Student Workplace for Gas Sensing Demonstration

Jan Prasek, Zdenek Pytlicek and Jaromir Hubalek

Abstract – **This paper deals with the problematic of testing devices for gas sensors that are developed for monitoring of gases in the environment and processes. The universal student workplace with the device for gas sensing demonstration in classes has been developed in this work. The device is designed for up to eight different gas sensors in two TO-12 packages simultaneous testing. Two different gases could be connected and monitored during the measurement.**

Keywords – **Gas sensor, Nitrogen dioxide trace detection, Semiconductor sensor, Gas chamber**

I. INTRODUCTION

The monitoring and detection of toxic gases emissions in environment and industry processes is very important for environmental protection and human and animal safety. Gas sensors based on semiconductor active layers appear as a good solution for gas trace monitoring. The advantages of these sensors are their robustness, small size, small weight, simple design and low cost.

In last few years, there were described many works about gas sensors using different technology for their fabrication. Generally the thick film technology (TFT) is one of reported technologies used for gas sensors fabrication [1-4] due to its accessibility and non vacuum easy fabrication process. The thin film technology or semiconductor technology is the second technology used for gas sensors fabrication as it was reported in [5-7] for example.

The main difference between the developed gas sensors is in the used semiconducting materials for the active layers and methods for their preparation or deposition. Usually the SnO_2 [1, 2], WO_3 [8] or TiO_2 [4, 9] nanopowders are used as main sensing material, which can be covered with catalytic filters or modified by doping.

Next problem of gas sensors development is the verification of their sensing properties. Universal equipment for the verification does not exist. All researchers usually use their own setup using a little gas chamber for the sensor, the pressure tanks with detected gasses and one pressure tank with an inert gas for chamber cleaning. The problem is in the appropriate equipment for the selection of desired gas concentration. One solution is to use the pressure tanks with the desired premixed concentration. The second more sophisticated solution is to use the inert gas which is mixed with the detected gas to the predefined concentration using mass flow controllers.

The aim of this work was to design and implement the appropriate sophisticated student workplace for gas sensing demonstration in the classes to bring them more complex and practice information about gas sensing problematic.

J. Prasek is from the Department of Microelectronics, Faculty of electrical engineering and communication, Brno University of Technology, Udolni 53, 60200 Brno Czech Republic, e-mail: prasek@feec.vutbr.cz

Z. Pytlíček a master's degree student at the Department of Microelectronics, Faculty of electrical engineering and communication, Brno University of Technology, Udolni 53, 60200 Brno Czech Republic, e-mail: xpytli02stud.feec.vutbr.cz

J. Hubalek is from the Department of Microelectronics, Faculty of electrical engineering and communication, Brno University of Technology, Udolni 53, 60200 Brno Czech Republic, e-mail: hubalek@feec.vutbr.cz

II. CONSTRUCTION OF USED GAS SENSORS

The sensors used for gas sensors demonstration could be fabricated using TFT, thin film technology or semiconductor technology on a ceramic or Si substrates. In our case there are two possibilities of used sensors for the demonstration.

A. Four-Element Micro-Hotplate Gas Sensor

The four-element integrated micro-hotplate is fabricated on Si substrate. The structure of the micro-hotplate chip sensor consists of the polysilicon heaters, insulating layers, the electrodes and the gas sensing layers. The heater is also used as a temperature sensor. The sensing layers are fabricated from 5 μm thick SnO_2 or WO_3 nanoparticle films. Each chip is wire bonded on a TO-12 package as it is shown in the figure 1.

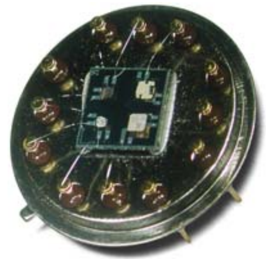

Fig. 1. Four-element micro-hotplate wire bonded on the TO-12 package

B. Thick-Film Gas Sensor

The TFT gas sensor is fabricated using standard thick-film techniques. The structure of the TFT gas sensor consists of platinum heater element covered by insulating layer, the gold electrodes and the gas sensing layer. The

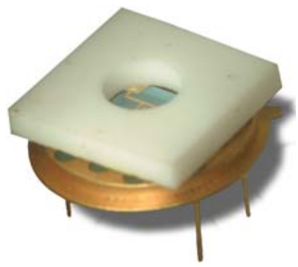

Fig. 2. TFT gas sensor with mounted on the TO-12 package bonded through a ceramic support

heater is also used as a temperature sensor. The screen-printed sensing layers are made from 5 µm thick SnO_2, WO_3 or TiO_2 nanoparticle films. Each sensor is bonded on the TO-12 package through a ceramic support (due to high operating temperatures > 400 °C) as it is shown in the figure 2.

III. Construction of the Student Workplace

Student workplace was designed to be suitable for practical gas sensing demonstration in the classes of "Microsensors and micromechanical systems" subject and subject "Biosensors" that will be newly opened in the next school year. The workplace design and its implementation are shown in the next subsections.

