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Evaluation of Design Parameters of Pipe Systems for Highly Pure Gases by Ball Surface Acoustic Wave Trace Moisture Analyzer

球状弾性表面波微量水分計による高純度ガス配管システムの設計パラメータ評価

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1. Introduction

In purging pipe systems for highly pure gases, the substance most difficult to be removed is water. It is important to design the system with small adsorption and easy desorption of water molecule. Specifically, general guidelines are the reductions of a pipe length and an inner surface roughness and the increase of a line velocity. However, quantitative evaluation of the effect of these design parameters has not been realized because of a lack of practical trace moisture analyzer (TMA) with sufficient sensitivity and fast response. In this situation, TMA based on a ball surface acoustic wave (SAW) sensor realized the measurement of 1000 ppbv moisture with a time constant of seconds [1-4] and succeeded in measuring the difference of inner surface treatments of 1/4 inch (in.) outer diameter stainless steel tubes only with a length of 100 mm [5]. In this study, we try to evaluate the design parameters quantitatively by measuring the adsorption process of standard concentration moisture using the ball SAW TMA.

2. Experiment

An experimental set up is shown in **Fig. 1**. Dry N_2 flow (10 ppbv) was wetted by the diffusion tube method [6] and wet N_2 flow (700 ppbv) was generated **[Fig. 1(a)]**. Sample tubes were purged and wetted using dry and wet N_2 flows with a flow rate of 100 ml/min. The ball SAW sensor with sol-gel SiOx coating was installed downstream [1] and was used as TMA calibrated with a cavity ringdown spectroscopy TMA [3,5]. The samples were SUS316L stainless steel tubes with inner surface treatments of bright annealing (BA) and electropolishing (EP) with nominal values of the maximum roughness R_y were 3 and 0.7 μm, respectively, which were connected to the measurement system using general-purpose unions (Swagelok$^{\text{TM}}$) **[Fig. 1(b)]**. After purging the sample for 10 h, the cycle of the alteration between dry and wet N_2 flows in periods of 1 h was repeated 6 times **[Fig. 1(c)]**. The period between the time of switching dry to wet N_2 flow and the time of significant concentration increase (SCI) is defined as the time of moisture transit through the sample, denoted by t_s, which is related to the number of adsorption site [5]. The sensor response was temperature-compensated delay time change of a roundtrip waveform between the 3rd and the 7th turns measured using burst waveform undersampling circuit [3,5].

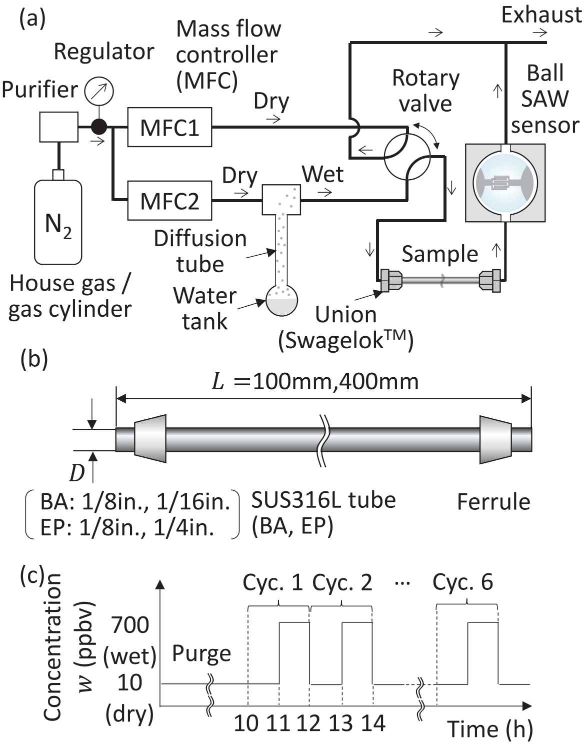

Fig. 1 Experimental set up. Schematic illustrations of (a) measurement system and (b) tube sample. (c) Diagram of set concentration.

3. Result

The variation in moisture transit by a pipe length L is shown in **Fig. 2**, where horizontal axis represents lapse time from the switching. t_d

denotes the time at SCI with no sample. In 1/8 in. BA tubes, t_s was reduced from 550 s to 150 s as L was reduced from 400 mm to 100 mm. However, in EP tubes, t_s was 55 s even in L of 400 mm, and 20 s in L of 100 mm. Therefore, the reduction of R_y was more effective for reducing t_s than that of L.

