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Pellet Sensor Based Asthma Detection System Using Exhaled Breath Analysis

Pauroosh Kaushal
Department of Instrumentation and Control
College of Engineering Pune
Pune, India

R.P. Mudhalwadkar
Dept of Instrumentation & Control
College of Engineering Pune
Pune, India

Abstract—**Human breath is largely composed of oxygen, carbon dioxide, water vapor, nitrogen and numerous compounds in trace concentration. Exhaled Breath analysis is non-invasive, real-time and low cost technique which can be applied in medicine field both as a diagnostic tool and as a way to monitor the progress of therapies. This paper proposes a pellet sensor which responds to the exposure of exhaled breath. A proportion of zinc oxide and tin oxide nanopowder was used to fabricate gas sensor in the form of pellet. The pellet sensor response for asthmatic exhaled breath varies from normal exhaled breath response. The electrical conductivity, sensitivity, response time and recovery time of pellet sensor with asthmatic exhaled breath exposure has been studied and compared to the normal response. As a part of standard data collection, a spirometer apparatus for differentiating normal person and asthmatic patient is used. The response of pellet sensor is different for normal and asthmatic subjects with stable and repeated response. Characterization of pellet sensor is done for both normal and diseased case. The comparison between normal and asthmatic pellet sensor response can be used as an assistive tool for asthma disease detection.**

Keywords—Breathe analysis; asthma; pellet sensor; exhaled breath; tin oxide; zinc oxide

I. INTRODUCTION

Breath is a complex matrix where flow rate, temperature, humidity, and gas concentration are multifarious and time-dependent variables. The analysis of the breath allows assess different body functions in a convenient and flexible way. Certain gases in the breath are known to be indicators of the presence of diseases and clinical conditions. For example, acetone has been linked to diabetes; ammonia is an indicative of renal disease etc [1], [2]. Exhaled nitric oxide and other volatile organic compounds (VOCs) in breath is an easy to measure, noninvasive measure of airway inflammation like asthma [3], [4].

Asthma is an inflammatory disease of the airways characterized by chronic inflammation of the airways, which subsequently results in increased contractibility of the surrounding smooth muscles, leading to symptoms of asthma like wheezing, coughing, chest tightness etc. Physical examination, medical history of subject and spirometry results is the tests for detection and management of asthma. The work proposes a non invasive system which can be used to analyze exhale breath for asthma detection. In the literature, there are various techniques to examine traces of these gases concentration in exhaled breath. The measurement of nitric oxide is based on conversion of NO to NO_2 based on chemiluminescent reaction was developed [5]. Another technique used to monitor nitric oxide in exhaled breath for application in detecting asthma was tunable-diode laser absorption spectroscopy [6]. In another literature, Polyvinylidene fluoride (PVDF) film in cantilever configuration is used as a sensing element to form the breath sensor. This sensor records the breathing patterns [7].

In this paper, we propose a technique for exhaled breath analysis is metal oxide semiconductor (MOS) gas sensors. When metal oxide crystals like SnO_2 are heated at certain high temperature, they exhibit sensitivity towards oxidizing and reducing gases by a variation of their electrical properties. This technique eliminates the disadvantages of other techniques by its low cost and easy operation features. The system makes use of MOS sensor, made up of tin oxide doped with zinc oxide that at are sensitive to exhaled breath. There is a close relationship between the gas sensitivity of metal oxides and their surface chemical activity and thus having excellent gas sensing properties. Characterization of the sensor for response of normal and asthmatic exhaled breath is done. In order to obtain asthmatic exhaled breath sample, subject is first tested with asthma condition with the help of spirometer. If the test confirms asthma condition, the response of pellet sensor for exhaled breath sample is recorded. The comparison of sensor response is done which distinguishes normal and asthmatic person making it an assistive tool for asthma detection.

II. MATERIAL AND METHOD

This section is focused on fabrication of sensor which is prepared in the laboratory in the form of pellets. Tin oxide nanopowder and zinc oxide nanopowder are selected. The resistance of pellet changes when gases pass through it and adsorbed on the surface. Formations of Pellets involve the following steps:

A. Weighting

The two powder ratio is pre decided and the weighing is done, deciding the percentage composition of mixture. The weight ratios decided for pellet design is a mixture of zinc oxide nanopowder (10%) and tin oxide nanopowder (90%).

