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Extraction of mechanical reflectance of acoustic Bragg reflector by GHz pulse echo technique

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1. Introduction

A solidly mounted resonator (SMR)[1] consists of a piezoelectric layer on Bragg reflector with low and high acoustic impedance layers. The advantage of the SMR is high power durability towing to the fixed substrate which can promote heat dissipation. Our group previously reported an experimental method to acquire the mechanical transmission property of the sole Bragg reflector by using pulse echo technique[2]. In the method, although solid salol was used as an acoustic coupler, the acoustic attenuation was not sufficiently small to detect weak signals less than -25 dB in 2 GHz ranges. In this study, the use of SiO_2 delay line whose acoustic attenuation is relatively small is proposed.

2. The evaluation method

Fig. 1 shows the method to evaluate the mechanical transmission property of the reflector part with the signal reflects from the bottom of the substrate. First, ScAlN piezoelectric layer was grown on the backside of the substrate of Bragg reflector as an ultrasonic transducer. First, (1) the insertion loss of the transducer was measured with a network analyzer. Next, (2) after depositing the SiO_2 layer on the front side of Bragg reflector as a delay line, the insertion loss of the transducer was measured with a network analyzer. The loss due to the transducer was removed by subtracting (1) the insertion loss of the transducer from (2) that of the whole structure. After that, by subtracting (4) the propagation loss of SiO_2 delay line from (3), (5) the round-trip transmission loss of Bragg reflector in the case that SiO_2 was deposited on the front side was obtained. Finally, by dividing (5) by 2, one-way mechanical transmission loss of the sole Bragg reflector (5') was obtained.

To confirm the validity of the present method, we compared the theoretical transmission loss of the sole Bragg reflector estimated by this method with that simply calculated by mechanical circuit. The process of the present method described above was theoretically simulated by using Mason's equivalent circuit model. Fig. 2 shows the mechanical transmission property of the sole Bragg reflector from the mechanical circuit and the transmission property obtained by the present method. We can see a good agreement between the result of mechanical circuit and the present method, indicating that the proposed method allows the measurement of the experimental acoustic properties of the sole Bragg reflector.

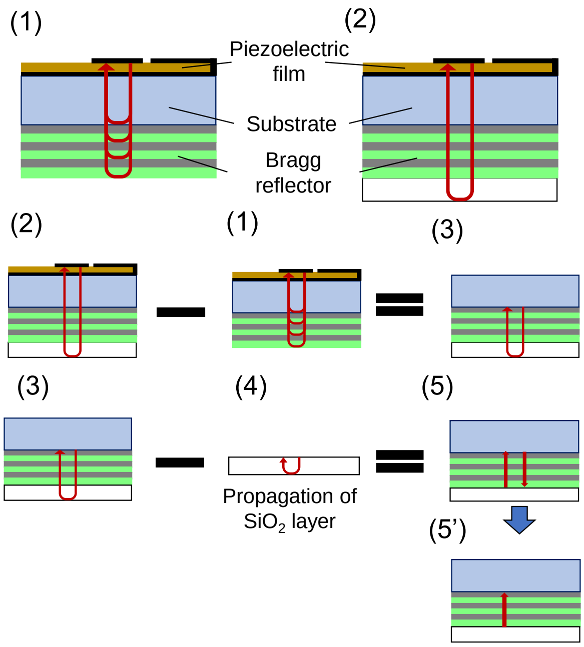

Fig. 1 The method to evaluate the sole mechanical properties of Bragg reflector

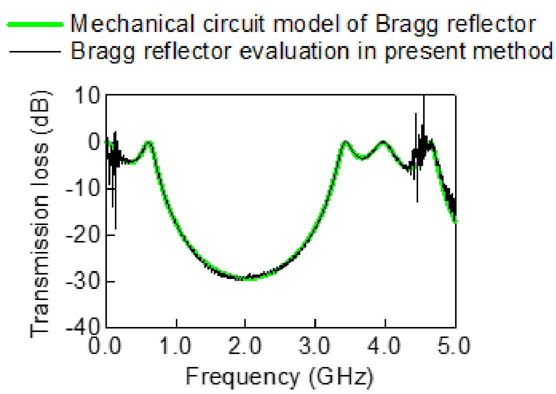

Fig. 2 Theoretical sole Bragg reflector property obtained by mechanical circuit (green line) and by the procedure of present method (black line).

