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Shortening interval of burst waveform undersampling measurement of ball SAW sensor for characterizing metal surface morphology

金属組織評価のためのボール SAW センサバースト波アンダーサンプリング測定の高速化

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1. Introduction

A ball surface acoustic wave (SAW) trace moisture (TM) sensor detected large difference of inner surface roughess of stainless steel tube for highly pure gas by monitoring TM passage.[1,2] Inverse gas chromatography (IGC) may be developed for analyzing the performance of such tubing system using this sensor. Although burst waveform undersampling (BUS) circuit was useful for ppbv level measurement,[3] the minimum interval was about 3 s for conventional 300 points record length and 1000 times integration.[2] However, the time resolution was probably insufficient for studying the impact of the local surface morphology by bending and welding. In this study, the interval was shorten by the integration number reduction and partial waveform usage. It was applied for characterizing bending-induced (BI) morpology of SUS316L electropolished (EP) tube showin in **Fig. 1**.

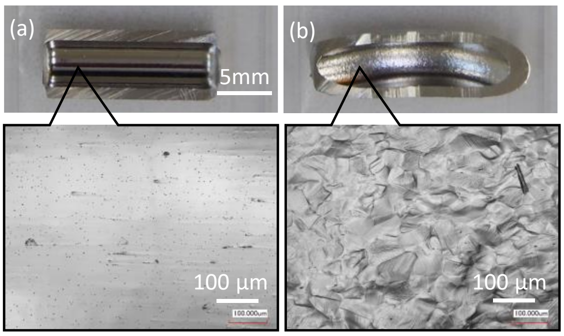

Fig. 1 Morphology change of EP surface of SUS316L tube by bending. (a) raw, (b) bent.

2. Shorting interval of BUS measurement

When harmonic ball SAW sensor with sol-gel SiOx film is excited by composite burst signal of 80 MHz and 240 MHz, SAWs of two frequencies are propagated on identical path, resulting in multiple roundtrips. **Fig. 2** shows BUS waveforms at 7th turn, where CH1 and CH2 are the outputs for 80 MHz and 240 MHz, respectively. Since they are undersampled at 100 MHz, the frequencies are down-converted to 20 MHz and 40 MHz, respectively.

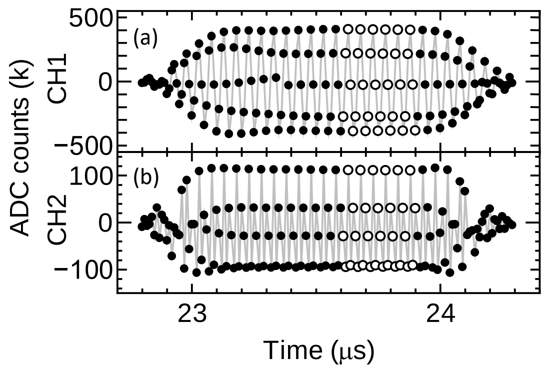

Fig. 2 BUS waveforms. (a) CH1 for 80 MHz, (b) CH2 for 240MHz. Open circles represent partial waveforms proposed in this study.

Since the repetition frequency of the burst signal was 1 kHz, 1 s was needed for integrating 1000 times. The interval was 2.54 s for conventional whole waveform with 150 points. It was decreased to 0.75 s in the case of 100 times integration. Moreover, it was decreased to 0.31 s when the waveform was limited to 30 points shown by open circles.

The delay time was determined by a wavelet transform,[3] When fractional delay time changes are represented by Δt_1 and Δt_2, the temperature-compensated value is expressed by

$$\Delta t = \Delta t_2/6 - \Delta t_1/(-4) \qquad (1).$$

Figure 3 shows Δt variation by injecting 520 ppbv H_2O N_2 flow (100 sccm) to SUS316L EP tube (O.D. 1/4 in., 500 mm) dried by 1.6 ppbv for 900 s. The type of symbols represents the acquisition condition, plotted with -1 ppm relative shift. Δt was negatively shifted by H_2O adsorption, empirically related to square root dependence on H_2O concentration in gas phase.[4] As a result, it was found that proposed method could extract Δt with practical signal-to-noise ratio in spite of 1/10 integration time and 1/5 record length compared with conventional condition.