B. Pulverizing

Pulverizing is done to mix properly both the powders to obtain a properly mixed ratio. This process is carried out with isopropyl alcohol being added at each interval.

C. Pressing

Before forming the pellets using any hydraulic press machine, the pulverized powder is mixed with a drop of Poly Vinyl alcohol (PVA) which acts as a binding agent. This process results in good formation of pellets and enhances the press effect carried out further. The pulverized powder is taken in the required quantity, 0.3 grams, and put into the die set. Pellets are pressed for duration of 5 mins usually with a pressure range from 90- 100 Kg/cm2 resulting in pellets of size 8mm.

D. Sintering

Sintering is the process wherein the formed raw pellets undergo heat treatment under closed conditions. This hardens the raw pellet and makes it quiet sturdy. Sintering is carried out at a temperature from 800ºC for 6 hours of time.

E. Contacts

Silver paste is used as a contact material. They are placed on the pellet ends to reduce contact resistance and so to get better response of the pellet sensor.

The output resistance is measured from the two ends of silver wire. Fig. 1 shows the pellet sensor with the contacts. The pellet is placed in a small enclosure, where sample gas is injected. The enclosed assembly collects breath sample, responds to the exhaled breath of normal and asthmatic person and interpretation is done. The enclosure of the system is done in such a way that there will not be any interference of external air with the breath sample. The dimension of the box is chosen in such way to cover whole sensor system and heater inside it which maintains the temperature through the experiment. After the sensor resistance is settled under constant temperature, the subject is instructed to inhale. After maximal inhaling, the subject is instructed to exhale the air in 2 blow through the mouth piece. The mouthpiece collects exhaled breath sample and injects it on pellet. The response of the pellet is recorded and plotted. This procedure is repeated for both normal and asthmatic subjects. The results are analyzed and the sensor is characterized for normal and asthma samples.

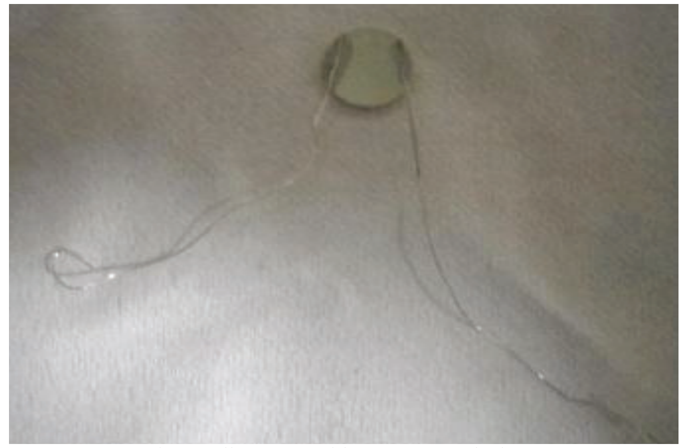

Fig.1: Pellet sensor with contacts attached

III. RESULTS AND DISCUSSION

The composition of exhaled breath has a great impact on response of the gas sensor. As a part of standard data collection, a spirometer apparatus for assisting to differentiate normal person and asthmatic patient is used. The spirometer calculates the predicted values of PEF, FEV1, FVC and FEF 25 75 based on person's blow, age, sex and height. The predicted or ideal values for a particular patient are compared with spirogram. If the values of spirogram fall below ideal values, the person can be labeled as infected and has airflow obstruction. One Flow FVC Spirometer is used for data collection. Figure 2 and figure 3 shows data of two different normal subjects and figure 4 shows data of asthma infected patient. The parameters recorded are tabulated in table 1.