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3. Experiment method

Ta and SiO_2 layers were used as the high and low impedance layers of Bragg reflector, respectively. Two pairs Bragg reflector whose central frequency was 1 GHz was deposited on a silicon substrate. The thickness of each layer estimated from the SEM image is shown in Table. I. $Sc_{0.40}Al_{0.60}N$ transducer layer (3.2 μm) was grown on the Bragg reflector substrate (0.6 mm) by the RF magnetron sputtering system[3, 4].

1st Pair		2nd Pair	
Ta (nm)	SiO_2 (nm)	Ta (nm)	SiO_2 (nm)
1020	1446	1043	1441

Table. I Thickness of each layer of Ta/SiO_2 Bragg reflector.

4. Experimental result

Fig. 3 shows the (1) experimental insertion loss of the sole transducer and (2) that of the experimental echo signal reflected at the bottom of the delay line deposited on the front side of Bragg reflector. These measurements were performed with a network analyzer. Fig. 4 shows the experimental transmission loss obtained using the present method and theoretical mechanical transmission loss. The theoretical curve was calculated from the mechanical circuit using the thickness of each layer determined from the SEM image.

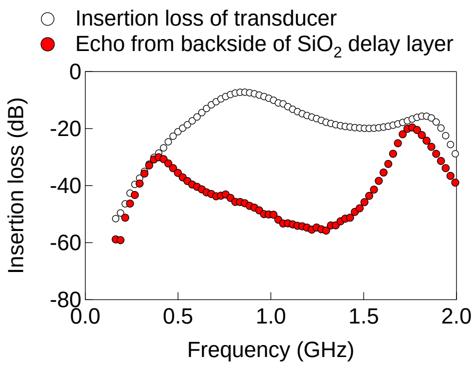

Fig. 3 Experimental insertion loss of transducer (white plot), and echo from back side of SiO_2 delay layer (red plot)

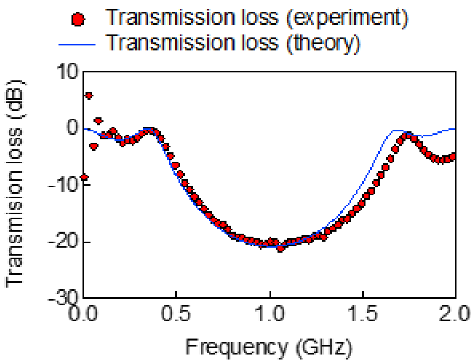

Fig. 4 Theoretical (blue line) and experimental (red plot) acoustic transmission loss of Bragg reflector.

5. Conclusion

The experimental and the theoretical transmission loss of Bragg reflector agreed well. It was confirmed that our method enables the measurement of the transmission loss of the sole Bragg reflector (when SiO_2 was deposited on the front side).

Acknowledgment

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References

1. K. M. Lakin, K. T. McCarron, and R. E. Rose, Proc. IEEE Ultrason. Symp., 2, 905 (1995).
2. N. Ishii, K. Kondo, and T. Yanagitani, Proc. IEEE Ultrason. Sympo., 1 (2021).
3. K.-H. Sano, R. Karasawa, and T. Yanagitani, IEEE Trans. Ultrason., Ferroelectr., Freq. Control, 65 (11) 2097 (2018).
4. T. Yanagitani, and M. Suzuki, Appl. Phys. Lett., 105 (12) 122907 (2014).