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# The Fully Wireless Pressure Sensor Based on Endoscopic Image

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**Abstract**

**In this study, development result of fully wireless pressure sensor based on endoscopic image for an endoscopic surgery is reported for the first time. Sensor device has structural color by nm scale narrow gap, and the gap is changed by air pressure. Structural color of the sensor is acquired by camera image. Pressure detection can be realized with the existing endoscope configuration only. Inside air pressure of the human body is required to be measured under the NOTES operation using the sensor. Especially, monitoring of the air pressure have two important purposes. The first importance is quantitative measurement of tumor sizes under a constant air pressure for treatment selection. The second importance is prevention of putting the patient in danger caused by over transmission of air. The developed sensor was evaluated, and the detection principle by only endoscopic image has been successfully demonstrated.**

## 1. Introduction

Recently, NOTES (Natural Orifice Transluminal Endoscopic Surgery) has been developed and used for minimally invasive treatment. There has been a growing interest in this treatment methods because they are possible to decrease risk of the complications from the wound. However, this operation has a problem that doctor cannot obtain enough information except for visual information. For example, precise determination of tumor size is a very important subject, and the size is especially dependent on intraluminal air pressures [1]. To solve the problem of pressure monitoring, we have developed and evaluated "electrical type" wired pressure sensor using CMOS-MEMS technology [2]. The application effect of the wired sensor has been demonstrated in an animal's stomach [3]. However, the wired sensor has a problem that electric wiring is indispensable for power supply and signal detection. Since most operation tool is disposable, wireless sensor is needed to reduce operation time. On the other hand, "Optical type" pressure sensor using organic material with structural color is reported by other group [4-5]. However, the optical type sensors have some subjects to realize NOTES application and fully wireless. Tolerance for environment of inside body like gastric acid, detection method of structural color without optical fiber, fast response to the pressure, and detectable pressure range. In this study, "optical-type" pressure sensor using silicon MEMS technology with fast response is proposed and developed, and wireless detection of structural color method is realized by camera of existing in the endoscope.

## 2. Conceptual of Sensor Device with Structural Color

Figure 1 is conceptual diagram of the fully wireless pressure sensor based on endoscopic image. The sensor is embedded inside of the side-wall of the plastic endoscopic hood. The hood is attached at the tip of a flexible endoscope as shown in Fig. 1. Since 2×2 mm size sensor chip is smaller than 13 mm diameter endoscopic hood, endoscopic camera-vision is almost not disturbed.

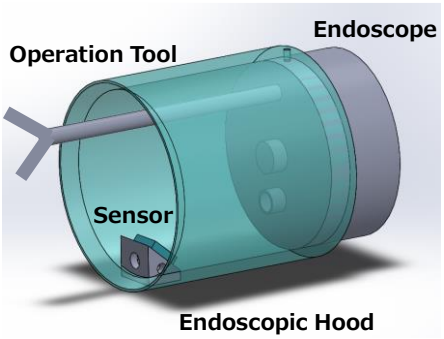



Fig. 1 Conceptual diagram of the fully wireless pressure sensor based on endoscopic image.

Figure 2 shows the sensor structure and sensing principle. The device consists of silicon diaphragm with 5μm thick-ness, boss structure to produce structural color, etched glass to form narrow gap. Device structural color depends on length of the narrow gap that is changed by air pressure.

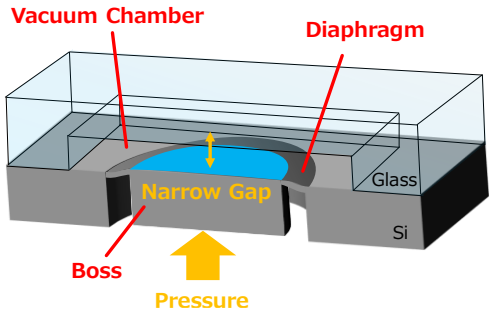


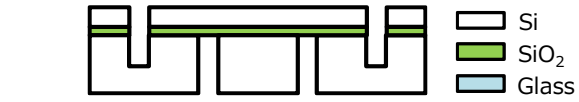

Fig. 2 Device structure and sensing principle

## 3. Structural Color Detection by Endoscopic Image

The structural color of the sensor is obtained from the image of the endoscopic camera. Generally, obtained vision data from camera is using the RGB color model that contain information of brightness and saturation. In this study, "hue" in the HSB (Hue, saturation, brightness) color model is used to evaluate only color change.

