Conference Program

The 17th International Conference On Mechatronics Technology

October 15th – 18th, 2013

Ramada Plaza Jeju Hotel, Jeju Island, Korea

Organized by

University of Ulsan, Republic of Korea

Korea Society of Fluid Power and Construction Equipment

Assefa Asmare Tsegaw, Fang-Jung Shiou, Wei-Yao Hsu, Zong-Ru Yu

FF01 **A silicone rubber bimorph actuator driven by bidirectional ECF jet generator**
Sang In Eom, Shinichi Yokota, Joon-Wan Kim, Kazuhiro Yoshida, Kazuya Edamura

FF02 **Study on Output Characteristics of downsized ECF micropump**
Hongri Gu, Joon-Wan Kim, Shinichi Yokota, Kazuya Edamura

Mechatronic Sensing and Control

October 17th[Thursday], 14:40-16:20, Room2

Session Chair: Prof. Sung Dong Kim

MSC01 **Impact Energy-based Study of Stabiltiy for Field Robot**
Chi-Thanh Nguyen, In-Ho Kim, Soon-Yong Yang

MSC02 **A study On Development of SmartPhone Monitoring system for Industrial Medium Engine**
Joo-Hyun Ko, Chan-Jeong, Yong-Seok Kim, Kwang-Sik Jeong, Hyo-Seong Lee, Ki-Moon Shin, Soon-Yong Yang

MSC03 **Reaching All Targets and Ensuring Connectivity Maintenance in Multi-Robot System**
Pham Duy Hung, Minh-Trien Pham, Tran Quang Vinh, Ngo Trung Dung

MSC04 **Linearization of Pressure Level Sensor using Contact Resistance Change**
Jung-Ho Park, Dongwon Yun, So-Nam Yun, Yun-Jin Jeong, Dong-Won Lee, Yun-Jong Han

MSC05 **An Analysis on a Direct Drive Servo valve**
Sung Dong Kim, Heewook Ahn, Sehyeong Jeon

Control Applications

October 17th[Thursday], 16:10-17:30, Room1

Session Chair: Prof. Ill-Yeong Lee

CA01 **Four-wheel-synchronization Electric Vehicle Based Sliding Mode Control**
Thanh Liem Dao, Kyoung Kwan Ahn

CA02 **Pressure Control of Roll-to-Plate Printing System**
Hyunchang Kim, Youngman Choi, Dongwoo Kang

CA03 **Improvement of Control Performance of an Overlap Type Proportional Directional Control Valve**
Ill-Yeong Lee, Dong-hoon Oh, So-Nam Yun

Fault Diagnosis

October 17th[Thursday], 16:30-17:30, Room2

Session Chair: Prof. Sung Ho Hwang

FD01 **Real-time Compensation of Abbé Errors on Machine Tools**
Kuang-Chao Fan, Kun-Yin Li

FD02 **Power losses of hydrostatic piston shoe bearings for a swash plate type axial piston pump rotating at low speed**
Yong-cheol Kwon, Yeh-sun Hong

FD03 **Detection of Semantic Faults in a motion-networked based manipulator**
Tae-IL Eom, Sang Hoon Ji

Linearization of Pressure Level Sensor using Contact Resistance Change

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***Abstract* – In this study, a novel MEMS pressure level sensor using resistance change of pressure switch array resulted from a physical contact of diaphragm with an applied pressure is presented. First, concept and working principle of the proposed pressure level sensor are introduced and basic characteristics of the fabricated prototype are experimentally investigated. Then, a new approach for linearity compensation of the proposed mechanism is analytically investigated with contact analysis results obtained by using commercial FEM tools, which is to control a pattern slope of the deposited ITO resistor. Finally, based on the obtained analysis results, the pressure level sensor is re-fabricated and basic characteristics including durability are experimentally investigated.**

Keywords – Pressure Level Sensor, Contact Resistance, Contact Analysis, Linearization

1 INTRODUCTION

Many pressure sensors such as piezoresistive and capacitive types have been reported and investigated for industrial applications [1-2]. However, most of these sensors need some improvements on low stress strength, offset drift with temperature change, complicated electric circuit to amplify a feeble signal and so on. In general, pressure level sensors used to measure a liquid level in storage tank or vessel employ piezo-resistive type pressure sensors or strain gauges. Those sensors need some amplifiers due to the very week electric signals and relatively complicated electric circuits for a noise or temperature compensation. In this study, to overcome those disadvantages, a novel pressure level sensor using contact resistance change is presented.

