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Fabrication Effects on Polysilicon-based Microcantilever Piezoresistivity for Biological Sensing Application

(Kesan Proses Fabrikasi Terhadap Piezorintangan Mikrokantilever Berasaskan Bahan Polisilikon untuk Aplikasi Penderiaan Biologi)

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ABSTRACT

In principle, adsorption of biological molecules on a functionalized surface of a microfabricated cantilever will cause a surface stress and consequently the cantilever bending. In this work, four different type of polysilicon-based piezoresistive microcantilever sensors were designed to increase the sensitivity of the microcantilevers sensor because the forces involved is very small. The design and optimization was performed by using finite element analysis to maximize the relative resistance changes of the piezoresistors as a function of the cantilever vertical displacements. The resistivity of the piezoresistivity microcantilevers was analyzed before and after dicing process. The maximum resistance changes were systematically investigated by varying the piezoresistor length. The results show that although the thickness of piezoresistor was the same at 0.5 µm the resistance value was varied.

Keywords: Biological sensing; piezoresistive; microcantilever; resistivity

ABSTRAK

Pada prinsipnya, jerapan molekul biologi pada permukaan yang difungsikan oleh kantilever yang telah difabrikasi akan menyebabkan tegangan permukaan dan akibatnya lenturan pada kantilever. Dalam kajian ini, empat jenis sensor piezorintangan mikrokantilever berasakan bahan polisilikon direka untuk meningkatkan sensitiviti sensor mikrokantilever memandangkan tekanan yang terlibat adalah sangat kecil. Reka bentuk dan pengoptimuman dilakukan dengan menggunakan analisis elemen hingga memaksimumkan perubahan pertahanan relatif daripada piezorintangan sebagai fungsi perpindahan menegak kantilever. Ukuran rintangan dari piezorintangan mikrokantilever dianalisis sebelum dan selepas proses 'dicing'. Perubahan maksimum nilai rintangan diselidiki secara sistematik dengan mengubah ukuran panjang piezorintangan. Keputusan kajian menunjukkan bahawa walaupun ketebalan piezorintangan adalah sama iaitu sebanyak 0.5 µm tetapi nilai rintangan adalah berbeza.

Kata kunci: Mikrokantilever; penderiaan biologi; piezorintangan; rintangan

INTRODUCTION

A microcantilever is a device that can act as a physical, chemical or biological sensor by detecting changes in cantilever bending or vibrational frequency (Porter & Eastman 2001; Sepaniak et al. 2004; Tabard-Cossa et al. 2005). It is the miniaturized counterpart of a diving board that moves up and down at a regular interval. This movement changes when a specific mass of analyte is specifically adsorbed on its surface similar to the change when a person steps onto the diving board.

Microcantilevers have wide applications in the field of medicine, especially for the screening of diseases, detection of point mutations, blood glucose monitoring and detection of chemical and biological warfare agents (Mohd Zahid 2008; Nina et al. 2008; Sepaniak et al. 2004). The commercial cantilevers are typically made of silicon, silicon nitride, or silicon oxide and are available in a wide variety of different shapes, dimensions and force sensitivities. Recent developments combine the latest integrated circuit (IC) and complementary metal oxide semiconductor (CMOS) technologies has produced intelligent and extremely small cantilevers in the form of an array. These sensors have several advantages over the conventional analytical techniques in terms of high sensitivity, low cost, simple procedure, low analyte requirement (in µl), non-hazardous procedures and quick response (Porter & Eastman 2001; Sepaniak et al. 2004). Microcantilevers have been proven to be an outstanding sensor platform for extremely sensitive chemical and biological sensors and piezoresistive based microcantilever transducers are also becoming popular in recent years (Sepaniak et al. 2004; Vashist 2007; Venkata Chivukula 2006).

The fabrication techniques used in MEMS consist of the conventional techniques developed for integrated circuit processing and a variety of techniques developed specifically for MEMS. The three essential elements in conventional silicon processing are deposition, lithography and etching.