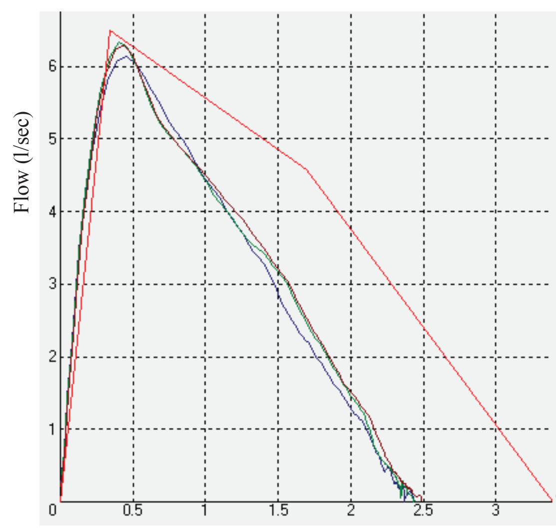

Fig.2: Spirogram of normal subject 1

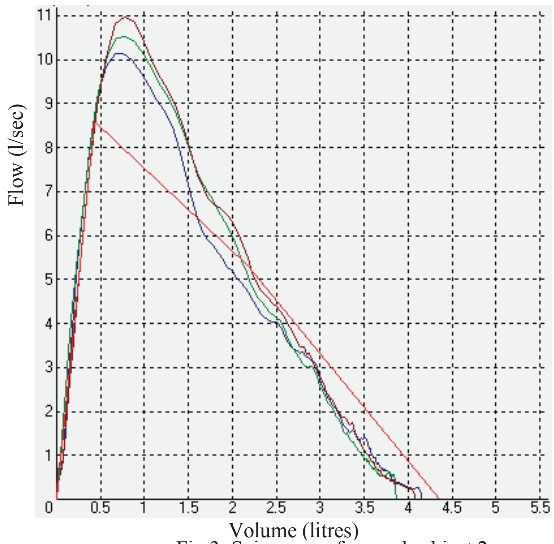

Fig.3: Spirogram of normal subject 2

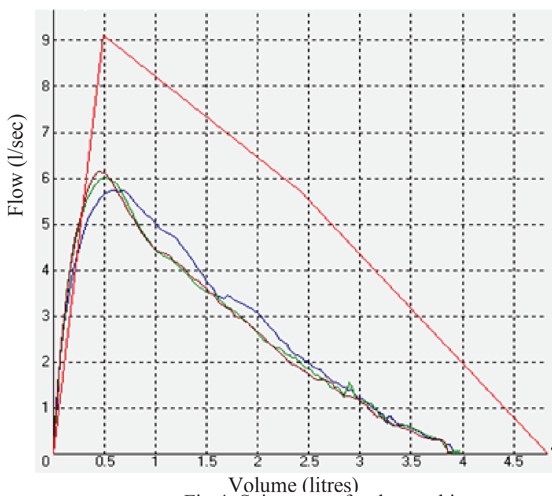

Fig 4: Spirogram of asthma subject

To record exhaled breath response on pellet, a mouthpiece is used for direct injection of sample on pellet. After 20 minutes of switching on the heater, stable resistance is observed in the range of 200k to 350kΩ. After inhaling the air, the subject is instructed to exhale the air in two blows through the mouth piece. The change in resistance is observed and response curve is plotted. The response curve is plotted for both normal and asthmatic subjects as shown in figure 5, 6, 7 and 8.Characterization of pellet sensor for asthmatic exhaled breath sample is tabulated and comparison of exhaled breath response between normal and asthmatic is done as shown in table 2 and table 3. It is clear from experimentations that pellet sensor response is different from normal and asthma subject. The sensor response due to exhaled breath of asthma subject has higher settling time and lower peak amplitude as compared to normal subject. The response curve of pellet sensor can discriminate between normal and asthma subject. The results obtained are also correlating with parameters of spirometer.