2 PROPOSED PRESSURE LEVEL SENSOR

2.1 Concept and Working Principle

Figure 1 shows a concept and working principle of the proposed pressure level sensor using contact resistance change [3-4]. It basically consists of a silicon substrate that has a thin-metal deposited diaphragm and a switch array micro-patterned on Pyrex glass. The switch array to measure the pressure change is formed by connecting serially a few of electrodes and resistances on a resistor made by indium tin oxide (ITO). The change of the electrical resistance between both ends of the ITO resistor is measured by using a simple electric circuit. When a pressure based on a depth of liquid is applied to the diaphragm, the diaphragm is expanded to the glass and an initial contact between the diaphragm and the micro-patterned pressure switch array is generated. Then, a change of contact resistance is occurred with an applied higher pressure and it is converted to sensor signal through an electric circuit.

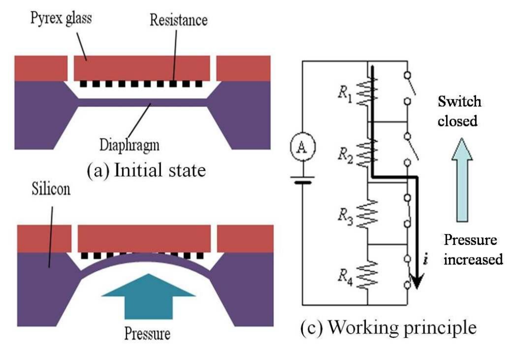


Fig. 1: Concept and working principle of the proposed pressure level sensor using contact resistance change

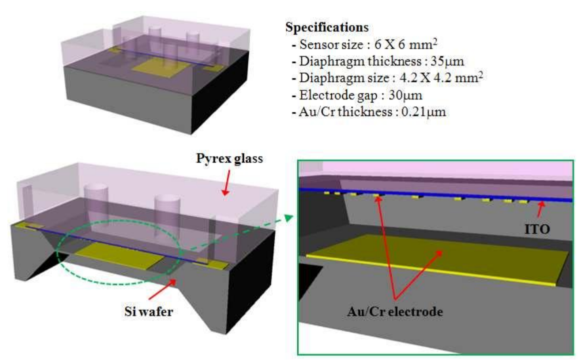


Fig. 2: Schematics of the designed pressure level sensor

2.2 Fabrication and Basic Characteristics

Figure 2 shows schematics of the designed pressure level sensor. The fabrication process starts with a silicon substrate (N-type, (100)) with a surface area of 6x6mm^2 and a thickness of 0.3mm. The silicon substrate is etched up to depth of 30μm in tetramethyl ammonium hydroxide (TMAH) 15% solution. The thin Au/Cr is then deposited by RF sputtering and lift-off is performed. Then, the silicon backside etching is also performed. On the other hands, ITO patterning on Pyrex glass is performed and metal lift-off is also performed. Here, a distance between Au/Cr electrodes could be adjusted for linearity compensation of sensor output. Finally, the glass is anodically bonded to the silicon substrate after the sanding process. Figure 3 shows photographs of the fabricated prototype sensor. Basic characteristic between applied pressure and resistance change is experimentally investigated and obtained result is shown in Fig. 4. However, the result shows some problems such as an insufficient linearity and low pressure characteristic.