Etching of boronphosposilicateglass (BPSG) material as a sacrificial layer is important in order to release the mechanical parts of sensors and actuators. In this approach, BPSG is chosen due to its availability in MEMS process, its compatibility to elevated temperature during polycrystalline silicon (poly-Si) deposition and annealing, and because it can be etched selectivity with respect to silicon and some metal of interest. In this work, four different type of piezoresistive microcantilever was designed with different BPSG layer thickness, microcantilever beam thickness and polysilicon-based piezoresistor length. Resistivity testing was performed before and after wafer dicing and also before and after Boronphosposilicateglass (BPSG) sacrificial layer etching. This is important to enhance the sensitivity and for the optimization of the piezoresistive microcantilever design. From the four designs, we can identify the suitable piezoresistive microcantilever design for the biological sensing application.

METHODS

Figure 1 shows the four piezoresistive microcantilever design named as PZR10, PZR20, PZR30 and PZR40, respectively. The differences between these designs are the BPSG layer and poly 1(microcantilever beam) thickness. The piezoresistor (poly 2) remain the same at 0.5 µm. The variations are as shown in Table 1. Nevertheless, they can be differentiated by the length of piezoresistor (PZR). Figure 2 shows the piezoresistive microcantilever design. It consists of aluminum contact, PZR microcantilever, microcantilever beam and BPSG sacrificial layer. The cross-section of the PZR microcantilever observed by FESEM is as in Figure 3. Aluminum contact was used to connect the PZR with the measurement source unit (MSU), which supplies the voltage and current to the aluminum contact before measure the resistance. The resistance value depends on the length of PZR microcantilever. The size of microcantilever beam is the same for all design of PZR. BPSG sacrificial layer was then etched to release the microcantilever beam.

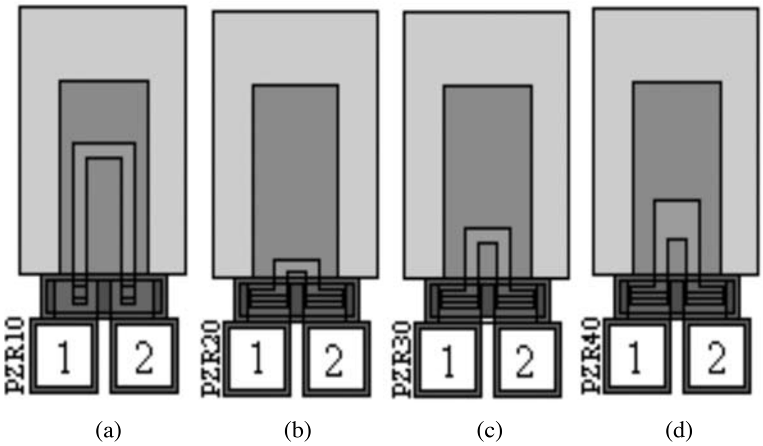


FIGURE 1. Piezoresistive microcantilever; (a) PZR10 (b) PZR20 (c) PZR 30 (d) PZR40 microcantilever design