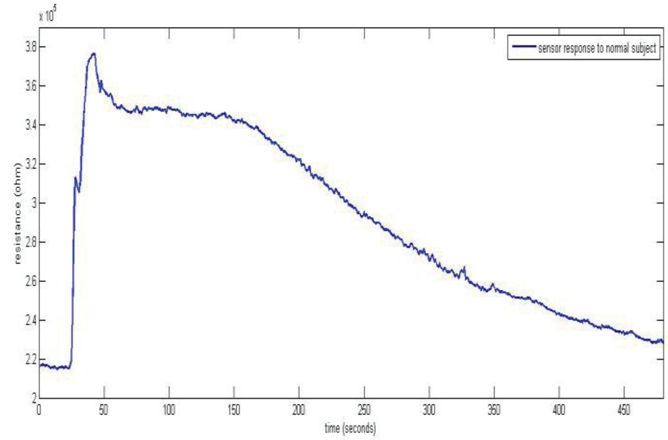

Fig.5: Subject 1 normal human breath response

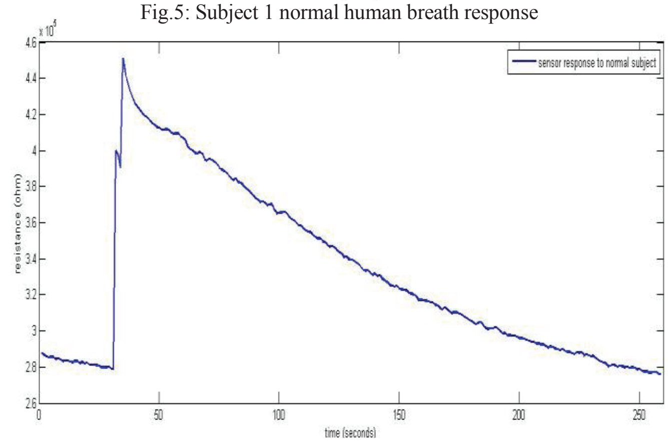

Fig.6: Subject 2 normal human breath response

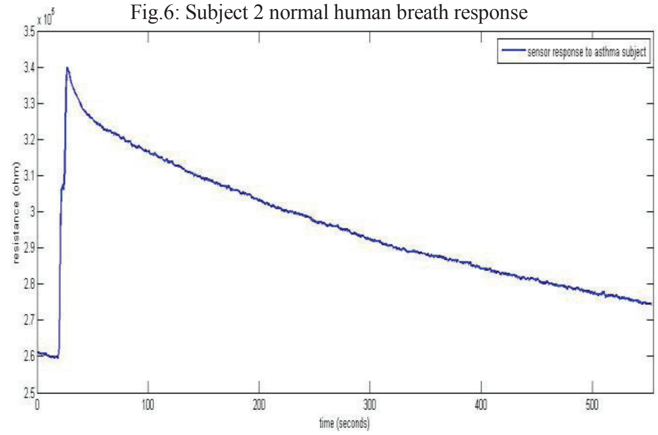

Fig.7: Response of asthma subject 1 breath

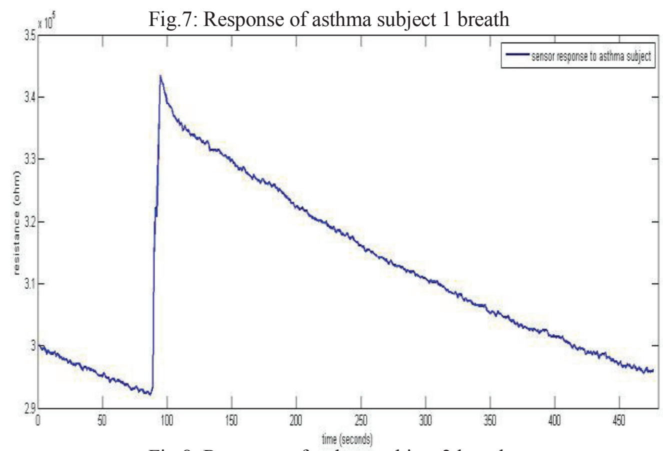

Fig.8: Response of asthma subject 2 breath

TABLE I. PARAMETERS OF SPIROGRAM OF THREE SUBJECTS

Subject	PEF(l/min)				FEV1(l)				FVC(l)				FEF(l/sec)			
	Predicted	***C1***	***C2***	***C3***	***Predicted***	***C1***	***C2***	***C3***	***Predicted***	***C1***	***C2***	***C3***	***Predicted***	***C1***	***C2***	***C3***
Normal	390	370	380	380	2.96	2.3	2.3	2.35	3.39	2.45	2.45	2.5	3.75	3.35	3.5	3.5
Normal	515	610	630	660	3.7	3.7	3.65	3.7	4.35	4.15	3.85	4.05	4.4	4.5	5.35	5.35
Asthma	547	345	360	370	4.07	3.05	2.95	2.95	4.84	3.9	4	3.9	4.6	2.65	2.35	2.4

