the real part of the reflection coefficient of a sensor as a function of time for different concentrations of toluene.](image)

By spotting several frequencies of interest for which we observe noticeable modifications of the signal as a function of the toluene concentration introduced into the measurement cell, we obtain a precise signature of the response of the sensor to the target gas.

Results obtained with silicalite-1 and NaX through this technique as well as a theoretical approach focused on the gas-material interactions analyzed through this technique will be presented. Perspectives envisaged in short terms and middle courses will also be tackled.

References