1P3-8

Proceedings of Symposium on Ultrasonic Electronics, Vol. 34 (2013) pp. 145-146
20-22 November, 2013

Loss Reduction of Longitudinal-Type Leaky SAW by Loading with High-Velocity Thin Film

高音速薄膜装荷による縦型漏洩弾性表面波の低損失化

Fumiya Matsukura‡ and Shoji Kakio (Univ. of Yamanashi)
松倉 史弥‡，垣尾 省司 (山梨大院・医工)

1. Introduction

The longitudinal-type leaky surface acoustic wave (LLSAW) has attracted interrest for application to high frequency SAW devices owing to its high phase velocity close to that of a longitudinal bulk wave.[1)] However, it exhibits a large inherent attenuation owing to the continuous radiation of two types of bulk wave.

In our previous work, to reduce the attenuation of the LLSAW, we proposed loading with a dielectric thin film with a higher velocity than the substrate. It was found that the propagation properties of an LLSAW on an X-cut 36˚Y-$LiNbO_3$ (X36˚Y-LN) substrate, the propagation loss can be reduced by loading with an aluminum nitride (AlN) thin film from the sample without a film.[2)]

In this study, to achieve a further reduction of the attenuation of the LLSAW, the propagation properties of the LLSAW on an X36˚Y-LN substrate with an AlN thin film deposited by long-throw sputtering (LTS) which the substrate is not exposed to plasma directly, were investigated.

2. Sample Preparation

Using an RF magnetron sputtering system (ULVAC MPS-2000) with a long-throw sputter (LTS) cathode, an AlN thin film was deposited. In general, the LTS cathode can produce a thin film with a smooth surface under appropriate conditions, because the substrate is not exposed to plasma directly.

First, a simple delay line with a single-electrode interdigital transducer (IDT) pair with a period λ of 8 μm, an overlap length W of 50 λ, 30 finger pairs, and a propagation path with a length L of 5, 10, 25, or 50 λ were fabricated on X36˚Y-LN substrates using a 0.013-λ-thick Al film. Next, an AlN thin film was deposited on the IDT pair and the metallized propagation path. A metal aluminum target with a purity of 4N was used. The RF power applied to the cathode was 150 W. The gas flow ratio of Ar to N_2 was set to 30 : 15 ccm and the gas pressure was 0.75 Pa. The substrate temperature was set to 150 ˚C. Samples with film thicknesses (h) of 0.3-2.0 μm were fabricated.

g12me032@yamanashi.ac.jp

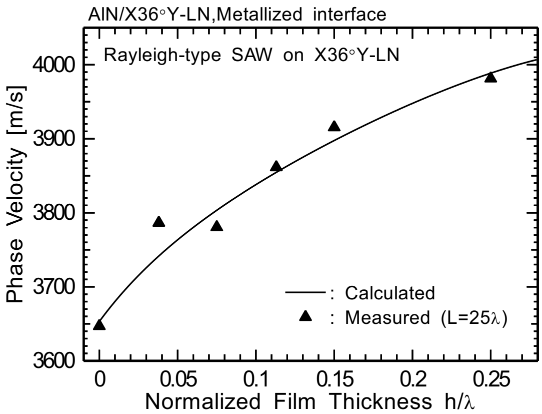

Fig.1 Phase velocity of R-SAW.

3. Elastic Constants of AlN Thin Film

To determine the elastic constants c_{11} and c_{44} of the AlN thin film, which were required for our theoretical calculation, a Rayleigh-type SAW (R-SAW) and an X36˚Y-LN substrate were chosen as the SAW mode and substrate, respectively.

The phase velocity of the R-SAW on X36˚Y-LN substrate was determined by multiplying the center frequency of the measured frequency response between the IDTs by λ and is plotted in **Fig. 1** for L=25 λ, as a function of the normalized film thickness h/λ. The phase velocity increased monotonically with the film thickness. Then, the elastic constants c_{11} and c_{44} of the AlN thin film were determined simultaneously to minimize the difference in the square of the errors between the calculated and measured phase velocities for the R-SAW. The calculated phase velocities are also shown in Fig. 1. From the above procedure, c_{11} and c_{44} were determined to be 2.10×10^{11} and 0.80×10^{11} N/m^2, which are 61 and 68% of those of a single-crystal AlN thin film,[3)] respectively. The phase velocity of a longitudinal bulk wave v_l on the AlN thin film was estimated to be approximately 8,000 m/s from the relationship $v_l=\sqrt{c_{11}/\rho}$, which is higher than that on the LN substrate.