TABLE II. CHARACTERISTIC OF PELLET SENSOR FOR ASTHMA BREATH

No of subject	Peak resistance(MΩ)	Response time (sec)	Settling time(sec)	Preheating time(min)	Resistance ratio(1/sensitivity)
1	0.336	12	550	20	1.3
2	0.341	9	380	20	1.15

TABLE III. COMPARISON OF EXHALED BREATH RESPONSE BETWEEN NORMAL AND ASTHMATIC

Type of subject	Peak resistance(MΩ)	Settling time(sec)	Resistance ratio(1/sensitivity)
Normal	0.37 - 0.45	210 - 280	1.63 – 1.68
Asthmatic	0.33 – 0.34	380 - 550	1.15 – 1.3

IV. CONCLUSION

In the paper, a fabrication technique is used to obtain a metal oxide semiconductor pellet sensor is discussed. The fabricated pellet sensor is subjected to normal and asthmatic exhaled breath. It can discriminate exhaled breath of patients with asthma from normal subjects. The results obtained for pellet sensor in response of exhaled breath of asthma patient indicates less amplitude in resistance change and higher decay time as compared to normal exhaled breath. The response is differentiated by normal breath response by 300kΩ change in resistance. The different response curve obtained from pellet sensor are correlated with parameters of spirometer. Pellet sensor showed stable and repetitive response for exhaled breath of normal and asthma patient cases. The future work includes classification of asthma condition into mild, moderate and severe categories using exhaled breath analysis for better diagnosis and management of the disease.

REFERENCES

[1] Anton Amann , Guy Poupart , Stefan Telser , Maximilian Ledochowski , Alex Schmid and Sergei Mechtcheriakov, “Applications of breath gas analysis in medicine,” International Journal of Mass Spectrometry, vol 239, pp 227–233, october 2004

[2] Darryl Hill, Russell Binions, “Breath Analysis for Medical Diagnosis”, International Journal on Smart Sensing and Intelligent Systems, vol. 5, issue 2, june 2012.

[3] D. Robin Taylor, MD, FRCPC, “Nitric oxide as a clinical guide for asthma management” Journal of Allergy, Asthma and Immunology, pp 259-262, Feb 2006.

[4] Silvano Dragonieri, Robert Schot, Bart J.A. Mertens, Saskia Le Cessie, Stefanie A. Gauw,Antonio Spanevello, Onofrio Resta, Nico P. Willard, Teunis J. Vink, Klaus F. Rabe,Elisabeth H. Bel, Peter J. Sterk, “An electronic nose in the discrimination of patients with asthma and controls” The Journal of Allergy and Clinical Immunology vol. 120, issue 4 , pp 856-862, october 2007.

[5] Jill K. Robinson, Mark J. Bollinger, John W. Birks, “Luminol/H2O2 Chemiluminescence Detector for the Analysis of Nitric Oxide in Exhaled Breath” Analytical Chemistry, vol. 71, issue 22, pp 5131-5136 november 15, 1999.

[6] Chad Roller, Khosrow Namjou, James D. Jeffers, Mark Camp, Adam Mock, Patrick J. McCann, Joe Grego, “Nitric oxide breath testing by tunable-diode laser absorption spectroscopy: application in monitoring respiratory inflammation,” Applied Optics, vol. 41, issue 28, pp 6018-6029, october 2002.

[7] Roopa.G, K.Rajanna, M.M. Nayak, “Non-Invasive Human Breath Sensor,” Sensors IEEE, pp 1788-1791, october 2011