진동형 각속도계의 최적 구동신호 튜닝에 대한 연구

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A Study on the Optimal Drive Signal Tuning of Vibratory Gyroscope

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Abstract - This paper describes a method to find an optimal driving condition of vibratory gyroscope. Mechanical coupling between driving and sensing mode degrades the performance of vibratory gyroscope. When the resonant frequencies of driving and sensing parts are fixed, frequency and amplitude of driving source affect mechanical coupling. Thus, they should be optimally tuned. To investigate the influence of driving source on mechanical coupling, we measured frequency response and displacement of driving and sensing mode using laser vibromenter. The measured frequency response and displacement show that the gyroscope has minimum mechanical coupling when the frequency of driving source is set to the intermediate value of driving and sensing part resonant frequency. Measurement also shows that the mechanical coupling increases abruptly at a certain driving voltage as the voltage increases.

1. Introduction

Mechanical interference between driving and sensing mode is well known to degrade the performance of vibratory gyroscope[1-4]. A number of studies have been focused on mode coupling reduction. Some research groups discussed independent arrangement of springs, and discussed parasitic capacitance compensation of gyroscope[3,4]. And others investigated the effect of the resonant frequency difference on gyroscope characteristics using two-dimensional laser displacement meter[2]. They tried to find out optimal frequency mismatch.

This paper describes a method to find the optimal driving condition of vibratory gyroscope when the frequency mismatch is fixed. When the resonant frequencies of driving and sensing parts are fixed, frequency and amplitude of driving source affect mechanical coupling. Thus, they should be optimally tuned. To investigate the influence of driving source on mechanical coupling, we measured frequency response and displacement of driving and sensing mode using laser vibrometer.

2. Gyroscope model

Figure 1 shows schematic diagram of the tested in-plane type z-axis gyroscope. When the center mass is driven by electrostatic force, rotation about the z-axis causes the mass to move in the y-direction due to the Coriolis force. The mass shows elliptical motion. The proposed gyroscope consists of a set of springs that are placed symmetrically about a proof mass, which are made by single crystal silicon. These springs are anchored at one end, and connected to the mass at the other end by a rolling pin condition which constrain the springs to act only along the driving and sensing axis. The gyroscope has symmetric comb electrodes for driving and sensing modes. A detailed description of the device structure is reported on [5].

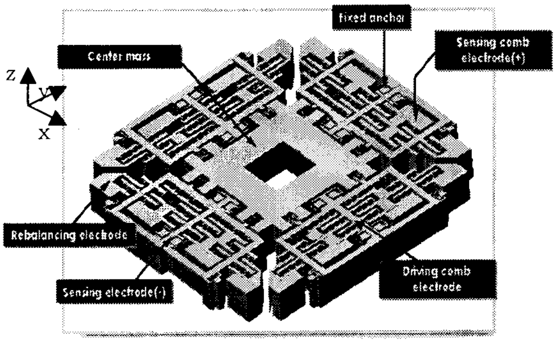


Figure 1. Schematics of the tested gyroscope

3. Fabrication

Figure 2 shows the fabrication process of the gyroscope. At first, metal film is patterned on the silicon substrate to prevent footing during DRIE(Fig. 2(a)). Feed-through hole that is 150 μm in diameter is formed in glass substrate using sandblast(Fig. 2(b)). After bonding two wafers, gyroscope is patterned by

DRIE(Fig. 2(c)). Getter deposited glass cap wafer(Fig. 2(d)) is anodically bonded to the SiOG wafer under 10^{-4} Torr(Fig. 2(e)). Then, Metal layers are patterned around the feed through hole for wiring pad. Finally, feed-through hole is filled with conductive epoxy by spin coating process for the electric connection between silicon electrode and wire bonding pad(Fig. 2(f)). Figure 3 shows SEM photograph of the fabricated gyroscope.

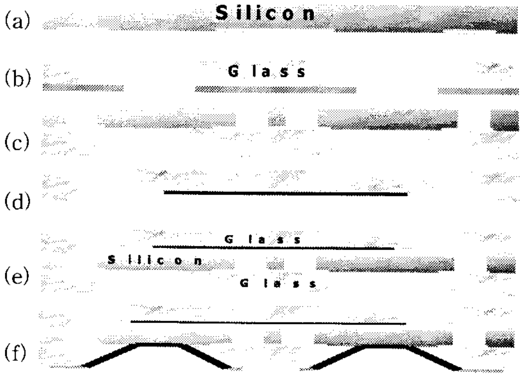


Figure 2. Fabrication process sequence

Figure 3. SEM image of fabricated gyroscope

4. Measurements

Figure 4 shows response of the sensing part when various driving frequency is applied to the driving part. Small vibration of sensing part is measured using laser vibrometer. If there is no coupling, the plot should draw flat region only. However, two peaks appeared in the plot. Frequencies of two peaks are equal to the resonant frequency of driving and sensing mode.

Figure 5 shows coupling rate of sensing part displacement (=coupling) to driving part displacement when the frequency of driving source is varied from 7607.5 to 7611.5 Hz. The amplitude of driving signal is fixed to bias 5 V and ac 0.5 V_{peak}. When the frequency of driving signal is equal to the resonant frequency of driving mode, the coupling rate is 8~10 % as shown in figure 5(a). When the frequency of driving signal is equal to the resonant frequency of sensing mode, the oscillator exhibited maximum perturbation up to 400 % as shown in figure 5(c). The coupling is minimized at intermediate driving frequency. When the driving frequency is set to 7609.5 Hz, the coupling rate is reduced to 4 % as shown in figure 5(b).