Fig. 3: Photographs of the fabricated prototype sensor

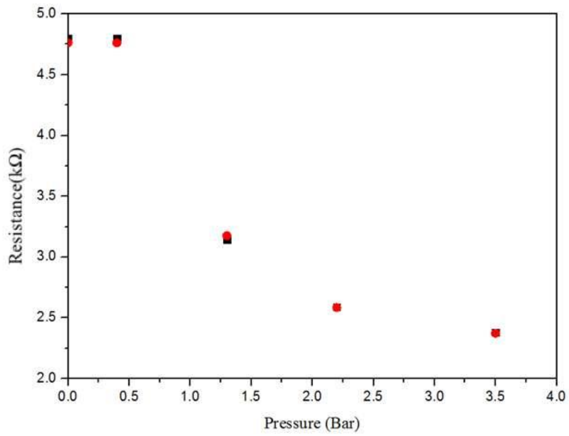


Fig. 4: Experimental result of the fabricated prototype sensor

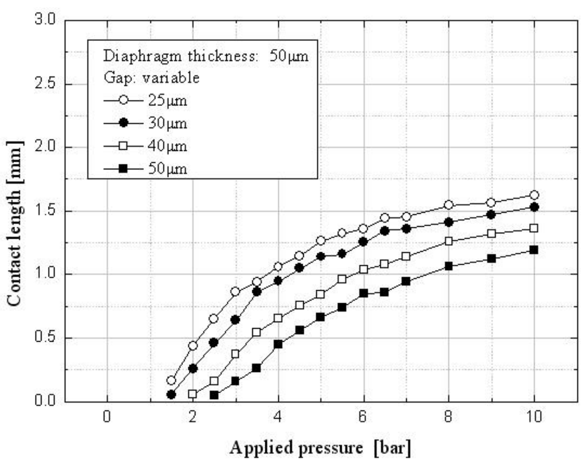
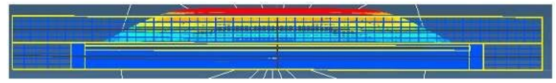


Fig. 5: Analysis results of contact length with different gap

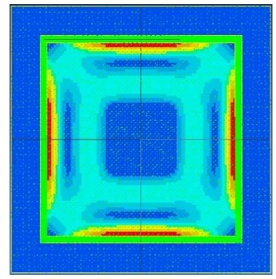
3 LINEARIZATION

3.1 Contact Analysis

Based on shape parameters of sensor chip and maximum stress with a pressure of 10bar, a thickness of silicon diaphragm is changed to be 50μm. First of all, contact analysis is performed with different gap distance between diaphragm and bottom surface of Pyrex glass. Figure 5 shows obtained results of contact length with applied pressure. Nonlinearity could be confirmed due to the contact mechanism. Considering an easiness of fabrication process, the gap distance of 30μm is selected in this study. Figure 6 shows analysis results of displacement and stress with a pressure of 10bar. It is ascertained that the contact length is 1.53mm and maximum stress is 526MPa with a diaphragm thickness of 50μm and a gap of 30μm.



(a) Displacement characteristic



(b) Stress characteristic

Fig. 6: Displacement and stress characteristics obtained by contact analysis with applied pressure of 10bar

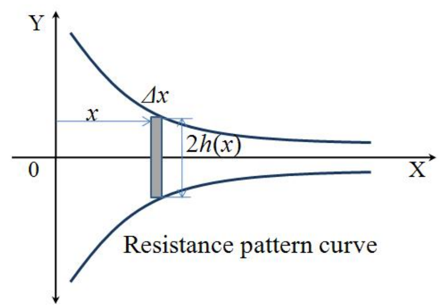


Fig. 7: Model of resistance pattern for linearization

3.2 Design of Linearization

To compensate a nonlinearity of contact length with an applied pressure, it is needed that a pattern slope of the deposited ITO resistor should be properly controlled as shown in Fig. 7. Differential resistance ΔR at an arbitrary distance of x from the center of diaphragm is derived as follows:

$$\Delta R = \rho \frac{\Delta x}{2t' \times h(x)} \tag{1}$$

where t' and ρ are thickness of resistor and specific resistance, respectively. If resistance change along with applied pressure is constant for linearization which is written as follows.

