Proceedings of Symposium on Ultrasonic Electronics, Vol. 31 (2010) pp. 85-86
6-8 December, 2010

# Construction of Acceleration Sensor Using a Coupled Vibrator
結合型振動子を用いた加速度センサの構成

Jiro Terada[1], Sumio Sugawara[2] and Yoshikazu Mito[2†] ([1]Faculty of Eng., Osaka Inst. of Tech.; [2] Faculty of Sci. and Tech., Ishinomaki Senshu Univ. )
寺田　二郎 [1]，菅原　澄夫 [2]，水戸　義和 [2‡] ([1] 大阪工業大 工; [2] 石巻専修大 理工)

## 1. Introduction

Recently, a small low-cost acceleration sensor with high sensitivity has been required for application to the attitude control and navigation systems of moving objects, such as vehicles. To develop such a sensor, the authors have studied an acceleration sensor that utilizes the phenomenon that the resonance frequency of a bending vibrator changes by the axial force.[1-11)]

A new construction of the acceleration sensor using a coupled vibrator is proposed here, and investigated experimentally. The sensor detects the acceleration from a change of vibration amplitude of the coupled vibrator.

## 2. Structure of Sensor

**Fig. 1** shows the structure of the acceleration sensor using the coupled vibrator. The two bending vibrators[3)] are mechanically coupled as shown in the figure. The coupled vibrator is fixed to the frame at both ends, and the center portion of the vibrator is connected to mass at both sides with short bars. Also the mass is fixed to the frame with four support bars.

The vibration mode of the coupled vibrator is shown in **Fig. 2(b)**. **Fig. 2(a)** shows the vibration mode of the bending vibrator, the displacements at the both ends are designed so as to become very small.[2)] The experimental sample of the sensor is made from stainless steel (SUS304). The volume of the sensor is made from stainless steel (SUS304). The volume of the experimental sample is about 80 ×90×8 mm$^3$.

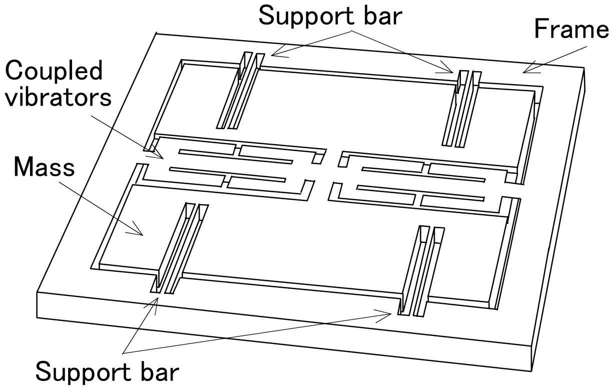
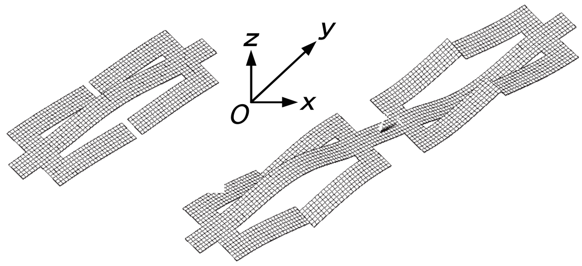



Fig. 1　Structure of sensor.




(a) Bending vibrator　　(b) Coupled vibrator

Fig. 2　Vibration modes of vibrator.

## 3. Driving and detecting methods of Sensor

**Fig 3(a)** shows a cross section of the sensor. Four small piezoelectric ceramics (2×8×0.1 mm$^3$) are bonded on the long arms of the coupled vibrator, and electrically connected for driving and detecting the vibrator as shown in **Fig. 3(b)**. The vibrator is driven with the constant amplitude using an AGC amplifier, and the output signals are detected differentially. The sensor output is obtained using a synchronized detector.

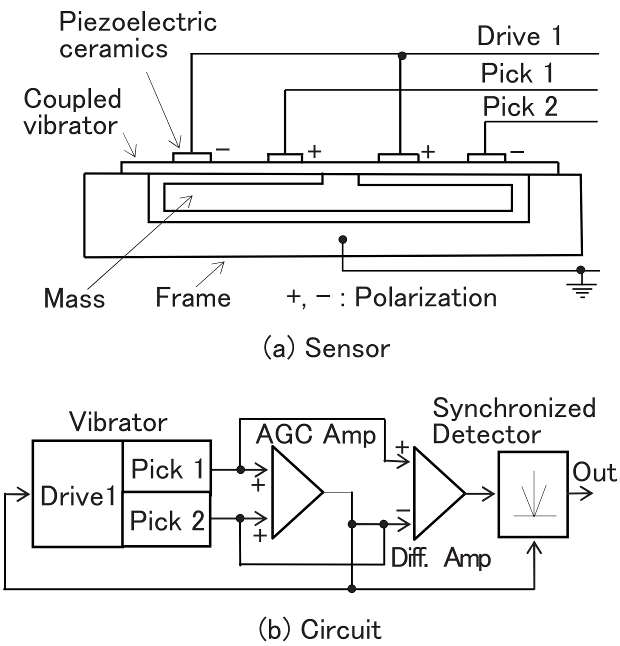



Fig. 3　Driving and Detecting methods of sensor.

Mail address: teramat@rsh.oit.ac.jp

## 4. Sensor Characteristics

The experimental sample of the sensor is shown in **Fig. 4**. The measured values of resonance frequency and quality factor are about 770Hz and 145, respectively. The sensor characteristics are measured using the gravitational field, and the acceleration is changed by rotating the sensor around the axis along the length of the vibrator.

