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Frequency dependence analysis of ball SAW sensor's responses
ボール SAW センサの応答の周波数依存性解析

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1. Introduction

A ball surface acoustic wave (SAW) sensor can realize highly sensitive measurement using multiple roundtrip propagation of naturally collimated SAW [1]. The fabrication of Pd sensitive film with 20 nm thickness succeeded in measuring H_2 concentration with a range from 10 ppm to 100% by single element for the first time [1, 2]. In response to this achievement, recently, it was presented that acoustoelectric (AE) effect due to the conductivity change of Pd nano-cluster film, which was much thinner than 20 nm, was useful. However, the measurement of the frequency dependence of the response is required for investigating the origin of working mechanism of the film. In this study, we analyze the frequency dependence of the response of the ball SAW sensor with small pair number of an interdigital transducer (IDT), applying a wavelet transform to a roundtrip waveform.

2. Measurement implementation

Schematic illustration of a measurement apparatus is shown in **Fig.1**. H_2 concentration from 1% to 0.05% was generated using mass flow controllers connected to gas cylinders of N_2 and 3%H_2-N_2, and each concentration gas was changed alternatively by N_2 every 5 minutes (standard measurement). The waveforms were measured using a pulser receiver. The ball SAW sensor with IDT of 3 pairs was fabricated on quartz ball with ϕ3.3 mm diameter.

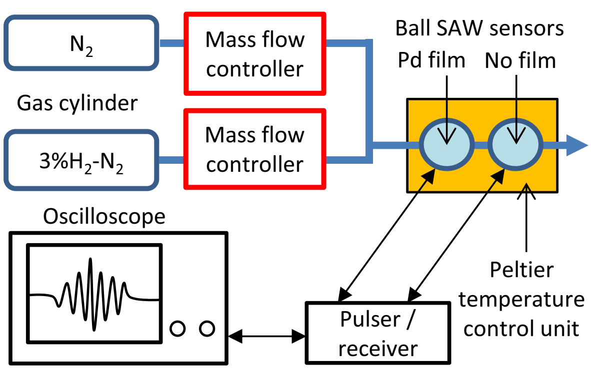

Fig. 1 Schematics of measurement apparatus.

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As a H_2 sensor, Pd film with 20 nm thickness was fabricated on one fourth of the SAW propagation route using RF magnetron sputtering at Ar pressure of 20 mTorr. On this condition, porous structure was estimated since the sheet resistance was 8 times higher than that fabricated at 5 mTorr with faster sputtering rate. Moreover, no film sensor was connected after Pd film one as a reference for compensating thermal drift of the delay time response. Their temperatures were kept at 35℃ using a Peltier temperature control unit.

3. Result

3.1 Waveform of ball SAW sensor

Typical waveform of Pd sensitive film ball SAW sensor was shown with the power spectrum in **Fig.2**, measured at the 10th turn within N_2 period. The peak frequency and the 20 dB band width were 155.3MHz and 62.8 MHz (119.6 MHz~182.4 MHz), respectively.

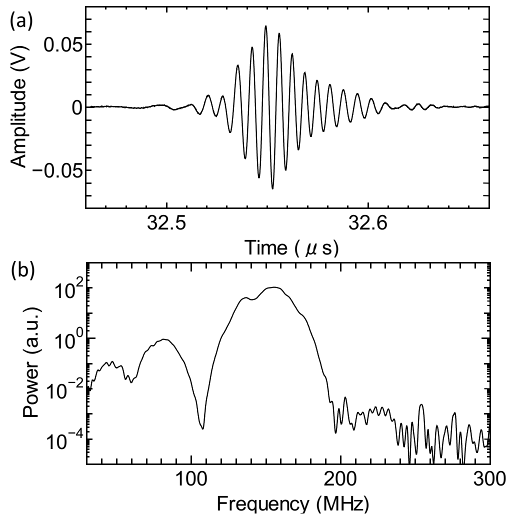

Fig. 2 Typical waveform of Pd sensitive film ball SAW sensor (a) waveform at the 10th turn. (b) power spectrum.

3.2 Response to H_2

The responses at 150 MHz are shown in **Fig.3**, calculated by the application of the wavelet transform to each waveform measured during the standard measurements. A mother wavelet was Gabor function and the analysis was performed with 1000 interpolations of sampling interval (100 ps) for enhancing the resolution in time domain. **Fig.3(a)** shows the delay time change where the response of no film sensor was subtracted. Although positive changes were observed in the periods of H_2 concentration of 1% and 0.5%, the sensitivity was low.

On the other hand, **Fig.3(b)** shows the amplitude change. Clear response was observed at each concentration and highly reproducible in subsequent three standard measurements. However, the sensitivity was significantly changed depending on the concentration, and was the highest at 0.05%. It suggests that higher sensitivity [1] may be achieved by an experiment using lower H_2 concentration.

