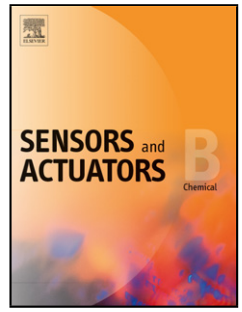
Accepted Manuscript



Title: Microwave flexible gas sensor based on polymer multi wall carbon nanotubes sensitive layer

Author: P. Bahoumina H. Hallil J.L. Lachaud A. Abdelghani K. Frigui S. Bila D. Baillargeat A. Ravichandran P. Coquet C. Paragua E. Pichonat H. Happy D. Rebière C. Dejous

PII: S0925-4005(17)30737-2
DOI: http://dx.doi.org/doi:10.1016/j.snb.2017.04.127
Reference: SNB 22215

To appear in: *Sensors and Actuators B*

Received date: 31-10-2016
Revised date: 26-2-2017
Accepted date: 22-4-2017

Please cite this article as: P. Bahoumina, H. Hallil, J.L. Lachaud, A. Abdelghani, K. Frigui, S. Bila, D. Baillargeat, A. Ravichandran, P. Coquet, C. Paragua, E. Pichonat, H. Happy, D. Rebi*gravee*re, C. Dejous, Microwave flexible gas sensor based on polymer multi wall carbon nanotubes sensitive layer, *Sensors and Actuators B: Chemical* (2017), http://dx.doi.org/10.1016/j.snb.2017.04.127

This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

ACCEPTED MANUSCRIPT

Microwave flexible gas sensor based on polymer multi wall carbon nanotubes sensitive layer

Bahoumina P. [1*], Hallil H. [1°], Lachaud J.L. [1], Abdelghani A. [2], Frigui K. [2], Bila S. [2], Baillargeat D. [2], Ravichandran A. [3], Coquet P. [3,4], Paragua C. [4], Pichonat E. [4], Happy H. [4], Rebière D. [1], Dejous C. [1]

(1) Univ. Bordeaux, Bordeaux INP, IMS, CNRS UMR 5218, F-33405 Talence, France
(2) Univ. Limoges/CNRS, XLIM UMR 7252, F-87060 Limoges
(3) CINTRA, CNRS/NTU/THALES, UMI 3288, Singapore 637553
(4) Univ. Lille, IEMN UMR CNRS 8520 F-59652 Villeneuve d'Ascq
(*)prince.bahoumina@ims-bordeaux.fr ; (°) hamida.hallil@ims-bordeaux.fr

Abstract — This study presents the feasibility and the first real time results of microwave flexible gas sensor based on poly (3,4-ethylenedioxythiophene) polystyrene sulfonate – multi wall carbon nanotubes (PEDOT:PSS-MWCNTs) as sensitive material, deposited by inkjet printing technology. The sensor is suitable for wireless applications, it consists of two stub resonators on kapton in order to provide a differential detection. The final aim of this work is to develop a low cost communicating sensor which can be integrated into real time multi sensing platform dedicated to the applications requiring low power consumption and adaptable for the Internet of Things (IoT), in order to do the detection of harmful gases such as Volatile Organic Compounds (VOCs). Preliminary results have shown a large influence of ethanol concentration on the electrical properties of the passive resonators at radio-frequency range. These vapors have induced additional insertion losses and frequency shifts on the first resonant frequency mode around 0.65 GHz. The sensor sensitivity to ethanol vapors exposition has been estimated to -642.9 Hz/ppm and -7 µdB/ppm for resonant frequency and insertion losses variations in differential mode, respectively, according to the values at 4 minutes of exposure to 500, 1000 and 2000 ppm. To deepen the study of the sensor, we have focused on the influence of ethanol on the conductivity of the sensitive layer, in terms of repeatability and sensitivity. We proposed a way of real-time reconstruction of the response by representing the difference of the insertion losses as well as the difference of frequencies calculated on the basis of the phase average value within a specified frequency range near the resonance. This lead to estimate a sensitivity of -9 µdB/ppm and 648.1 Hz/ppm, respectively, for ethanol concentrations ranging from 500 ppm to 2000 ppm at 10 minutes of exposure.