A. The Student Workplace Design

The designed experimental students' workplace is consisted of gas flow chamber with three closing valves, two mass flow controllers for desired gas concentration setup, two pressure tanks with tested and inert gas, control electronics and personal computer with software for experiment setup and the sensors' response evaluation. The designed experimental students' workplace setup is shown in the figure 3.

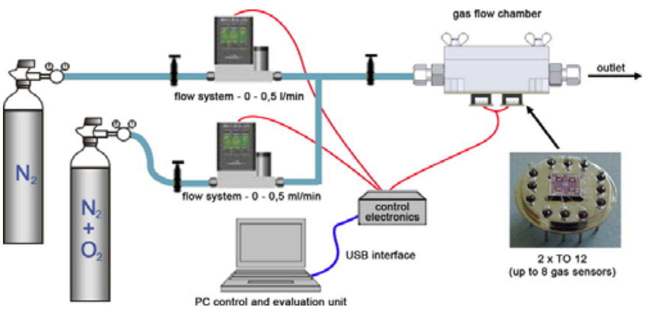

Fig. 3. Experimental students' workplace setup

B. Gas Flow Chamber Design

First of all, the testing gas flow chamber was designed to be suitable for two TO-12 packages. The chamber has an exchangeable output connector, which could be used as exchangeable reducer for differently connected sensors in the TO-12 package. The maximum of the sensors in one package is four. The gas chamber was designed to be hermetically closeable with one inlet and one outlet. The inner volume was designed to be as smallest as possible. The gas chamber design is shown in the figure 4.

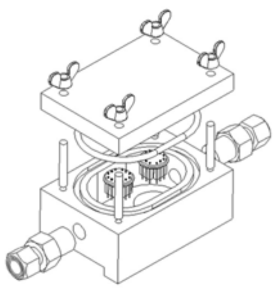

Fig. 4. Gas flow chamber design

The designed gas flow chamber was fabricated from plastic material Ketron® Peek 1000. This material has good mechanical properties and is sufficiently chemically resistant. The sample of the fabricated gas chamber is shown in the figure 5.

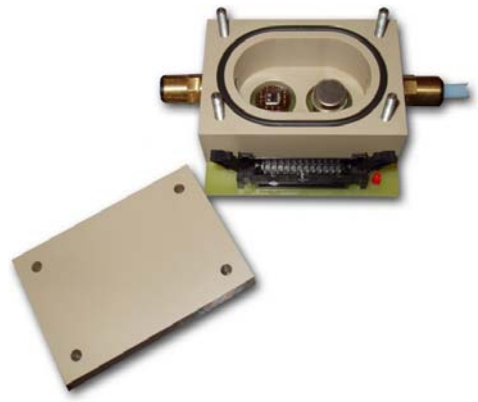

Fig. 5. Fabricated gas flow chamber for two TO-12 packages

C. The Student Workplace assembling

The main part of the workplace was assembled onto one plastic board. The main part consists of the control electronics, gas flow chamber, three closing valves and two mass flow controllers for desired gas concentration setup. The mass flow controllers were selected in order to be able to assure desired concentration of the testing and inert gas to mixture them in concentrations from 100 ppm to 10 ppb. For this purpose, the Alicat Scientific mass flow controllers for volumes 500 sccm for inert gas and 0.5 sccm for testing gas were purchased. The standard electromagnetic closing valves from M&M company were purchased. The assembled main part of the student workplace is shown in the figure 6.

Fig. 6. Assembled main part of the student workplace

D. Control Electronics

The control electronics was designed as two different parts due to its possible easy upgrade in the future. The control and communication part was designed to control desired concentration by mass flow controllers and valves and to arrange the communication between the PC and electronics blocks. The analog measuring part was designed to measure with the gas sensors. It includes the sensor temperature regulation and the conductivity measurement of the sensor's active layer. It allows to measure simultaneously up to eight gas sensors (four in each TO-12 package).

E. Control and Evaluation Software

The control and evaluation software was designed and programmed in the LabView environment (National Instrument, USA). The control software part is designed for experiment setup e.g. time schedule of measurement, mass flow rate, valves opening, heater parameters, etc. The measurement and evaluation part is designed for online sensors response demonstration and operations with measured data. The flow control window screenshot is shown in the figure 7.

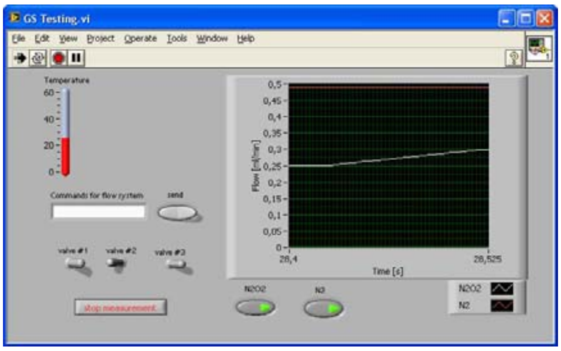

Fig. 7. Flow control window screenshot

IV. MEASUREMENT DEMONSTRATION TEST

Measurement demonstration test was done using thick-film gas sensor with WO_3 gas sensing active layer covered with platinum catalytic filter. The tested gas was NO_2. The results obtained during the measurement at operating temperature of 250 °C were exported to the MS Excel. The time dependence of the sensor resistance on the NO_2 concentration change is shown in the figure 8. According to figure 8, we were able to detect 1 ppm of the nitrogen dioxide.