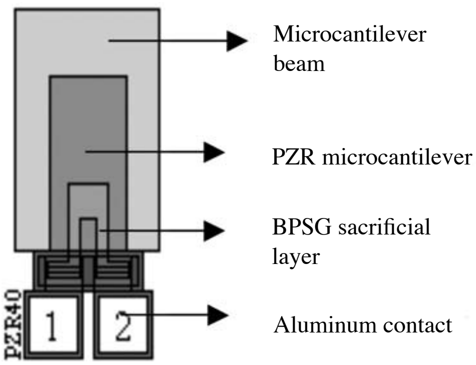


FIGURE 2. Description of PZR

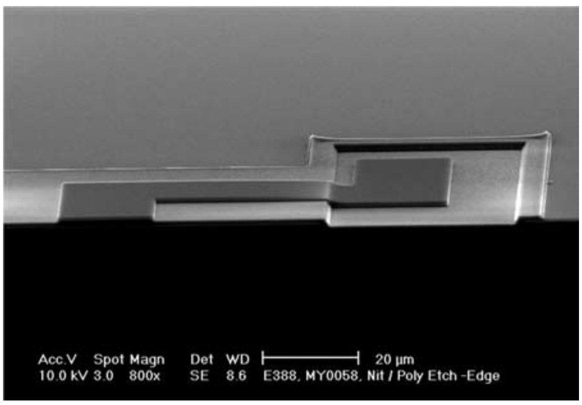


FIGURE 3. Cross section on PZR microcantilever

TABLE 1. BPSG, poly 1 and poly 2 thicknesses and length of poly 2

Length (µm)	Thickness (µm)		
Poly 2	BPSG	Poly 1	Poly 2
	1.8	0.5	0.5
160 (PZR10)	1.8	1	0.5
	0.9	0.5	0.5
	0.9	1	0.5
	1.8	0.5	0.5
40 (PZR20)	1.8	1	0.5
	0.9	0.5	0.5
	0.9	1	0.5
	1.8	0.5	0.5
80 (PZR30)	1.8	1	0.5
	0.9	0.5	0.5
	0.9	1	0.5
	1.8	0.5	0.5
120 (PZR40)	1.8	1	0.5
	0.9	0.5	0.5
	0.9	1	0.5

OHMIC (RESISTIVITY) TESTING

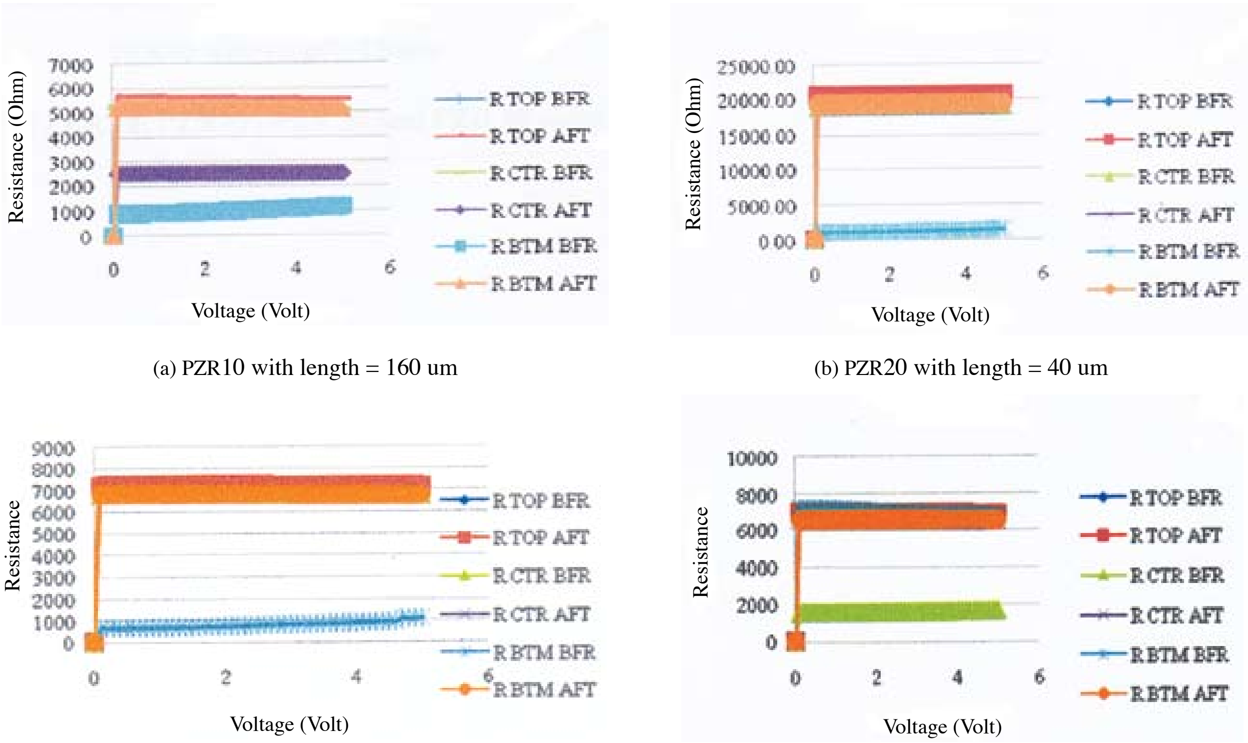
Ohmic test was used to measure the resistance value and to compare the resistance value by different length of piezoresistive microcantilever and the different thickness of BPSG sacrificial layer. The measurement was recorded before and after dicing and the etching process. The procedure of the ohmic testing measurement was started by holding the wafer by tweezers, then the wafer was put on the probe station and vacuumed. Two magnetically-attached probes were used with current/voltage supplied from the measurement source unit (MSU). The image was focused until the display in the video was clear and then the contact pad was scratched until the voltage was supplied. The result was displayed on ICS computer screen. Equipment used to conduct ohmic test are Probe Station, Computer (ICS – Interactive Characterization Software), Semiconductor Parameter Analyzer and Measure Source Unit (MSU).

