Design and Fabrication of the sensor for measuring the human bladder volume

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ABSTRACT

This paper presents the result of design and fabrication of the bladder volume sensor. Previous studies have focused on the measurement of inner bladder pressure. However there were some difficulties about the measurement of inner bladder pressure. In order to find a solution to some difficulties, we measure the bladder volume instead of the inner bladder pressure. A bladder volume sensor we designed detects a change of bladder volume simply. A bladder volume sensor consists of two micro electrodes, which were fabricated by MEMS technology. The micro electrodes were designed to have honeycomb patterns because hexagonal structures could maximize surface areas of electrodes and minimize the total size of sensor. Dimension of the electrode is 2928 ㎛(L) × 2720 ㎛(W) × 500 ㎛(H). A bladder volume sensor is a capacitive sensor and the sensitivity of it is 0.41 *pF/mm.*

Keywords: volume sensor, capacitive sensor, rat bladder, MEMS electrode

1 INTRODUCTION

A spinal cord injury is usually caused by traumatic causes like a traffic accident. Many hemiplegic or disabled patients are suffering from UTI(urinary tract infection) and other bladder diseases, which might cause death by complication and infection therewith. However, almost all of these bladder diseases can be prevented or predicted by observing the abnormal syndromes of the bladder urine volume or pressure variations. For instance, patients whose leak point pressure is greater than 40cmH_2O might have upper urinary tract deterioration because of voiding control by prevention of prevention of normal neural pathway [1], [2]. Therefore, periodic evaluation of these patients to discover their urodynamic situations and help these uro-ataxic to urinate normally have been recognized as one of the most important research topics in clinical medical investigations[3].

Sensing pressure in bladders is an important topic among many urology researches. Lots of ways to measure the urine pressure in a bladder have been reported [4]. In vitro, we place a bladder or its model in a controllable experimental site, and observe the response of every charging influence [5]. However, the result of such an experiment on a dead organ or a model is hardly to prove being the same as that in vivo. By contrast, we can insert a pressure sensor, in vivo, by catheterization through urethra or other incision [6] and get the readings of the pressure inside the bladder under different conditions. Previous studies have focused on sensing pressure in bladder. However there were some difficulties about the measurement of inner bladder pressure. When measuring the inner bladder pressure, we consider an abdominal pressure and thus patients suffer from invasive measuring method. The inserting of sensor in the bladder has been another difficulty. In case of it, the sensor should be inserted in the inner side of the bladder. It is hard medical treatment. In addition, it can cause the secondary ill like a bladder stone, bladder cancer.

In order to find a solution to some difficulties, we measure the bladder volume instead of the inner bladder pressure. A bladder volume sensor we designed detects a change of bladder volume simply. And the measurement of volume changes is able to know patient's condition through correlation between bladder volume and urine volume. A bladder volume sensor consists of two micro electrodes, which were fabricated by micro machining technology. Two micro electrodes which are located in the outer wall of the bladder can detect change of the between the electrodes. Change of electrode gap cause changes of capacitance (range: 2.88 *pF*~5.27*pF*). Then we can monitor the patient's condition. The result of the study was based on experiments of the bladder of rats. Because of there are many restriction in experiments of the bladder of humans.

2 EXPERIMENT AND FABRICATION

The result of the study was based on experiments of the bladder of rats instead of that of humans. The rats used in experiments of the bladder volume have 3cc. This volume corresponds to 1/170 of the people's bladder volume. Figure 1 is the photograph of experimental setup of bladder condition measurement. Referring to Figure 1, syringe pump supplies saline to rat with flow rate 0.04*ml/min.* And three way type pressure sensor detects a pressure of rat bladder, then this data is transmitted to PC. We obtain the information of the pressure of rat bladder by the Chart5 program (AD instruments co. USA). Next, we measure the size of rat bladder repetitive. A measurement of urine volume was based on the data of the Chart5 program and an input of saline. Finally, we measure a capacitance of rat's bladder by a LCR meter (Agilent co. USA)

2.1 Measurements of Bladder's Condition

Figure 2 shows a bladder pressure vs. time diagram of normal rat's bladder. A pressure of bladder changes with a average 5~7 minute period. A section ⓐ in figure 2 is a normal increasing of pressure section. In a section ⓑ, although a input of saline(urine volume) increase, but a volume of bladder(size) is a constant level. So, a pressure of bladder increases rapidly. And in a pressure peak point, a detrusor contraction occurs, a urination starts. Lastly, in a section ⓒ, a pressure of bladder decreases rapidly. According to a prior report [7], a bladder pressure vs. time diagram of normal rat's bladder is similar to figure 2.