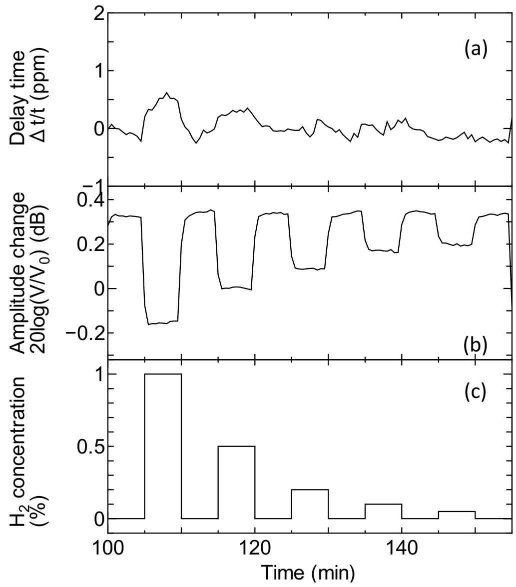

Fig.3 Standard measurement of H_2 gas. (a) delay time change (b) amplitude change (c) H_2 concentration.

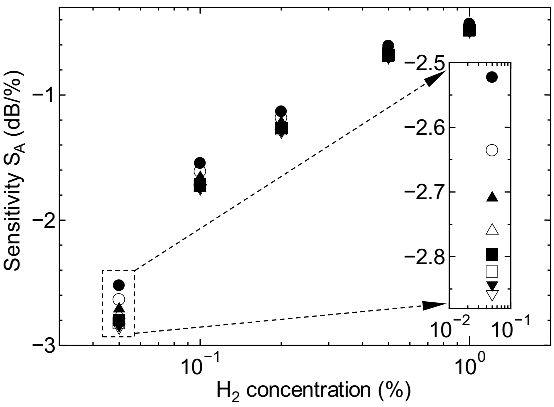

Fig.4 Variation of sensitivity on concentration. ●, ○, ▲, △, ■, □, ▼, ▽represent the data from 120 MHz to 190 MHz every 10MHz, respectively.

3.3 Frequency dependence of attenuation change

The frequency dependence of the attenuation change Δα is shown in **Fig.5**, where Δα were calculated from the change of averaged amplitudes between N_2 and subsequent H_2 periods between 100 MHz to 300 MHz every 10 MHz. Although Δα slightly increased from 120 MHz to 190 MHz as the frequency increased, clear dependence was not observed. This behavior was different from that of viscoelastic response, suggesting AE effect [3].

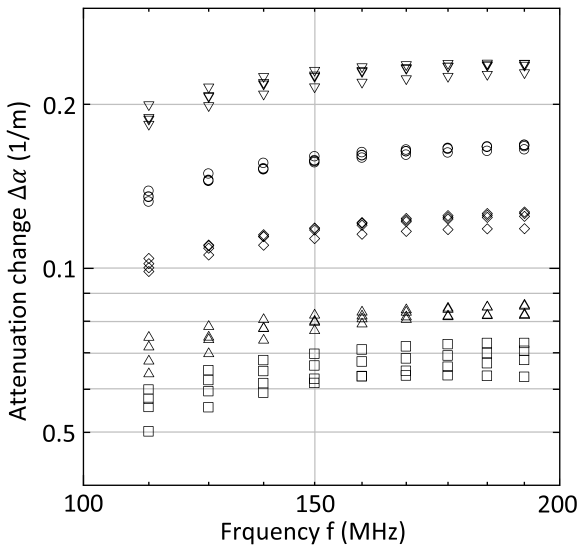

Fig.5 Frequency dependence of attenuation change by H_2 gas.▽, ○, ◇, △, □ repsresent the data of 1%, 0.5%, 0.2%, 0.1%, 0.05%, respectively.

4. Conclusions

It was found that high sensitivity of a ball SAW H_2 sensor was caused by porous structure of Pd sensitive film. The frequency dependence of the attenuation change by H_2 gas was measured by the application of a wavelet transform to a roundtrip waveform. Such an analysis enables detailed evaluation of working mechanism of the sensitive film and provides the methods useful for enhancing the sensitivity and the reproducibility of the sensor.

References

1.K. Yamanaka, S. Ishikawa, N. Nakaso, N. Takeda, D.-Y. Sim, T. Mihara, A. Mizukami, I. Satoh, S. Akao, and Y. Tsukahara: IEEE Trans. Ultrason. Ferroelectr. Freq. Control. **53** (2006) 793.2.
2.T. Abe, N. Iwata, T. Tsuji, T. Mihara, S. Akao, K. Noguchi, N. Nakaso, D. Sim, Y. Ebi, T. Fukiura, H. Tanaka, K. Yamanaka: Jpn. J. Appl. Phys. **46** (2007) 4726.
3.B. H. Fisher and D. C. Malocha: IEEE Trans. Ultrason. Ferroelectr. Freq. Control. **57** (2010) 698.