## 4. Fabrication Process

Figure 3 shows the fabrication process flow of the "optical type" pressure sensor. The starting material of the sensor is an SOI wafer with 5μm-thick device layer, and glass substrate for anodic bonding (SW-3, Asahi glass). First, front side of SOI wafer is etched for edge pattern forming to detect of sensor position in image processing. Next, back side of SOI wafer is etched for circular silicon diaphragm and boss structure forming. (Figure 3 (a)). After formation of the SOI structure, glass substrate is etched shown in Fig. 3 (b). Finally, each substrate is bonded by anodic bonding (Figure 3 (c)).




(a) Front and back side Si etching by ICP-RIE

(b) Glass etching by hydrofluoric acid.

(c) Anodic bonding of (a) and (b).

Fig. 3 Fabrication process of the fully wireless pressure sensor.

## 5. Evaluation

Fabricated sensor was evaluated. Figure 4 shows experimental setup to evaluate the characteristic of structural color change for air pressure. This setup consists of sensor chip in air chamber, camera to obtain sensor image, and an air pump, reference pressure sensor.

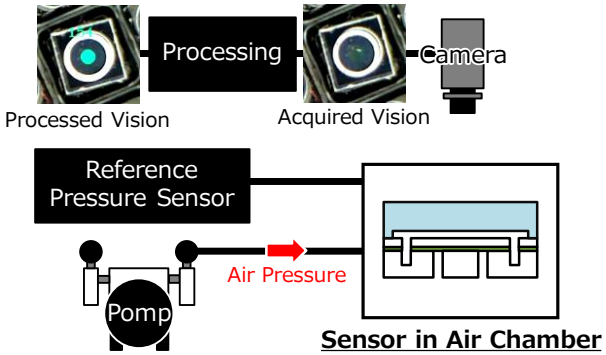
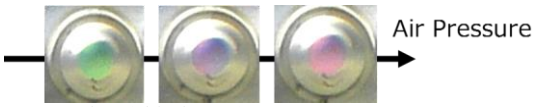
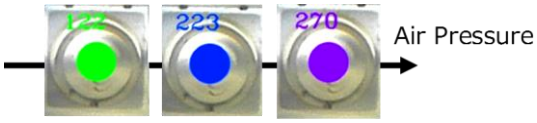



Fig. 4 Experimental setup for device evaluation.

Figure 5 shows obtained and processed image of the sensor chip. It is confirmed that color change for the air pressure change shown in fig.5 (a). In processed image (fig. 5 (b)), structural color of the sensor was quantitatively obtained as "hue".




(a) Before Processing (chip image)




(b) After processing view.

Fig. 5 Structural color change of the fabricated device.

Figure 6 shows relationship between air pressure and hue (processed structural color) of fabricated device. As shown in the figure, a mostly linear relationship between the hue and pressure is obtained in the measurement range (0-2.0 kPa).

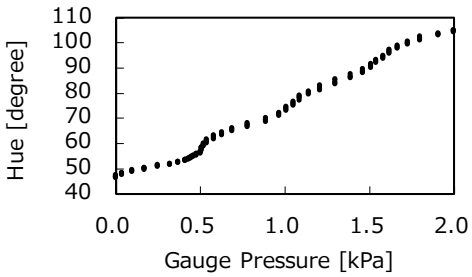



Fig. 6 Relationship between pressure and hue (structural color) of fabricated device.

## 6. Conclusions

In this study, the fully wireless pressure sensor based on endoscopic image is proposed and developed. Fabricated device was evaluated. Thorough the experiments, a mostly linear relationship between the hue and pressure is obtained.


## Acknowledgements

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