Fabrication and Packaging of an Integrated Pressure and Temperature Sensor with High Immunity Against External Disturbance Under Flexible Endoscopic Operation

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Abstract

In this study, an integrated pressure and temperature sensor with high immunity against external disturbance under flexible endoscopic operation has been fabricated and packaged. Microsensor with absolute pressure sensor and temperature sensor is embedded inside of the thin wall of a disposable endoscope hood. Using the device, intraluminal pressure and temperature of stomach can be measured and it is helpful to keep the inside condition of stomach. The application effect of the sensor has been successfully demonstrated under animal experimentation.

1. Introduction

Recently, minimally invasive tumor surgery with video image endoscope (i.e. flexible endoscope) has been developed and important. Also, tumor size determination is subject, and the size is especially dependent on the intraluminal air pressure [1]. However, objective assessment of the dependency has not been achieved yet [2], since there had been no method to monitor the intraluminal pressure in real time in the area of flexible endoscopic surgery. Also, excessive air is insufflated into the patient’s digestive tract by mistake, which may cause abdomen distension, and abdominal distress [3]. In order to solve the problem, we have developed an integrated pressure and temperature sensor with high immunity against external disturbance in vivo.

2. Fabrication and packaging of sensor

Figure 1 shows a schematic of the packaged integrated pressure and temperature sensor with high immunity against external disturbance on the endoscopic hood. The sensor is embedded inside of the side-wall of the plastic hood. The hood is attached at the tip of a flexible endoscope as shown in Fig. 2. Since the thickness of sensor is thinner than the hood wall, the field of camera-vision is not disturbed at all. The device consists of silicon diaphragm with 5µm thickness, a reference pressure chamber formed by SU-8, and piezoresistive detection circuit integrated on the diaphragm to detect pressure and temperature. The device is specially designed for the purpose of embedment in the endoscopic hood. For example, Cr metal is coated on the backside of the device to protect the signal from strong LED light of endoscope. Also, the device except for the movable diaphragm is completely embedded in acid-resistive polymers.

Fig. 1 Schematic of the packaged pressure and temperature sensor on the endoscopic hood.

Fig. 2 Cross-sectional view of the endoscopic hood with embedded MEMS pressure and temperature sensor.

The Pressure and temperature sensor was fabricated with our integration process with silicon MEMS technology. Figure 3 shows the fabrication process flow of the pressure/temperature integrated MEMS sensor. The starting material of the sensor device is an SOI wafer with 5µm-thick device layer. First, piezoresistors and wiring of the circuit are fabricated by ion implantation and Cr sputtering process on the active layer (Figure 3 (a)). Next, circular silicon diaphragm is fabricated by deep RIE process of the handle layer. After formation of the diaphragm, 0.5µm-thick chromium layer is sputtered (Figure 3 (b)). Then, reference air pressure chamber area is formed by patterning the SU-8 layer (Figure 3 (c)).
3. Device evaluation

Fabricated sensor was measured for performance evaluation. The measured pressure resolution is 0.8 mmHg. This performance is enough for the application of intraluminal pressure control. Robustness for the illuminated light was also evaluated. Forming the light shielding layer by Cr thin film, signal disturbance of 635nm wavelength light in the light source is removed by 98.8% from the original device without the light shielding film as shown fig. 4. On the other hand, 532nm wavelength light is removed by 99.9%. The remained influence corresponds to 1 mmHg pressure error for LED light of endoscope, and this value is almost negligible for the application. Also, 24hours durability tests in HCl solution of pH 1 and large deformation tests were performed to the fabricated hoods. After the performance and durability tests, the sensor-embedded endoscopic hood was applied to measure pressures and temperatures in some intraluminal points (stomach, esophagus, and rectum) and abdominal cavity of a beagle dog. Figure 5 shows overview of the mimic surgery at the medical department. Figure 6 shows obtained pressure and temperature signal from the sensor at the abdominal cavity. Real-time change of intraluminal pressure and temperature has been obtained using the sensor integrated endoscopic hood.

Fig. 5 Overview of the mimic surgery at the medical department using a dog.

Fig. 6 Obtained pressure and temperature signal from abdominal cavity.

4. Conclusions

In this study, the integrated pressure and temperature sensor with high immunity against external disturbance under flexible endoscopic operation has been fabricated and packaged. The packaged sensor was tested in an animal experimentation. The performance and robustness of the packaged sensor has been successfully demonstrated in this study.

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References