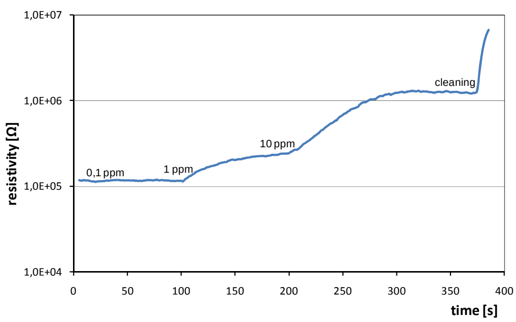

Fig. 8. Time dependence of the TFT gas sensor resistance on the change of NO_2 concentration

II. CONCLUSIONS

The new student workplace for the gas sensing demonstration was designed and implemented. It is designed in order to be suitable for students' attending two subjects at the Department of Microelectronic, Brno University of technology. The design and construction of used gas sensors and the students workplace is briefly mentioned in this paper. The designed experimental students' workplace is consisted of gas flow chamber with three closing valves, two mass flow controllers for desired gas concentration setup, two pressure tanks with tested and inert gas, control electronics and personal computer with software for experiment setup and the sensors' response evaluation. All parts were designed and implemented to be easily controlled by students. Finally the workplace was tested on the nitrogen dioxide detection for demonstration. We were able to detect 1 ppm of the nitrogen dioxide.

ACKNOWLEDGEMENT

The research has been partially supported by the Czech Ministry of Education, Youth and Sports in the frame of Research Plan MSM 0021630503 MIKROSYN *New Trends in Microelectronic Systems and Nanotechnologies* and by the Czech National Research Program's project 2E08051 *Research of methods and techniques for general public familiarization with a researcher work by information technologies*.

REFERENCES

[1] S.Ch. Lee, H.Y. Choi, S.J. Lee, W.S. Lee, J.S. Huh, D.D. Lee, J.Ch. Kim. *Novel SnO_2-based gas sensors promoted with metal oxides for the detection of dichloromethane*. Sensors and Actuators B: Chemical, Volume 138, Issue 2, 2009, pp. 446-452.

[2] F. Berger, E. Brunol, R. Planade, A. Chambaudet. *Detection of DEMP vapors using SnO_2-based gas sensors: understanding of the chemical reactional mechanism*. Thin Solid Films 436 2003, pp. 1–8.

[3] N.J. Choi, J.H. Kwak, Y.T. Lim, T.H. Bahn, K.Y. Yun, J.C. Kim, J.S. Huh, D.D. Lee. *Classification of chemical warfare agents using thick film gas sensor array*. Sens. Actuators B. Chem. 108 (1–2) 2005, pp. 298–304.

[4] E. Sotter, X. Vilanova, E. Llobet, A. Vasiliev, X. Correig. *Thick film titania sensors for detecting traces of oxygen*. Sensors and Actuators B: Chemical, 127 (2) 2007, pp 567-579.

[5] P.P. Sengupta, P. Kar, B. Adhikari. *Influence of dopant in the synthesis, characteristics and ammonia sensing behavior of processable polyaniline*. Thin Solid Films, 517 (13) 2009, pp 3770-3775.

[6] P. Ivanov, E. Llobet, A. Vergara, M. Stankova, X. Vilanova, J. Hubalek, I. Gracia, C. Cane, X. Correig. *Towards a micro-system for monitoring ethylene in warehouses*. Sensors and Actuators B: Chemical, Volume 111, 2005, pp 63-70.

[7] P. Ivanov, J. Laconte, J.P. Raskin, M. Stankova, E. Sotter, E. Llobet, X. Vilanova, D. Flandre, X. Correig. *SOI-CMOS compatible low-power gas sensor using sputtered and drop-coated metal-oxide active layers.* Microsystem Technologies-Micro-and Nanosystems-Information Storage and Processing Systems, 12 (1-2) 2005, pp 160-168.

[8] M.T. Ke, M.T. Lee, C.Y. Ch.Y. Lee, L.M. Fu. *A MEMS-based Benzene Gas Sensor with a Self-heating WO_3 Sensing Layer*. Sensors 9 (4) 2009, pp. 2895-2906.

[9] J.C. Kim, H.K. Jun, J.S. Huh and D.D. Lee. *Tin oxide-based methane gas sensor promoted by alumina-supported Pd catalyst*. Sensors and Actuators B: Chemical 45, 1997, pp. 271–277.