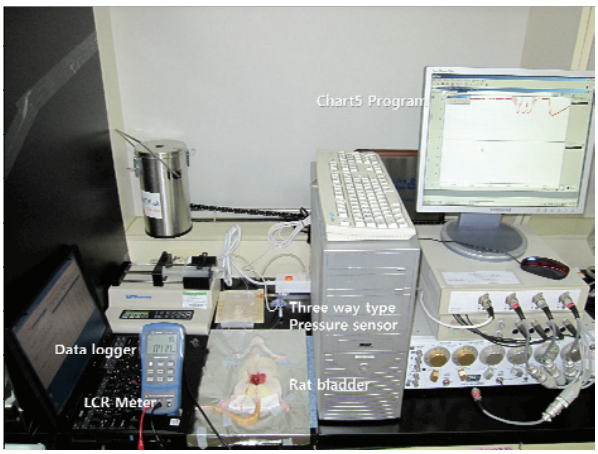

Figure 1: Photograph of experimental setup of bladder pressure measurement.

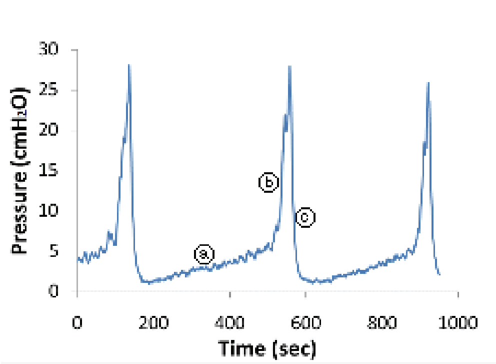

Figure 2: Bladder pressure vs. Time diagram.

Also, Figure 3 shows a volume (size) of bladder vs. urine volume (a input saline) diagram. Section headings should be 12-point boldface capital letters, centered in the column. Sub-section headings require initial capitals using boldface and left justification. Headings should appear on separate lines, using the Arabic numbering scheme. The abstract and reference section headings are not numbered.

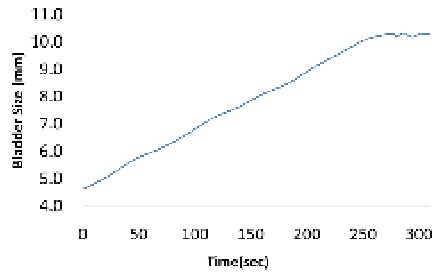

Figure 3: Bladder size vs. Time diagram.

2.2 Design and Fabrication of Electrodes

A bladder volume sensor we designed detects a change of bladder volume simply. A bladder volume sensor consists of two micro electrodes, which were fabricated by MEMS technology. Electrodes of bladder volume sensor were made by the Table 1 process. Its substrate was made of gold deposited Pyrex glass that is relatively less harmful to the human body. Honeycomb-shaped cavity of approximately 100um depth was formed on the electrode by HF etching for maximize the surface area.

Step	Process	Description
1	Pyrex glass Cleaning	Acetone
2	Poly-silicon deposition	3000 Å both side
3	PR patterning	electrode pattern
4	Partial P-Si etching	etch target area
5	HF etching	100~110um depth
6	Remained PR removal	Acetone
7	Remained P-Si etching	both side RIE
8	Cr/Au deposition	500/1000 Å
9	Dicing	

Table 1: MEMS electrode process flow chart

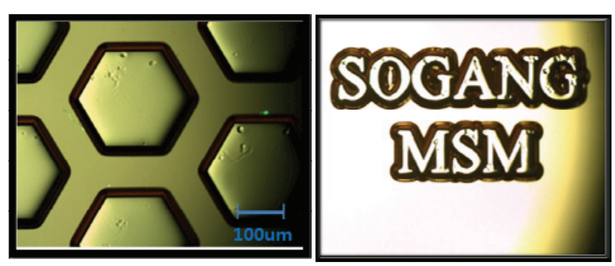

Figure 4: Honeycomb type electrode.

2.3 Analysis

Prior to testing in vivo, we predicted the behavior of designed sensor through the FEM analysis. We used the COMSOL (Ver. 3.4) program and selected 3D Electrostatics module. Figure 5 shows the distribution of electric field using two honeycomb-shaped electrodes and bladder model of experimental rat. The applied voltage of analysis is 1V and the bladder of rat was assumed to ellipsoid filled with saline solution. A change of capacitance about the size of the bladder can be found at the figure 6. About the same distance in the figure 6, the capacitance(C) of honeycomb-shaped electrode can identify average 12% larger than that of flat electrode. As a result, the honeycomb-shaped electrode shows that it can be made smaller sensor than the flat electrode make it.

