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Proceedings of Symposium on Ultrasonic Electronics, Vol. 37 (2016)

16-18 November, 2016

High-Coupling Leaky SAWs on $LiNbO_3$ or $LiTaO_3$ Thin Plate Bonded to High-Velocity Substrate

$LiNbO_3$・$LiTaO_3$薄板と高音速基板の接合によるリーキー系SAWの高結合化

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1. Introduction

Leaky surface acoustic waves (LSAWs) and longitudinal-type LSAWs (LLSAWs) have a larger electromechanical coupling factor K^2 and higher phase velocity than Rayleigh-type SAWs (R-SAWs). However, LSAWs and LLSAWs have inherent attenuation because they lose energy by continuously radiating bulk waves into the substrate. To solve this problem, we previously reported that the attenuation of LSAWs and LLSAWs can be reduced by loading with an aluminum nitride (AlN) thin film with a higher phase velocity than that of the substrate.[1,2] However, K^2 is reduced owing to the small piezoelectricity of the AlN thin film.

On the other hand, by bonding a sapphire (Al_2O_3) substrate to a $LiTaO_3$ (LT) substrate, temperature-compensated SAW filters have achieved practical use.[3] Thus, substrate structures combining various different materials have been studied to improve the SAW property. In this study, to obtain a substrate structure with a higher K^2, the propagation properties of LSAWs and LLSAWs on an LT or $LiNbO_3$ (LN) thin plate bonded to a high-velocity substrate were investigated theoretically and experimentally.

2. Theoretically Calculation

AT-cut quartz and *c*-plane Al_2O_3 (*c*-Al_2O_3) were employed as support substrates with a high phase velocity. First, the values of K^2 for an LSAW on a 36° *Y*-cut *X*-propagating LT (36° *YX*-LT) thin plate and an LLSAW on an *X*-cut 31° *Y*-propagating LT (*X*31° *Y*-LT) thin plate bonded to these support substrates were calculated. **Figures 1** and **2** show K^2 as a function of the normalized LT thin-plate thickness h/λ (λ: wavelength). Note that K^2 for the LSAW and LLSAW has a maximum value when the propagation direction of the AT-cut quartz is 90° *X*-propagating (90° *X*) and 45° *X*, respectively. As shown in Figs. 1 and 2, K^2 for the LSAW and LLSAW increased with increasing h/λ, and the values of K^2 were larger than those in the case of a single LT substrate. In particular, in the case of bonding to a quartz substrate, the values of K^2 for the LSAW and LLSAW were two and three times higher than those on a single LT substrate, respectively. Similar trends were observed for an LN thin plate.

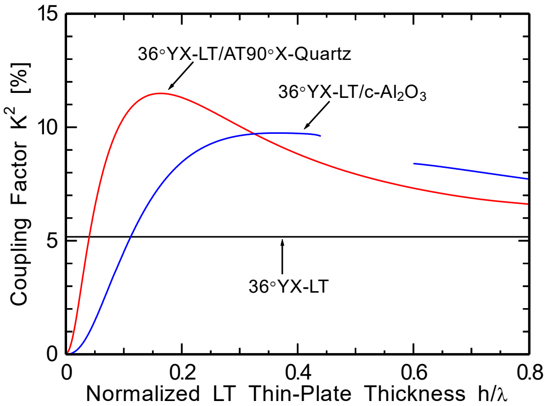

Fig. 1　K^2 for LSAW vs LT thin-plate thickness.

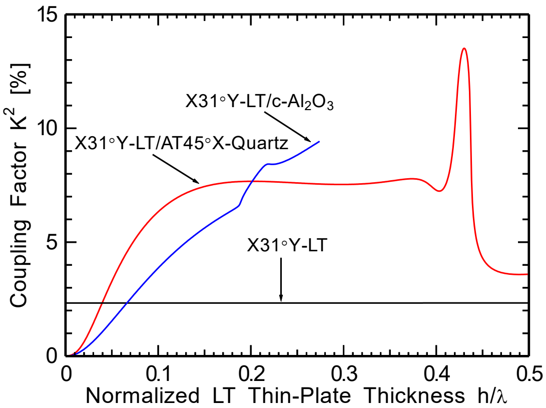

Fig. 2　K^2 for LLSAW vs LT thin-plate thickness.

Then, using the finite element method (FEM), the resonance properties in the case of forming an interdigital transducer (IDT)-type resonator having the parameters shown in **Table I** on an *X*36° *Y*-LN thin plate bonded to these substrates were analyzed. These simulations were performed with Femtet software (Murata Software). The LN thin-plate thickness h/λ was set to 0.20. **Figure 3** shows the simulation results. The admittance ratio and resonance *Q* of the bonded substrate were larger than those of the single LN substrate. Furthermore, large resonances at a lower frequency than that of the LLSAW were observed for the bonded substrate. Therefore, it is considered that an R-SAW and LSAW are highly coupled with the bonded structure.