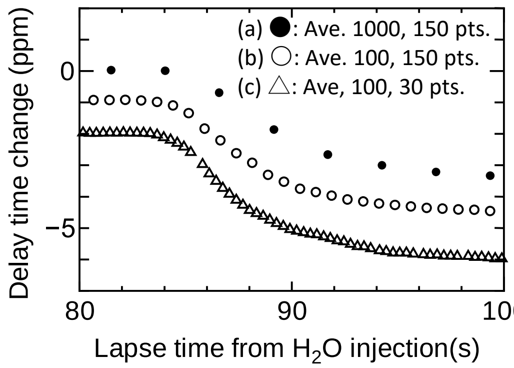

Fig. 3 Variation in the delay time change Δt by 520 ppbv H_2O injection, where the data of each symbol type is shifted by -1 ppm. Measurement intervals are (a) 2.54 s, (b) 0.75 s, and (c) 0.31 s, respectively.

3. Application for BI morphology

The impact of BI morphology was measured using the condition of Fig. 3(c). H_2O concentration was set to 20 ppbv to detect small variation sensitively. **Fig. 4** shows schematics of samples. Sample A was raw EP tube (VALEX, VIM/VAR, 500 mm). It was in-situ bent 6-times by 15° as sample B to avoid exposing ambient air. Moreover, Sample C was prepared by 10-times 30° bent and stretched over whole length with similar tube to sample A.

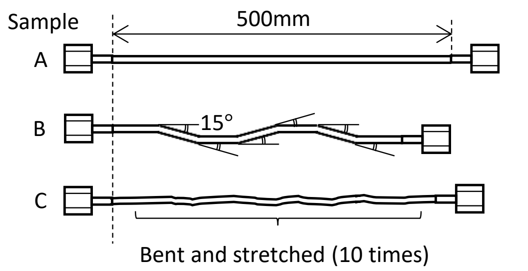

Fig. 4 EP-tube Samples. (a) raw, (b) 6-times 15° bent, (c) 10-times 30° bent and stretched.

Figure 5 shows a result of 20 ppbv H_2O injection to the samples dried by 1.6 ppbv N_2 flow (100 sccm) for 1800 s. The curve for each sample was averaged over three data with similar Δt saturation among sequential six measurements. The data of samples A and C were obtained after 5 and 10 days exposures in trace moisture environment (< 1000 ppb). The data of sample B were obtained after 12 h of the measurement of sample A. Although Δt falling by H_2O arrival was expected to be delayed by increasing adsorption area due to BI morphology, it was moved forward as the bending working became severer.

Figure 6 shows the result of the sample wetted by 20 ppbv for 1800 s dried by 1.6 ppbv N_2 flow. Early raise of Δt in sample C was clear although there was not significant difference between samples A and C.

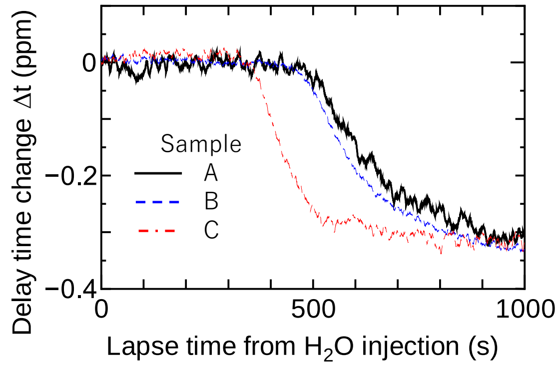

Fig. 5 Variation in the delay time change Δt by 20 ppbv H_2O injection.

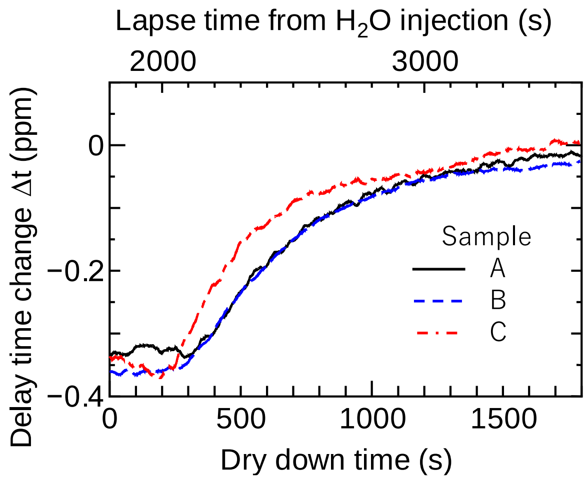

Fig. 6 Variation in the delay time change Δt by drying with 1.6 ppbv.

4. Conclusions

Reduced-interval BUS measurement method was developed for the ball SAW TM IGC. It was found that the bending-induced morphology may change the H_2O adsorption/desorption behavior.

Acknowledgment

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References

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