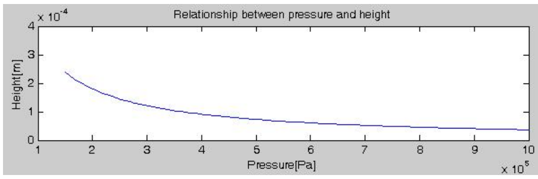
$$\frac{dR}{dP} = c \tag{2}$$

Considering $x = f(P)$ and chain rule, equations (3) and (4) are derived as follows.

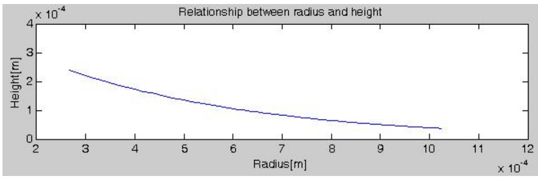
$$\frac{dR}{dP} = \frac{dR}{dx}\frac{dx}{dP} \tag{3}$$

$$\frac{\rho}{2t' \times h(x)}\frac{dx}{dP} = c \tag{4}$$

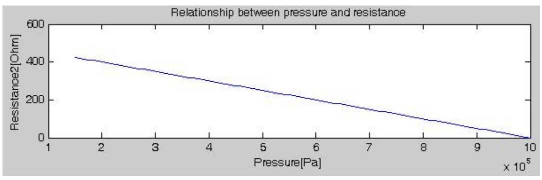
It we derive dx/dP through curve fitting from the result of Fig. 5, a resistance pattern slope $h(x)$ for compensation of linearity could be obtained.



(a) Relation between pattern shape and pressure



(b) Relation between pattern shape and x-axis coordinate



(c) Relation between resistance and pressure

Fig. 8: Analysis results for linearization

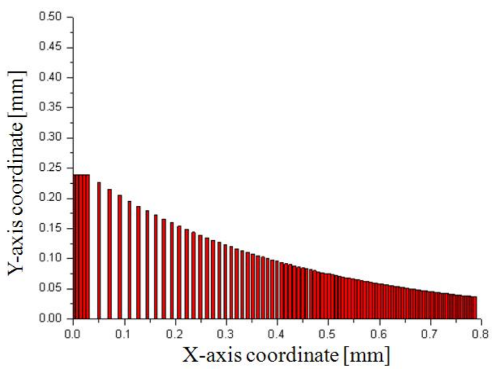
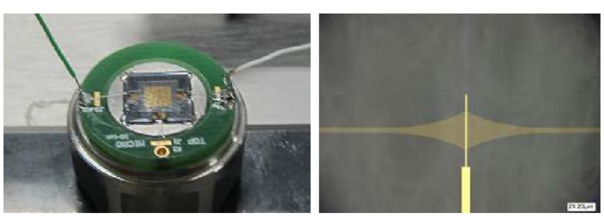


Fig. 9: Resistance pattern for fabrication process



(a) Re-fabricated sensor (b) ITO pattern

Fig. 10: Re-fabricated pressure level sensor

Figure 8 shows a sample of analysis results. Here, t' = 100nm, ρ = 9.2x10^{-4} Ω·cm and c = 5,000. The upper figure presents a pattern shape with applied pressure. Next figure is a pattern shape with x-axis coordinate transformed from the applied pressure. Bottom figure indicates resistance change with applied pressure. Figure 9 shows a resistance pattern from the center of diaphragm for fabrication process, which is equivalent to first quadrant of ITO pattern on Pyrex glass.

