Proceedings of the International MultiConference of Engineers and Computer Scientists 2013 Vol II,
IMECS 2013, March 13 - 15, 2013, Hong Kong

Alcohol Vapor Detection By Using Nanoporous Silicon as Based Sensor

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Abstract—**In this paper, we are concerned with fabrication of alcohol vapor sensor based on nanoporous silicon. In order to use nanoporous silicon as alcohol vapor sensor, we made nanoporous silicon onto p-type silicon wafer by electrochemical etching of silicon wafer in hydrofluoric acid solution. The structure of this sensor consists of nanoporous silicon layer and aluminum electrode which is deposited on the top of nanoporous silicon layer by evaporator. In this research, we are concerned the variation of electrical properties of this sensor due to presence of different concentration of alcohol vapor. From the experiment, it is found that this sensor can detect the different concentrations of alcohol vapor in the rang 1000 ppm to 250 ppm.**

***Index Terms*— Alcohol vapor sensor, Nanoporous silicon, Electrochemical etching.**

I. INTRODUCTION

Today, the nanoporous silicon is a very interesting material for both its optical and electrical properties. Since the observation of strong room temperature visible photoluminescence from nanoporous silicon, there have been extensive researches to develop optoelectronics [1] and gas sensors [2]. Nanoporous silicon is usually obtained by electrochemical etching method using a silicon wafer. Its large internal surface versus volume ratio can reach several hundreds of m^2 per cm^3 which can adsorbs chemical vapor materials [3].

In this paper, we are concerned fabrication of alcohol vapor sensor by using nanoporous silicon. The alcohol vapor sensor based on nanoporous silicon was tested in a controlled environment of different concentration of alcohol vapor condition. In this research, the sensing parameters were direct current from electrical properties of nanoporous silicon alcohol vapor sensor.

II. EXPERIMENT DETAILS

The nanoporous silicon are prepared by an electrochemical etching of p-type silicon wafers of (100) crystalline orientation and with a resistivity of 1-2 Ω-cm. The electrochemical etching was performed in the usual cell, illumination the front of the wafer with a 500 W halogen lamp, in a hydrofluoric acid solution with 48% concentration at a current density of 30 mA/cm^2 for 20 min as shown in Figure 1.

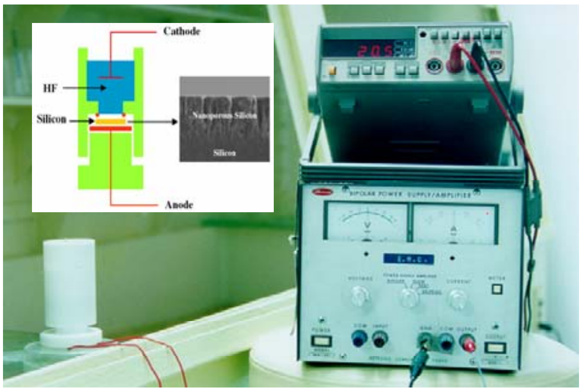

Fig. 1. Picture of electrochemical etching for prepared nanoporous silicon.

The samples were washed in C_3H_7OH and air dried. The sample porosity has been determined by the gravimetric method [4].

The surface and cross section image of nanoporous silicon was obtained by scanning electron microscope (SEM).

For electrical measurement, we chose a planar configuration: two Al contacts were deposited onto the surface of the nanoporous silicon by evaporation method. The size of both contacts is the same (symmetrical) and area of 1000x5000 μm^2. The internal separation between the contacts is 500 μm. After the contacts deposition, the nanoporous silicon were wired with a copper wire and mounted to the circuit board which will shown in Figure 2.

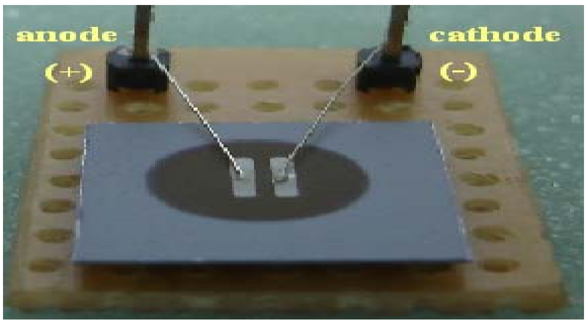

Fig. 2. Picture of nanoporous silicon alcohol vapor sensor.

