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Solidly Mounted Lamb Wave Resonators Using $LiNbO_3$ Thin Plates

$LiNbO_3$薄板を用いた音響多層膜型 Lamb 波共振子

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1. Introduction

Some devices using plate waves have been reported by several groups, but most of them are not suitable for filters/duplexers of mobile phone due to their low frequencies of up to 600MHz [1-7]. Recently, high frequency anti-symmetric A_1 mode Lamb wave resonators in $LiNbO_3$ have been reported by some of the authors, however they have a large phase velocity (Vp) dispersion for $LiNbO_3$ thickness, and their devices use fragile membrane structures [1-3].

This paper is focused on a symmetric S_0 mode Lamb wave in a $LiNbO_3$ substrate having almost no Vp dispersion for $LiNbO_3$ thickness, and composed of so-called solidly mounted resonator (SMR), that has been reported for thin film bulk acoustic film wave devices, in order to evade fragile structures.

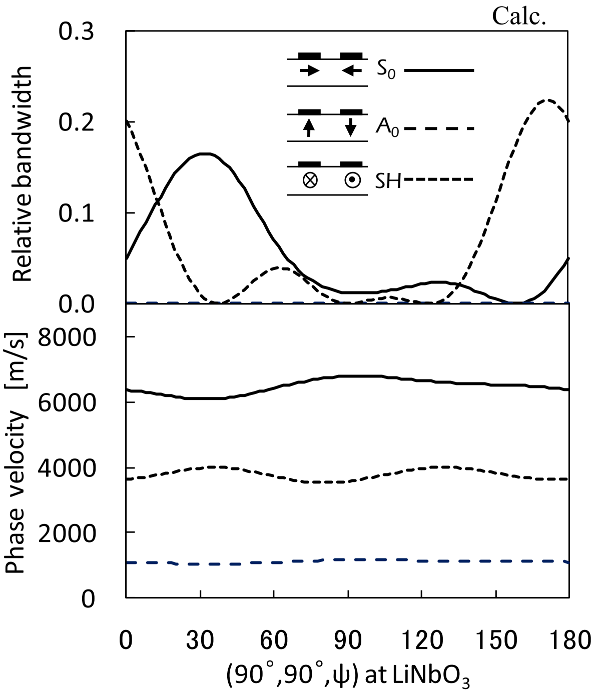


Fig. 1 Calculated plate wave characteristics in X-cut $LiNbO_3$.

2. S_0 mode Lamb wave in $LiNbO_3$

Lamb wave comprises several modes and the strongest excitation mode is depends mainly on a substrate orientation. Figure 1 shows dependence of Vp and bandwidth (BW) in X-cut $LiNbO_3$ as function of ψ at (90˚,90˚, ψ). It is seen that an S_0 mode Lamb wave is the strongest excitation mode, and a large BW can be obtained when ψ is about between 30˚ and 40˚, and the Vp is about 6000m/s at the ψ range. In addition, both BW of shear horizontal (SH) mode and A_0 mode are almost zero within the ψ range. That means that there is no unnecessary response due to spurious mode existences.

The Vp of the S_0 mode is 1.5 times faster than that of SH mode, and the S_0 mode has almost no Vp dispersion for $LiNbO_3$ thickness when the thickness is less than 0.4λ as shown in Fig. 2.

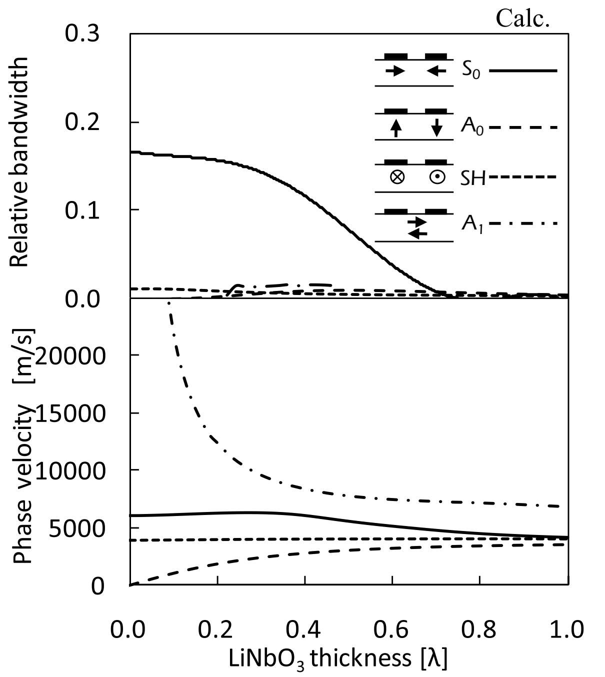
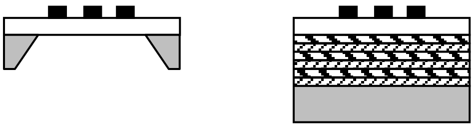


Fig. 2 Calculated $LiNbO_3$ thickness dependence of plate wave characteristics in (90˚,90˚,30˚) $LiNbO_3$.

