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Consideration on influence of reflected waves at junction boundary in double layered thickness-shear resonator using α-quartz
水晶を用いた二層構造厚みすべり振動子の接合境界での反射波の影響についての検討

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1. Introduction

We have proposed a double layered thickness-shear resonator with the aim of improving its temperature dependence of resonance frequency, and have demonstrated the operating characteristics using Ca_3Ta-$Ga_3Si_2O_{14}$(CTGS)[1][2]. So far, we have very-fied the effect of the temperature compensation. In the case of CTGS, however, there was almost no influence of the waves reflected at junction boundary. In this paper, we investigate the influence of reflection waves at junction boundary of the double layered resonator using α-quartz.

2. Specimen preparation

The specimen was prepared by bonding 129.55°Y-cut quartz (thickness=0.1215 mm) as #1 layer and 0°Y-cut quartz (thick-ness=0.1120 mm) as #2 layer with optical contact method[3]. The thickness ratio x was determined based on Eq. (1) to minimize frequency change in the range from 100 to 300 ℃ resulting in x=0.520.

$$df_{DL} = df_{\#1} \cdot x + df_{\#2} \cdot (1-x) \cdots (1)$$

Here, $df_{\#1}$ and $df_{\#2}$ are frequency change for #1 and #2 layers, x is the thickness ratio of #1 layer to the total substrate thickness.

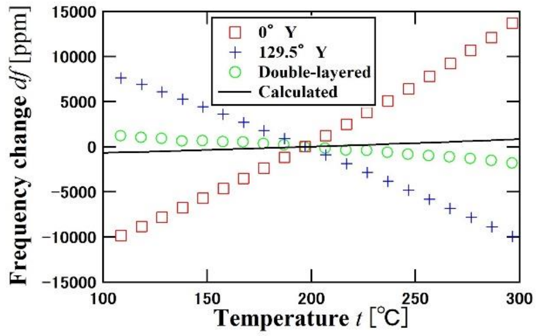

Fig. 1 Resonance frequency changes of each resonator.

3. Experimental result

The resonance frequency was measured using an impedance analyzer (HP4294A) at a temperature range of 100 to 300 ℃ for the double layered resonator specimen mentioned above. The result was shown in Fig. 1. The results for single layer of 0°Y-cut and 129.55°Y-cut quartz resonators were also shown in Fig. 1. The result of double layered resonator was close to the solid line calculated by Eq. (1) exhibiting slight deviation toward the result of 129.55°Y -cut quartz resonator.

4. Discussion

Table 1 shows the acoustic impedance of the shear waves propagating along the

Table 1 Acoustic impedances of the shear waves and the reflection coefficients.

	Acoustic impedance[10^6kg/s・m^2]		Reflection coefficient[%]
0° Y	10.39	0° Y→129.5° Y	-5.19
129.5° Y	9.364	129.5° Y→0° Y	5.19

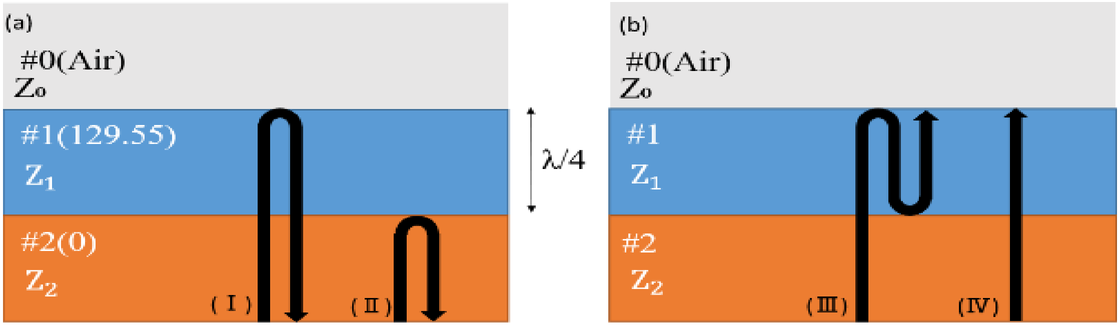

Fig. 2 Schematic diagram of waves reflected or transmitted at each boundary. Waves propagating towards the bottom surface of the #2 layer (a), and top surface of the #1 layer (b).

thickness direction of quartz substrate (0 °Y- and 129.55°Y-axes) and the calculated value of the reflection coefficient at the boundary. Here, we consider the reflected waves generated at the boundary using three layered structure model as shown in Fig. 2. In the three layered structure of #0(Air)/#1(129.55 ° Y) /#2(0 °Y), the layer #1 is expected to act as an acoustic matching layer because the relationship among their impedances is $Z_2 > Z_1 > Z_0$ and the thickness of the layer #1 is almost λ/4 in the fundamental resonance mode.

In Fig. 2(a), wave (I) is reflected at the top surface of the #1 layer with phase inversion because of $Z_1 > Z_0$ and returns to the bottom surface of the #2 layer. Wave (II) is reflected at the boundary #2/#1 with phase inversion because of $Z_2 > Z_1$ and returns to the bottom surface of the #2 layer. Since the path difference between wave (I) and (II) is λ/2, the initial phases are inverted each other. Therefore, when both waves return to the bottom surface of the #2 layer, they are reverse phase. As a result, the amplitude of the wave decreases at #2 layer.

In Fig. 2(b), from $Z_2 > Z_1 > Z_0$, wave (III) is reflected at boundary #0/#1 with phase inversion and boundary #1/#2 without phase inversion. Alternatively, wave (IV) propagates to the top surface of #1 layer without phase inversion. Since the path difference between wave (III) and (IV) is λ/2, the initial phases are inverted each other. Therefore, when both waves reach the top surface of #1 layer, the amplitude of the wave increase because they are in phase.

Accordingly, the waves reflected at the junction boundary strengthen in the #1 layer where the acoustic impedance is small, and conversely weaken in the #2 layer. Since the amplitude on the #1 layer is relatively large, the result for the double layered resonator is slightly closer to the result for 129.55°Y (#1 layer) from the calculated one.

5. Summary

We investigated the influence of the reflected waves at junction boundary of the double layered resonator using α-quartz. For the case with thickness ratio of *x*=0.520, the layer with smaller acoustic impedance acts as a matching layer and acoustic energy in the layer increases. As a result, the temperature characteristics of the double layered resonator strongly reflects the characteristics of the layer with smaller acoustic impedance.

Reference

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