3.3 Re-fabrication and Experiments

Figure 10 shows photographs of re-fabricated pressure level sensor and ITO pattern. By using the re-fabricated sensor, basic characteristics are experimentally investigated. Obtained results are shown in Fig. 11. It could be confirmed that dead zone of pressure is exit due to the mechanism and better linearization is achieved up to the pressure of 10bar than the previous prototype. Figure 12 shows a schematic of experimental apparatus for durability. Air compressor and pressure booster is used for durability test up to pressure of 10bar. Photographs of the constructed experimental apparatus are shown in Fig. 13. Durability test is performed with applied pressures of 5bar and 10bar, respectively. The results are shown in Fig. 14. From the above experiments, the validity of the proposed pressure level sensor should be verified although the sensitivity needs some improvements.

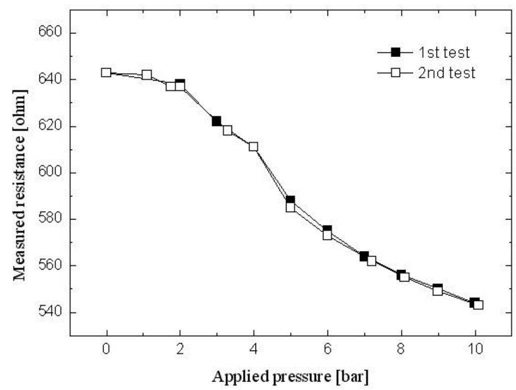


Fig. 11: Experimental results of re-fabricated sensor

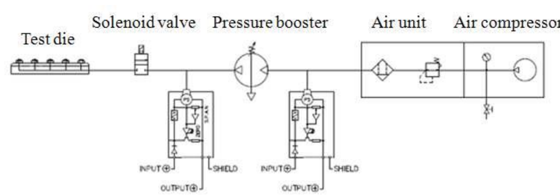


Fig. 12: Schematic of experimental apparatus for durability

Fig. 13: Photographs of constructed experimental apparatus

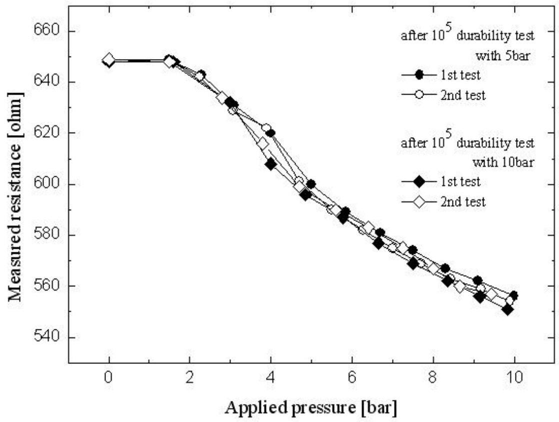


Fig. 14: Experimental results of durability test

4 CONCLUSIONS

In this study, a novel MEMS pressure level sensor using resistance change resulted from a physical contact of diaphragm with an applied pressure was presented. For improvement of nonlinearity of the fabricated prototype, analytical study to control a pattern slope of the deposited ITO resistor on Pyrex glass was performed. Re-fabrication was also done and the basic characteristics including durability were experimentally investigated. From the results, we could confirm that the validity of the proposed pressure level sensor is effective although the sensitivity needs some improvements.

ACKNOWLEDGEMENT

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REFERENCES

[1] W.P. Eaton and J.H. Smith, “Micromachined pressure sensors: review and recent developments", *Smart Mater. Struct.*, Vol. 6, pp.530-539, 1997.

[2] A. Huang, J. Lew, Y. Xu, Y-C. Tai, and C-M. Ho, "Microsensors and Actuators for Macrofluidic Control," *IEEE Sensors Journal*, Vol. 4, pp. 494-502, 2004.

[3] J.-H. Park, and et al, “A study on Micro Pressure Sensor Using Pressure Switch Array”, [C]//*Proc. of the KSME Spring Conference*, pp. 3203-3207, 2006. (in Korean)

[4] J.-H. Park, and et al, “A study on Design of Pressure Level Sensor Using Contact Resistance Change of Diaphragm”, [C]//*Proc. of the KSME Spring Conference (PD Division)*, pp. 165-166, 2012. (in Korean)