The measured characteristics are shown in **Figs. 5** and **6**. The relationship between the acceleration $\alpha$ and the output voltage $V_{out}$ becomes linear as shown in **Fig.5**. Here, $V_{out}$ shows the differential voltage between $V_{pick1}$ and $V_{pick2}$, which are the output voltages at the terminals Pick1 and Pick2 in **Fig. 3**. The sensitivity of 0.43V/G and the linearity of 0.2% were realized experimentally. Here, G=9.8m/sec$^2$. **Fig. 6** shows the relationship between the frequency $f$ and the gain $A$. The frequency response of the sensor is obtained as about 800Hz from the figure.

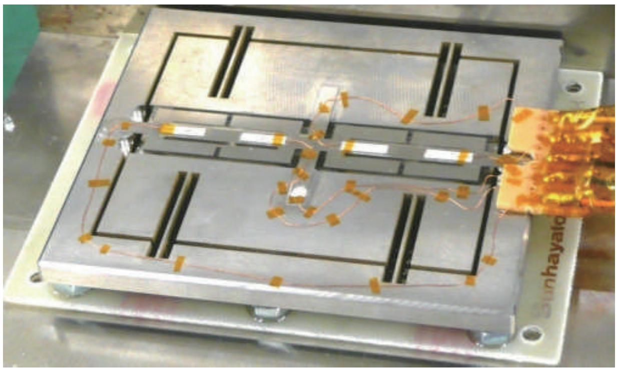


Fig. 4　Experimental sample of sensor.

## 5. Conclusions

A new construction of the acceleration sensor using the coupled bending vibrator was proposed, and the sensor characteristics were measured experimentally. The obtained results are summarized as follows.

(1) The acceleration sensor can be realized using the change in the vibration amplitude of the vibrator.
(2) The sensitivity of 0.43V/G is realized using the large experimental sample of the sensor.
(3) The linearity of 0.2% is also realized using the differential detection of the coupled vibrator.

Based on these results, the MEMS sensor was constructed from a silicon single-crystal and piezoelectric thin films, and designed by the finite-element method so as to have the volume of $4\times4\times0.5$ mm$^3$. The following result was also obtained.

(4) The sensitivity of 0.5V/G can be realized.

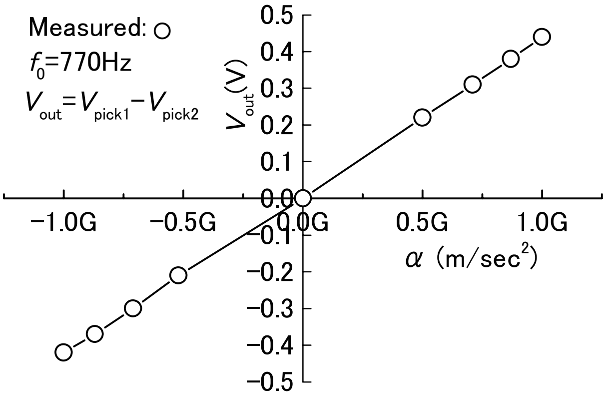



Fig. 5　Measured characteristic of $\alpha - V_{out}$.

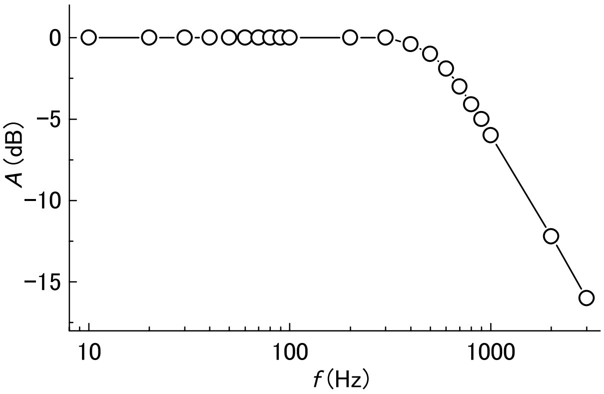



Fig. 6　Measured frequency response of $f - A$.

## References


1) S. Sugawara, K. Masuda, and Y. Tomikawa: Jpn J. Appl. Phys., **40** (2001) 3683.
2) S. Sugawara, J. Takahashi, and Y. Tomikawa: Jpn J. Appl. Phys., **41** (2002) 3433.
3) J. Takahashi, S. Sugawara, and J. Terada: Jpn J. Appl. Phys., **42** (2003) 3124.
4) J. Takahashi, and S. Sugawara: Jpn J. Appl. Phys., **43** (2004) 3035.
5) S. Sugawara and J. Terada: Proc. 27th Symp. Ultrasonic Electronics, 2004, p. 185 [in Japanese].
6) S. Sugawara and J. Terada: Choonpa Tekuno, **18** (2004) No.1 20 [in Japanese].
7) S. Sugawara, H. Suzuki and T. Saito: Jpn J. Appl. Phys., **46** (2007) 4652.
8) S. Sugawara, T. Watanabe, and J. Terada: Jpn J. Appl. Phys., **47** (2008) 4048.
9) S. Sugawara, and J. Koike: Jpn J. Appl. Phys., **47** (2008) 6578.
10) S. Sugawara, M. Yamakawa, and S. Kudo: Jpn J. Appl. Phys., **48** (2009) 07GF04-1.
11) S. Sugawara, and Y. Kajiwara: Jpn J. Appl. Phys., **49** (2010) 07HD02-1.