4. Calculated Attenuation

Figure 2 shows the calculated attenuation of the LLSAW as a function of the normalized thickness h/λ for the metallized interface between the AlN thin film and the X36˚Y-LN substrate using

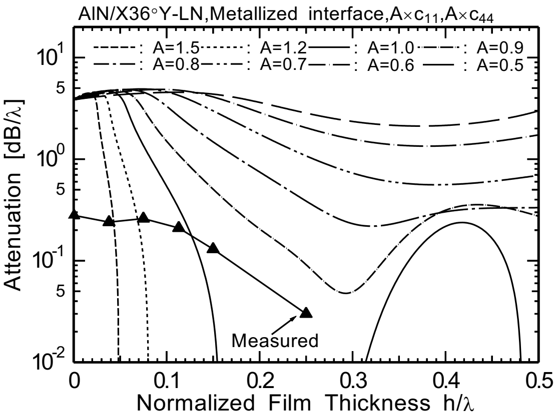

Fig.2 Calculated attenuation of LLSAW.

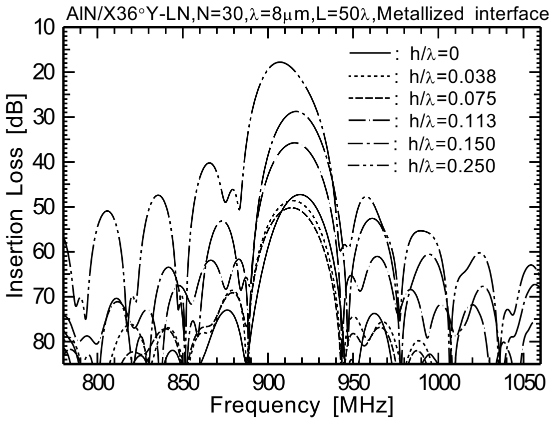

Fig.3 Frequency responses of LLSAW.

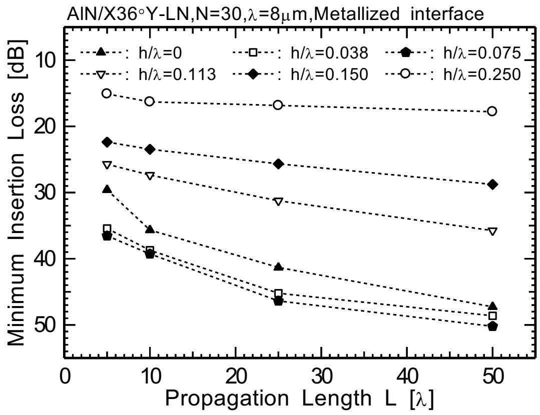

Fig.4 Minimum insertion loss vs propagation path length of LLSAW.

the determined elastic constants. Moreover, the attenuation, which was calculated using the material constants of Ac_{ij} changed by the parameter A from the determined elastic constants. The parameter A was set to values ranging from 0.5 to 1.5. When the parameter A was 1.0, the attenuation first increased and then decreased with increasing film thickness. It was found theoretically that an LLSAW without attenuation can be obtained at a film thickness above h/λ=0.16. Moreover, when the parameter A was below 0.8, the attenuation decreased with increasing film thickness, but zero attenuation was not obtained.

5. Measured Propagation Properties

Figure 3 shows the frequency responses of the LLSAW measured at around 900 MHz using a network analyzer for L=50 λ. The minimum insertion loss *IL* first increased and then decreased with increasing film thickness. When the film thickness was 0.250 λ, *IL* was 29.5 dB less than that of the sample without a film. Moreover, in comparison with the previous results (6.8 dB reduction at 0.175 λ),[2)] the significant reduction of *IL* was obtained.

Figure 4 shows the measured *IL* as a function of the propagation path length *L*. A nonlinear relationship between *L* and *IL* can be observed in all the samples in Fig. 4. This is due to the bulk radiation loss in the excitation of the LLSAW. Therefore, the propagation loss *PL* was considered to be slope of the line between *IL* for a path length of 50 λ and that for a path length of 10 λ. By loading with an AlN thin film with a thickness of 0.250 λ, *PL* was reduced from 0.28 dB/λ for the sample without a film to 0.03 dB/λ. Figure 2 also shows the experimental propagation loss of the LLSAW. In comparison with the calculated attenuation, the measured *PL* indicates a similar tendency. Therefore, it was found that the propagation loss was reduced by loading with an AlN thin film.

6. Conclusions

In this study, the propagation properties of an LLSAW on an X36°Y-LN substrate, in which an AlN thin film with a higher velocity than that of the substrate was loaded, were investigated theoretically and experimentally. It was found that the propagation loss can be reduced to approximately 1/10 by loading with an AlN thin film from the sample without a film. In the future, the utilization of an AlN thin film with a larger piezoelectricity will be investigated to prevent the reduction in K^2.

Acknowledgment

This work was supported by the Adaptable and Seamless Technology Transfer Program through Target-Driven R&D sponsored by the Japan Science and Technology Agency (JST).

References

1. T. Sato and H. Abe: Proc. IEEE Ultrason. Symp. (1995) 305–315.
2. F. Matsukura *et al.*: Jpn. J. Appl. Phys. **52** (2013) 07HD02.
3. K. Tsubouchi and N. Mikoshiba: IEEE Trans. Sonics and Ultrason. **SU-32** (1985) 634.