3. Solidly mounted Lamb wave Resonator with Acoustic Quarter-Wave Multilayers

Lamb wave devices generally need a membrane structure, but it could be in danger of collapse. This time, solidly mounted Lamb wave resonators with acoustic quarter-wave multilayers were examined in order to obtain a stronger structure compared with a membrane one, as shown in Fig. 3.



(a) Membrane type (b) SMR type

Fig. 3 Cross sectional views of structures of Lamb wave resonators.

Figure 4 shows calculated characteristics of S_0 mode Lamb wave resonators with/without acoustic quarter-wave multilayers. The x-axis corresponds to the phase velocity which can simply be expressed in the product of frequency and wave length of IDTs (λ). AlN and SiO_2 films were alternately formed as acoustic quarter-wave multilayers on a fused silica substrate, and a thin $LiNbO_3$ plate with Al interdigital transducers (IDTs) was stacked on the multilayers. All thickness of the films and the $LiNbO_3$ plate were optimized as following: six layers composed of AlN(0.13λ)/SiO_2(0.09λ), $LiNbO_3$ plate of 0.07λ and Al-IDTs of 0.05λ and the orientation of the $LiNbO_3$ plate was (90˚,90˚,35˚). A frequency characteristic of a structure without acoustic quarter-wave multilayers was also shown as a comparison in Fig. 4. According to the calculation, it is shown that acoustic quarter-wave multilayers can function as acoustic bragg mirror to Lamb waves.

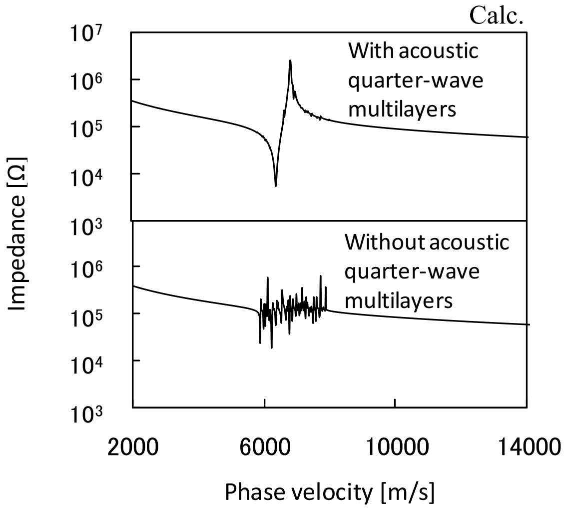


Fig. 4 Calculated characteristics of Lamb wave resonators with/without acoustic quarter-wave multilayers.

A one-port resonator was fabricated using above mentioned conditions, and detailed designs of Al-IDTs are following: λ=2.5μm, aperture =37.5μm, number of pairs of IDTs =60 and number of each grating reflectors=20.

Figure 5 shows a measured frequency characteristic of S_0 mode solidly mounted Lamb wave resonator. The impedance ratio at a resonant and an anti-resonant frequencies and the BW were 60dB and 6.4%, respectively. The resonant frequency was 2.41GHz, which corresponds to the phase velocity of 6025m/s.

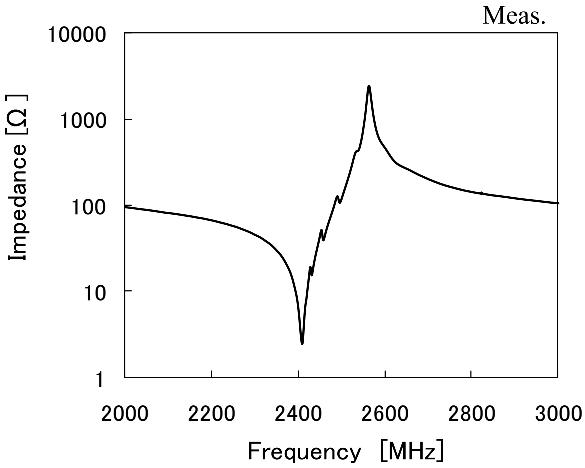


Fig. 5 Measured frequency characteristic of solidly mounted Lamb wave resonator.

4. Conclusions

As a result of calculation and measurement, good frequency characteristic of S_0 mode Lamb wave resonator was realized using X-cut thin $LiNbO_3$ plate with acoustic quarter-wave multilayers.

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