The MC System Probe Station was used for electrical and mechanical manipulation of MEMS. A maximum of 6 magnetically-attached probes were available for use with current/voltage supplied from Measure Source Unit (MSU) and multimeters. A color CCD camera and laser vibrometer were connected for video output and displacement and velocity measurements. ICS is a uniquely powerful instrumentation control and data analysis software package. Instruments supported by ICS drivers include Semiconductor Parameter Analyzers, DC Source Monitor Units, Curve Tracers, LCR Meters, Impedance Analyzers and Switch Matrices.

RESULTS AND DISCUSSION

For resistance measurement, there are four different length of poly 2 needed to investigate the resistance value for each of them. Figure 1 shows a different layout between PZR by their length of poly 2. The resistance values obtained depends on the length of poly 2.

From Figure 4 it can be observed that there are differences for the resistance values before and after dicing. This is because before dicing, the resistance was measured



(a) PZR10 with length = 160 um

(b) PZR20 with length = 40 um

(c) PZR30 with length = 80 um

(d) PZR40 with length = 120 um

FIGURE 4. RV graph of (a) PZR10, (b) PZR20, (c) PZR30 and (d) PZR40 before and after dicing

on the whole wafer within a big area. The fabrication of the wafer also effected the resistance values. After dicing with each sample in the size of 1 cm × 1 cm, the resistance was measured in a small area. It can be conclude that the small area gave better resistance value.

For the piezoresistive microcantilever with the same PZR length but the BPSG layer thickness increases, the resistance value was not affected. However for piezoresistive microcantilever with the same BPSG layer thickness, and the PZR length increases it can be observed that the resistance value also increased.

CONCLUSION

BPSG which is a material under silicon dioxide category has become a common material used as a sacrificial layer in surface micromachining in order to release sensor structures. For piezoresistive microcantilever resistance measurement before and after dicing process, various parameters such as BPSG layer thickness and PZR length that could affects the resistance changes of the piezoresistive cantilevers were thoroughly investigated. From the investigation, the length of piezoresistor (PZR) affected the resistance value. As the length of PZR increases, the resistance value also increases. The dicing process also shows that even with the same BPSG layer thickness but the PZR length increases the resistance value also increase. Even though the PZR length was similar, with the BPSG layer thickness increases, there was no changes in the resistance value. From this study, the best sensor performance is expected to be achieved when the silicon piezoresistor is thin, narrow and the length of polysilicon beam design should be in a variable size.

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REFERENCES

Mohd Zahid Ansari, C.C. 2008. Design and Analysis of a high sensitive Microcantilever Biosensor for Biomedical Applications. *Proceedings of International Conference on BioMedical Engineering and Informatics (BMEI'08)* 593-597.

Nina Korlina Madzhi, Anuar Ahmad & Lee Yoot Khuan. 2008. Design and Fabrication of Polysilicon-based Piezoresistive Microcantilever for Biological Sensing. *International Conference on Nanoscience and Nanotechnology* 1136: 801-806.

Porter, T.L. & Eastman, M.P. 2001. Sensor based on piezoresistive microcantilever technology. *Sensors and Actuators A: Physical* 88(1): 47-51.

Sepaniak, M., P.D. & Nickolay Lavrik. 2004. Cantilever transducers as a platform for chemical and biological sensors, *Review of Scientific Instruments* 75(7): 2229-2253.

Tabard-Cossa, M.G. & L.Y. Beaulieu1, P. 2005. A differential microcantilever-based system for measuring surface stress changes induced by electrochemical reactions. *Sensors and Actuators B* 107: 233-241.

Vashist, S.K. 2007. A Review of Microcantilevers for Sensing Applications. *Online Journal of Nanotechnology*, 3(June) DOI: 10.2240/azojono0115

Venkata Chivukula 2006. Simulation of SiO_2-based piezoresistive microcantilevers. *Sensors and Actuators B* 125(2): 526-533.

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