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Table I. IDT-type resonator parameters.

Al thickness [Å]	1,000
Wavelength λ [μm]	8.0
IDT finger pairs N	30.5 (single)
Reflector number N_R	0
Aperture width W [λ]	25

Table II. IDT parameters.

Al thickness [Å]	1,000
Wavelength λ [μm]	8.0
IDT finger pairs N	10 (single)
Propagation length [λ]	5, 10, 25, 50
Propagation path	Metallized

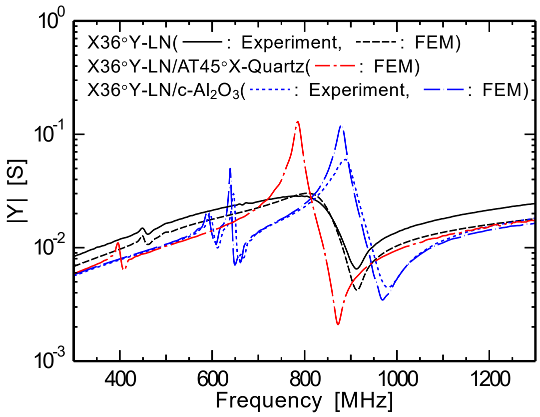

Fig. 3 Simulated and measured resonance properties.

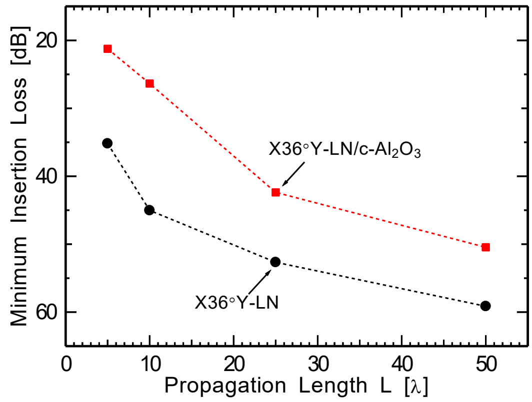

Fig. 4 Minimum insertion loss vs propagation length.

3. Experiment

After directly bonding a c-Al_2O_3 wafer and an X36° Y-LN wafer, the surface on the LN wafer side was polished and an IDT-type resonator with the parameters shown in Table I was fabricated using an Al thin film. The LN thin-plate thickness h/λ was set to 0.19. The resonance property was measured using a network analyzer and is shown in Fig. 3. It was found to be in good agreement with the FEM analysis results. The admittance ratio and resonance Q were increased from 12.9 dB and 4.1 for the single LN substrate to 22.6 dB and 22.4 for the bonded substrate, respectively. Furthermore, the values of K^2 for the single LN substrate and bonded substrate were determined to be 10.6 and 19.7% from the admittance property of a normal-type IDT (N=10) prepared at the same time, respectively.

Input and output IDTs with the parameters shown in **Table II** were fabricated on samples and the frequency response was measured. **Figure 4** shows the minimum insertion loss IL of the LLSAW as a function of the propagation length L. The minimum IL for the bonded substrate was less than that for the single LN substrate for all values of L. IL was approximated as the sum of the conversion loss CL, the bulk-wave radiation loss BL into the substrate from the IDT, and the propagation loss. The values of CL for the single LN substrate and bonded substrate were determined to be 6.9 and 6.5 dB from the measured admittance property, respectively. Therefore, it is considered that BL was lower for the bonded substrate. However, the minimum IL decreased nonlinearly with increasing L for both substrates. The property of the observed surface wave on the single LN substrate contained not only that of the LLSAW but also that of a surface-skimming bulk wave (SSBW).[1] Therefore, it is considered that an LLSAW and SSBW were simultaneously excited on the bonded substrate.

On the other hand, the values of K^2 for the R-SAW on the single LN substrate and bonded substrate were 0.35 and 1.58%, respectively. In addition, although no LSAW excitation was observed on the single LN substrate, it was observed on the bonded substrate (K^2=3.9%). From these results, the value of K^2 not only for an LLSAW but also for an R-SAW and LSAW was increased for the bonded structure.

4. Summary

In this study, we investigated LSAWs and LLSAWs on an LN or LT thin plate bonded with a high-velocity substrate. It was revealed that the resonance property was improved and K^2 was increased for the bonded structure. As the next step, we will experimentally investigate LSAWs and LLSAWs on thin plates bonded with other high-velocity substrates, the dependence of K^2 on h/λ, and the application of this structure to other SAW modes.

References

1. F. Matsukura and S. Kakio: Jpn. J. Appl. Phys. **53** (2014) 07KD04.
2. S. Kakio and K. Hosaka: Jpn J. Appl. Phys. **55** (2016) 07KD11.
3. M. Miura, T. Matsuda, M. Ueda, Y. Satoh, O. Ikata, Y. Ebata, and H. Takagi: Proc. IEEE Ultrason. Symp. (2005) 573.