Figure 6 shows frequency response of the sensing part when various level of ac driving voltage is applied to the driving part. The coupling at the intermediate frequency are 0, 10 and 30 dB, respectively, when the ac voltage is 0.1, 0.5 and 1 V_{peak}. The coupling increased by 10 dB when the ac voltage increased by 5 times from 0.1 to 1 V_{peak}. However, when the ac voltage increased twice from 0.5 to 1 V_{peak}, the coupling increased by 20 dB, which shows that coupling increases dramatically at a critical driving voltage. Thus, the driving voltage should be lower than the critical point.

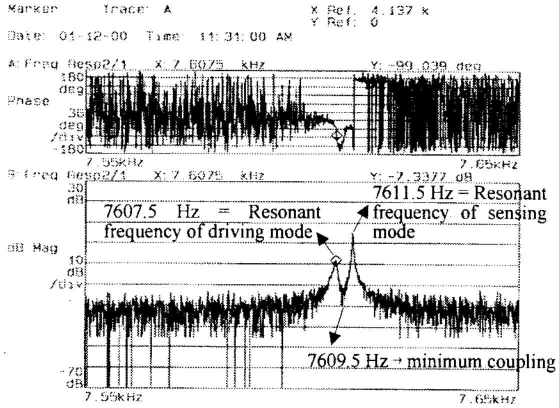
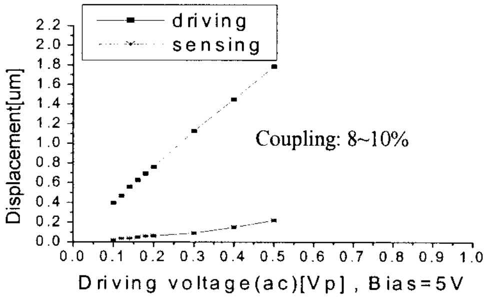
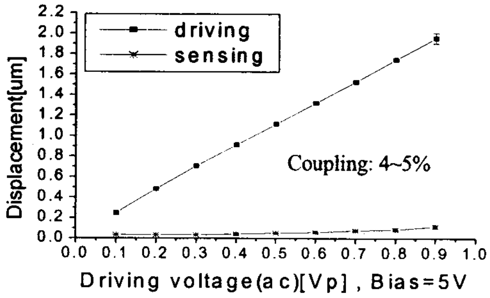


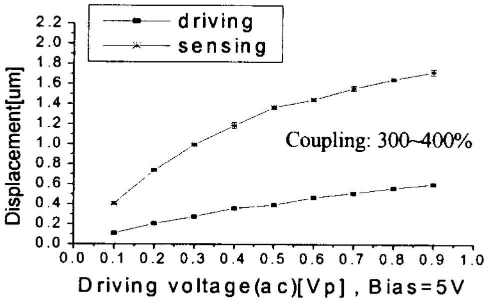
Figure 4. Response of sensing part (coupling) when various frequency of driving source applied to driving part (Bias 5 V + ac 0.5 V_{peak})



(a) 7607.5 Hz drive

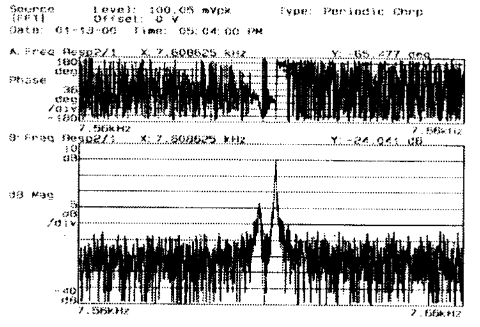


(b) 7609.5 Hz drive

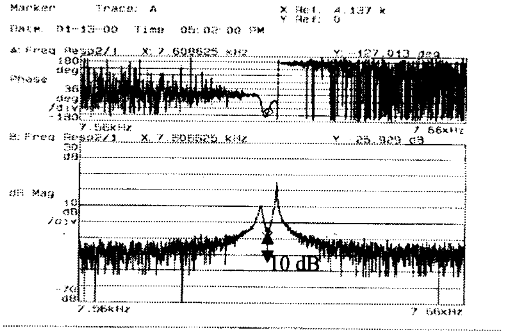


(c) 7611.5 Hz drive

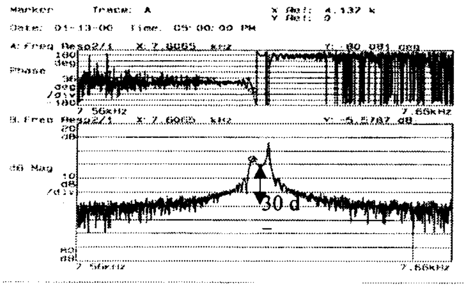
Figure 5. Displacement of driving and sensing part (coupling) at various frequency of driving source



(a) Bias 5 V + ac 0.1 V_{peak}



(b) Bias 5 V + ac 0.5 V_{peak}



(c) Bias 5 V + ac 1 V_{peak}

Figure 6. Response of sensing part(coupling) at various amplitude of driving source

5. Conclusion

In-plane type z-axis gyroscope is fabricated, and sensing part is measured by laser vibrometer to investigate the influence of driving source on mechanical coupling. The measured frequency response and displacement show that the gyroscope has minimum mechanical coupling when the frequency of driving source is set to the intermediate value of driving and sensing part resonant frequency. Measurement also shows that the mechanical coupling increases abruptly at a critical driving voltage as the voltage increases. Thus, the driving voltage can be maximized up to the critical driving voltage.

Acknowledgement

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[Reference]

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