In order to measurement the electrical sensing characteristics of alcohol vapor, the nanoporous silicon was biased between two electrode on the top of nanoporous silicon at a constant voltage, while the direct current was measured.

Manuscript received December 15, 2012; revised January 10, 2013.
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Measurements were performed in a sealed chamber kept at room temperature and at atmospheric pressure. The alcohol vapor was obtained by flowing nitrogen through a bubbler. The electrical properties of nanoporous silicon change in direct current in present of different concentration of alcohol vapor was monitored by a DC volt amperometric technique at constant bias voltage 20 V. The outlet of the test chamber was connected to a electrometer and all the system was controlled by a computer. Figure 3 shows a schematic diagram of this experiment.

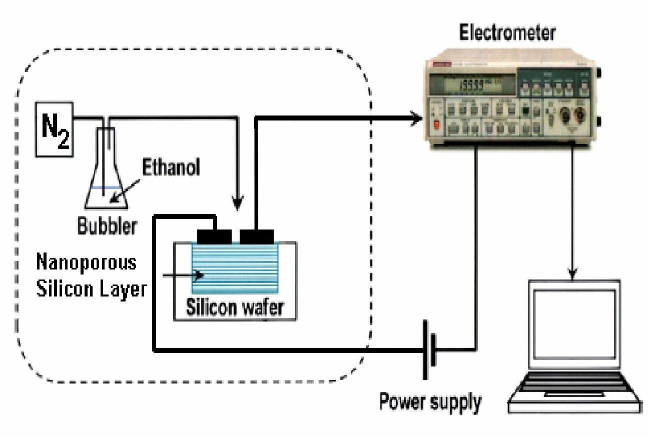
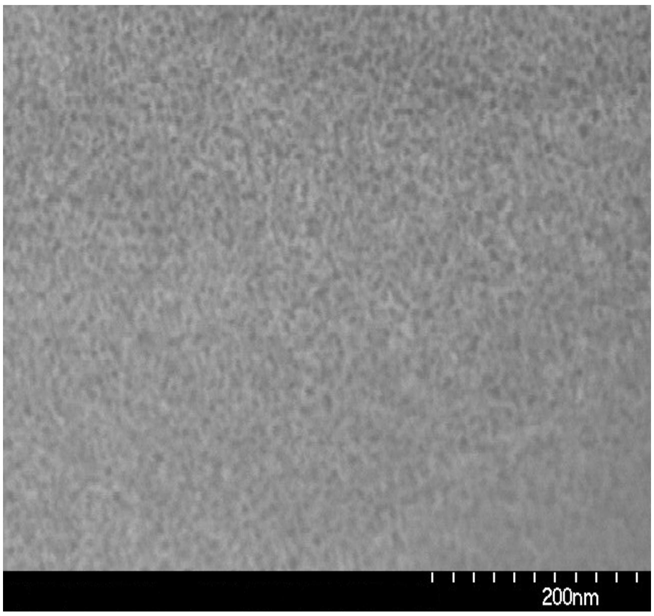


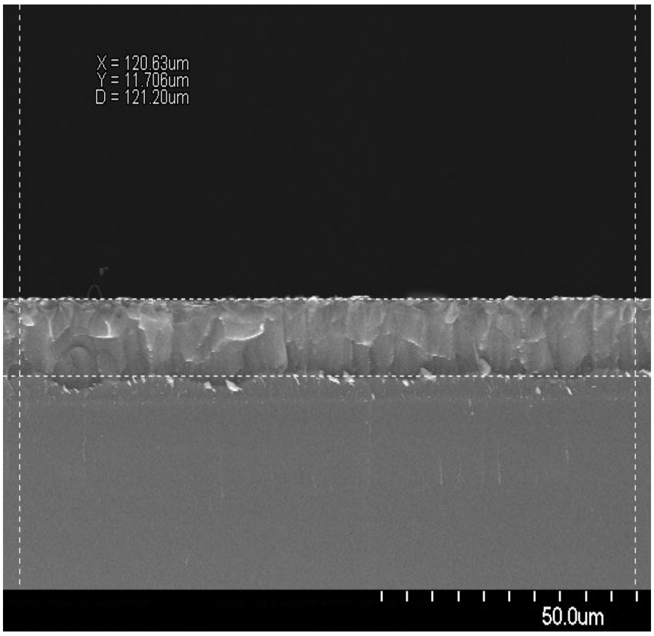
Fig. 3. Schematic diagram of the experiment setup for vapor sensing measurement.