Keywords — *Chemical gas sensor; electromagnetic transduction; inkjet printing; flexible substrate; microwave resonator; polymer multi-wall carbon nanotubes composite*

I. INTRODUCTION

The need for miniature sensors, integrated in all environments, highly selective and sensitive, with low cost and low power consumption, is growing more each year, due to the modernization and increasing global industrialization, which increase environmental pollution. This pollution concerns 7 million deaths in 2012, according to World Health Organization (WHO) [1]. It is known as a source of irritation, decreased lung capacity and odors. Some of these pollutants are considered carcinogenic, among them volatile organic compounds (VOCs) represent an issue as target compounds. Several classifications of carcinogenic agents exist, in particular those of the European Union (EU), the International Agency for Research on Cancer (IARC) and the Institut National de Recherche et de Sécurité (INRS). They provide information on the carcinogenic risk in the workplace of listed chemical substances (VOCs, heavy metals, ...etc). For example, the occupational exposure limit value for ethanol is 500 ppm in Germany and 1000 ppm in France and USA [2]. Unfortunately, powerful systems that allow the detection of these chemicals agents in real time are still urgently needed, as prevention tools in order to alert the people concerned. In this context and to respond to this problem, we propose the real-time monitoring and quantification sensor for toxic gas, by combining an electromagnetic transduction resonator with a chemical sensitive layer of carbonaceous material in the frequency band from DC to 6 GHz. This platform is suitable for the Internet of Things and embedded systems, which open revolutionary perspectives to the proliferation of sensing and control sites with communicating wireless sensor networks. The electromagnetic transducer has been selected due to advantages such as passive and possibly wireless device; well appropriate for networking and communicating operation with high-frequency working thread; functional in harsh environments; usable for real-time detection and providing an exploitable information directly. In addition, due to its planar structure, the device can be manufactured on flexible substrate by low cost inkjet printing technology [3], [4], [5], [6]. Studies have shown that carbon materials when used as the detection layer are very sensitive, their structural distribution increases their contact surface area with the target species and they can be easily integrated with printed technology due to the availability of ink solutions. They have shown an ability of high sensitivity to a wide variety of particles: volatile organic compounds (VOCs), hydrogen sulfide (H_2S), carbon dioxide (CO_2), ammonia (NH_3) and nitrogen dioxide (NO_2) [4], [7], [8], [9]. For this study, the device is based on electromagnetic transduction associated with composite sensitive nanomaterials such as poly (3,4-ethylenedioxythiophene) polystyrene sulfonate – multi wall carbon nanotubes (PEDOT:PSS-MWCNTs). This material was chosen for commercial availability as printing ink and for enhanced conductivity, this composite combining the advantages of both the polymer and the carbon nanotubes, as illustrated in the literature [10], [11], [12], [13]. In a first part we describe the sensor design based on a dual stub resonator on a flexible kapton substrate and simulation results, as well as a prototype and electrical characterizations. Then, a real time exposure to different concentrations of ethanol is used to study the sensitive material behavior. We summarize and discuss the vapors characterization results and the sensor sensitivity as proof of concept. Finally, perspectives are presented.

II. THEORETICAL STUDY

The operating principle of the sensor (Fig. 1) is based on the differential detection of the disturbance of the electromagnetic field due to the presence of target species on the sensitive layer. Indeed, these target species cause the variation of the electromagnetic properties (permittivity, conductivity and/or permeability), mainly of the sensitive material whose function is to immobilize them. These changes in

Accepted Manuscript

Download English Version:

https://daneshyari.com/en/article/5009331

Download Persian Version:

https://daneshyari.com/article/5009331

Daneshyari.com