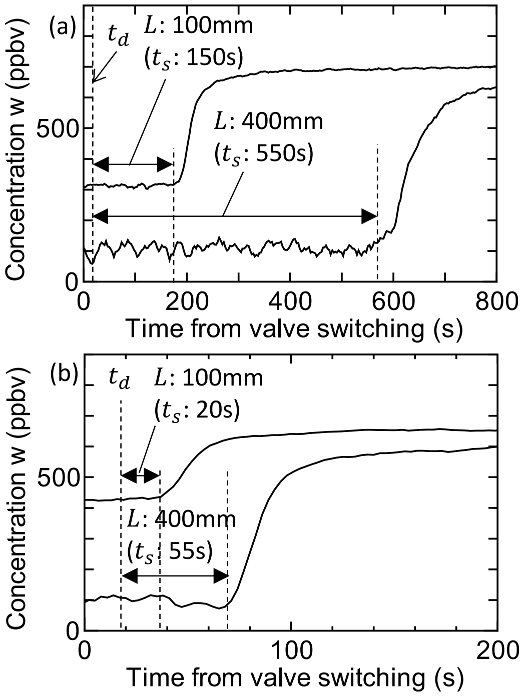

Fig. 2 Variation in moisture transit through 1/8 in. tube samples caused by length and inner surface treatment. (a) BA tubes and (b) EP tubes.

The variation by changing outer diameter D is shown in **Fig. 3** (L of 100 mm). The line velocities are 94, 690, and 6100 mm/s in D of 1/4, 1/8, and 1/16 in., respectively. t_s of 1/8 in. BA tube (150 s) was significantly reduced by EP tube with the same D (20 s) **[Figs. 3(a) and (b)]**. Moreover, t_s of EP tube was 45 s even in 1/4 in. **[Fig. 3(c)]**. Therefore, the reduction of R_y was effective for compensating insufficiency of the line velocity. On the other hand, t_s of 1/16 in. BA tube was 30 s, suggesting the realization of comparable performance to EP treatment by increasing the line velocity.

The variation by adsorption desorption cycles is shown in **Fig. 4**. In BA tube, the concentration at valve switching (0 s) increased and t_s was decreased as the number of the cycle increased. It might be caused by insufficient purging (1 h) after wetting (1 h), suggesting accumulation of moisture on the sample surface. On the other hand, the concentration increase was small and t_s was not changed in EP tube. Therefore, it was found that the reduction of R_y was effective for suppressing the accumulation of adsorbed moisture.

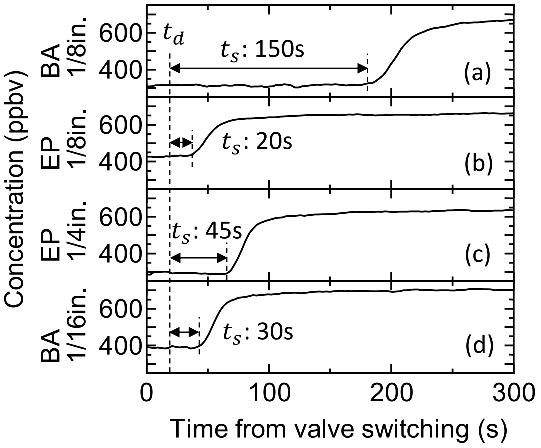

Fig. 3 Variation in moisture transit through 100 mm tube samples caused by outer diameter and inner surface treatment. 1/8 in. tubes of (a) BA and (b) EP. Tubes of (c) EP 1/4 in. and (d) BA 1/16 in.

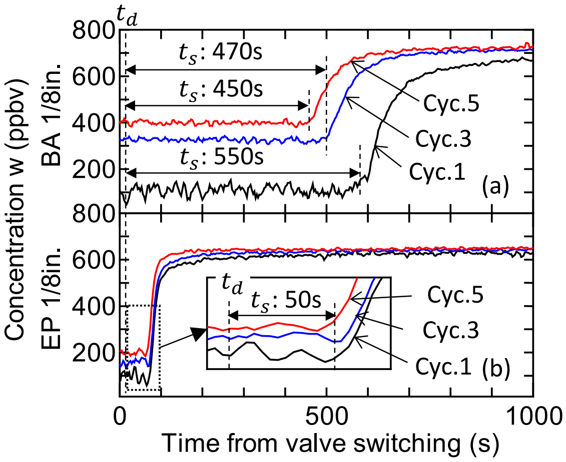

Fig. 4 Variation in moisture transit through 400 mm 1/8 in. tubes caused by adsorption desorption cycles. (a) BA tube. (b) EP tube.

4. Conclusion

The design parameters for highly pure gas pipe systems were evaluated by the ball SAW TMA. The reduction of the roughness of inner surface was the most effective for improving the performance. This TMA is easily applicable to practical pipe systems due to small sensor head (10 cm x 10 cm x 10cm).

Acknowledgment

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