III. RESULTS AND DISCUSSION

Figure 4 shows the surface and cross section images of nanoporous silicon. Figure 4 (a) indicates that the diameter of skeleton of nanoporous silicon structure is in the range from 20 to 50 nm. The surface image of nanoporous silicon indicates that the distribution of skeleton is even. The cross section image in Figure 4 (b) of nanoporous silicon illustrates that the nanoporous silicon exhibits a depth of 12 μm. The porosity of nanoporous silicon which has been determined by the gravimetric method is about 70%.



(a)



(b)

Fig. 4. (a) Surface and (b) cross section images of nanoporous silicon formed by electrochemical etching.

Figure 5 shows the direct current during exposure of alcohol vapor to nanoporous silicon by on-off alcohol vapor into the chamber.

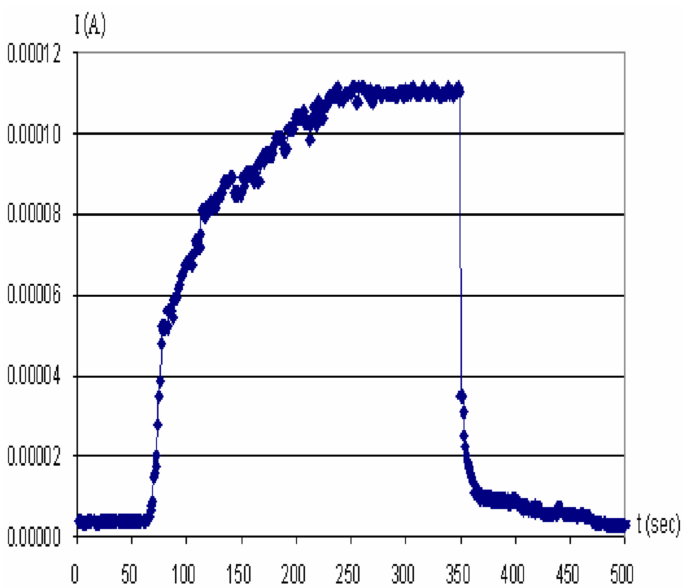


Fig. 5. Direct current during on-off exposure of alcohol vapor to nanoporous silicon.

When alcohol vapor has been introduced into test chamber, the direct current increases during exposure alcohol vapor to nanoporous silicon. And the direct current decreases to steady state rapidly when off alcohol vapor into nanoporous silicon.

In addition, the direct current of nanoporous silicon device on exposure to alcohol vapor by on-off gas under different alcohol vapor concentration also shown in the Figure 6.

ISBN: 978-988-19252-6-8
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

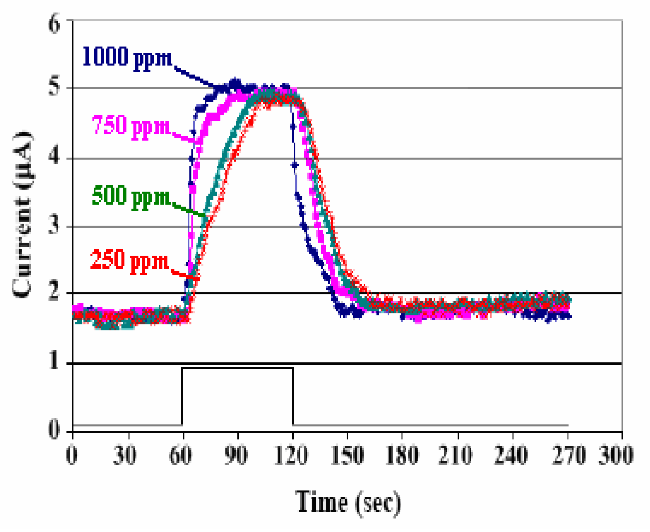


Fig. 6. Direct current during on-off exposure by different alcohol vapor concentration in the rang 1000 ppm to 250 ppm into nanoporous silicon.