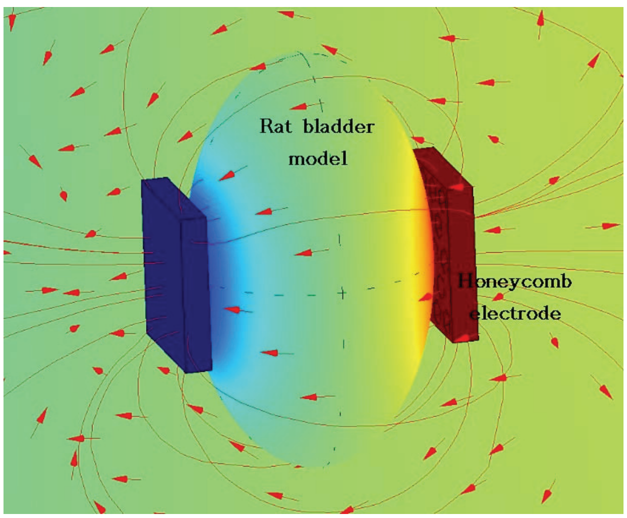

Figure 5: FEM Analysis of rat bladder model.

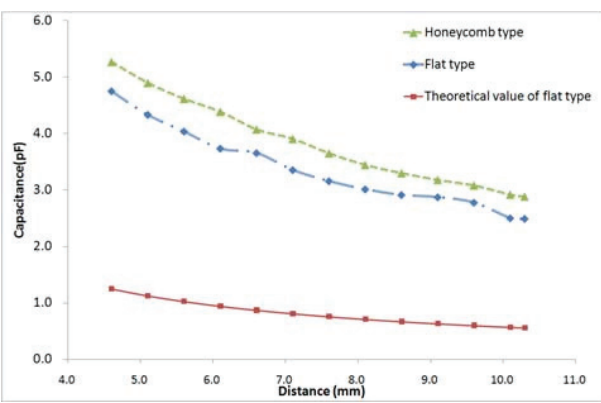

Figure 6: Capacitance of different electrode shape.

3 RESULTS AND DISCUSSIONS

Figure 7 show the correlation between bladder pressure and bladder volume obtained through base experiments. Preceding linear change of figure 2 ⓐ section can be seen also in the table 2. Through this relationship, measurement range of bladder volume sensor was set at 4.6mm to 10.3mm.

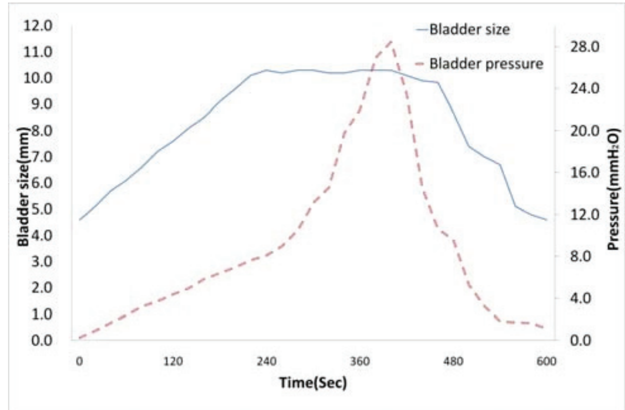

Figure 7: Correlation between bladder size and pressure.

Urine volume (㎖)	Bladder size(㎜)	Pressure (㎝ H_2O)	Honeycomb Capacitance(㎊)
0.001	4.6	0.26	5.27
0.023	5.1	0.93	4.90
0.046	5.6	1.52	4.61
0.069	6.1	2.37	4.38
0.092	6.6	3.2	4.07
0.115	7.1	3.5	3.90
0.138	7.6	4.38	3.65
0.161	8.1	4.95	3.44
0.184	8.6	5.21	3.29
0.207	9.1	6.39	3.17
0.23	9.6	6.96	3.08
0.253	10.1	7.63	2.91
0.281	10.3	8.09	2.88

Table 2: Correlation between bladder condition and capacitance.

4 CONCLUSION

This paper presents the result of design and fabrication of the sensor for measuring human bladder volume. A bladder volume sensor consists of two micro electrodes. The materials of the electrodes are biocompatible for human body. The micro electrodes were designed to have honeycomb patterns because hexagonal structures could maximize surface areas of electrodes and minimize the total size of sensor. Dimension of the electrode is 2928 ㎛(L) × 2720 ㎛(W) × 500 ㎛(H). A bladder volume sensor is a capacitive sensor and the sensitivity of it is 0.41 *pF/mm.* The sensitivity of the sensor is bigger than that of flat type electrode. The result of the study was based on experiments for the bladder of rats. Further study will be executed for a bladder of human body in order to aid the treatment for the dysuria patients.

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