It is found that the direct current can be observed from nanoporous silicon alcohol vapor sensor. Device can detect the different alcohol vapor concentrations in the rang 1000 ppm to 250 ppm. Response and recovery time are of about few minutes. For this structure of device (Al/nanoporous silicon/Al) as resistor sensor. We found that it has very high resistance. Then, for the better sensor performances might be obtainable after further optimization of desige and fabrication of our nanoporous silicon sensors, such as using finger-like structure for larger sensing area.

According to Ben Chorin [5], the sensitivity of nanoporous silicon to organic vapor is related to the change of the overall dielectric constant after absorption and is therefore proportional to the species dopole momentum.

The mechanism of the direct current response can be explained by both the electrical properties in nanoporous silicon structure and the charge tansfer reaction that occurs during the adsorption at the nanoporous silicon surface. The vapor adsorption at the nanoporous silicon leads to a change of the conductance of the nanoporous silicon because the adsorbed vapor can easily condence into a liquid in the micro-capillaries (pore) of nanoporous silicon layer [6,7].

IV. CONCLUSIONS

Nanoporous silicon can be used for gas sensing of alcohol vapor. We made the nanoporous silicon alcohol vapor sensor and investigated the change of direct current during exposure alcohol vapor into nanoporous silicon. Device can detect the different alcohol vapor concentrations in the rang 1000 ppm to 250 ppm. As the results, the relative change of direct current response and recovery time are of about few minutes. By direct current response and recovery time decreases with increasing concentrations of alcohol vapor. Moreover, the all sensing will return exactly to the initial value after removing the alcohol vapor. To increase the performance of this sensor and to diminish the response and recovery time we are planning to further optimization of desige and fabrication of our nanoporous silicon sensors, such as using finger-like structure for larger sensing area and using Pt heater for heat the device.

ACKNOWLEDGMENT

The authors would like to express their sincere thanks to Dr. S. Supadech of King Mongkut's Institute of Technology Ladkrabang for keen reading the manuscript. The authors are also thankful to Dr. S. Khunkhao of Sripatum University for encouragement throughout this work. And to Professor Dr. K. Sato of Tokai University for fruitful discussion.

REFERENCES

[1] U. Gosele and V. Lehmann, "Light-emitting porous silicon," Material Chemistry and Physics, Vol. 40, 1995, pp. 253-259.

[2] G. Garcia Salgado, T. Diaz Becerril, H. Juarez Santiesteban and E. Rosendo Andres, "Porous silicon organic vapor sensor," Opt. Mater, Vol. 29, 2006, pp. 51-55.

[3] L.T. Canham "Properties of Porous Silicon", IEE Inspec, London, UK, 1997, pp. 364.

[4] R. Herino, G. Bomchi, K. Barla and C. Bertrand, "Porosity and pore size distributions of porous silicon," J. Electrochem. Soc: Solid State and Technology, Vol. 14, 1987, pp. 1994-2000.

[5] M. Ben Chorin and A. Kux, "Gas sensing properties of porous silicon," Anal. Chem, Vol.67, 1995, pp. 3727-3732.

[6] S. Storck, H. Bretinger and W.F. Maier, "Characterization of Micro- and Mesoporous Solids by Physisorption Methods and Pore Size Analysis," Appl. Catal. A, Vol. 174, 1998, pp. 137.

[7] S.J. Kim, S.H. Lee and C.J. Lee, "organic vapour sensing by current response of porous silicon layer," J. Phys. D: Appl. Phys, Vol. 34, 2001, pp. 3505-3509.