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3.5GHz LLSAW resonators on a composite substrate comprises a thin $LiNbO_3$ plate and multilayers

$LiNbO_3$ 薄板と多層膜とからなる複合基板上の縦波型漏洩弾性表面波を用いた 3.5GHz 共振子

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1. Introduction

A longitudinal leaky surface acoustic wave (LLSAW) on a piezoelectric substrate is attractive because of its higher phase velocity than conventional SAWs such as a Rayleigh wave on a 128°YX $LiNbO_3$ substrate and an SH-leaky wave on 36°-48°YX $LiTaO_3$ substrates[1,2].

In general, the LLSAW gives rise to non-negligible propagation loss caused by enery leakage as bulk waves into the substrate. A lot of studies, such as Refs.[1-7], have been attempted to improve the *Q*-value of the resonators. Nevertheless, achieved performances were limited.

One of the authors previously reported a 2.4 GHz LLSAW resonator on a composite substrate composed of a thin $LiNbO_3$ plate and SiO_2/AlN reflector stacked on a glass substrate[8]. However, due to relatively small reflectivity of the reflector, achieved impedance ratio and frtactional bandwidth were limited to 60 dB of 6.4%, respectively.

This paper proposes use of Pt instread of AlN in the reflector stack. This replacement enables significant enhancement of the reflecticity, and it results in drastic improvement of LLSAW device performances. The impedance ratio of 71 dB and the fractional bandwidth of 9.5% were simultaneously achieved experimentally at 3.5 GHz.

2. Wave guide structure

Figure 1 shows a proposed device structure for the LLSAW. The Euler angle and thickness of $LiNbO_3$ plate are (90°,90°,40°) and 0.2λ (λ is the IDT period), respectively. An acoustic multilayered mirror comprising SiO_2 films with 0.14λ thickness and Pt films with 0.09λ thickness are arranged between the thin $LiNbO_3$ plate and a silicon handle substrate.

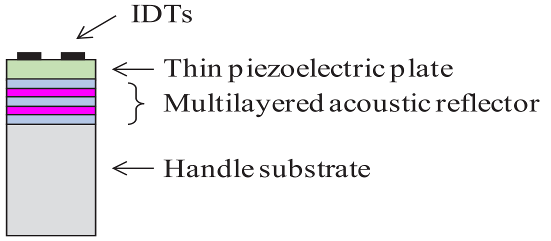

Fig.1 Proposed structure

Table 1 shows ratios of acoustic impedance between SiO_2 and Pt in conjunction with that between SiO_2 and AlN. Owing to large ratios, the SiO_2/Pt reflector is expected to offer much larger reflectivity than the SiO_2/AlN reflector which was used in the previous work[8].

Table 1 Acoustic impedance ratio

	SiO_2/Pt	SiO_2/AlN
longitudinal wave	6.5	2.6
transverse wave	4.3	2.4
	This work	Previous work[8]

Figure 2(a) shows the displacement distribution of the LLSAW in the proposed structure. The calculation was performed by an FEM at a resonance frequency. It is seen that wave energy is well confined in vicinity of the top surface, and its leakage to the substrate is hardly visible.

For comparison, **Fig. 2(b)** shows the result for the structure using the SiO_2/AlN reflector[8]. In this case, the wave energy penetrates deep into the reflector stack, and its leakage to the substrate is clearly seen. These properties are owed to

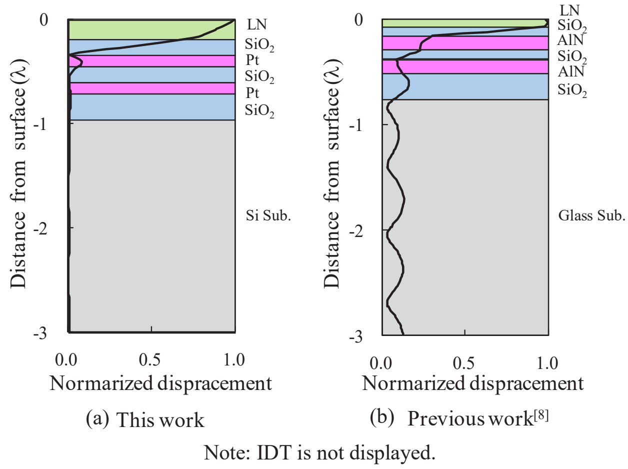

Fig.2 Calculated field distribution

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insufficient reflectivity of the SiO_2/AlN reflector.

From this result, the proposed structure is expected to offer the Q value much better than the previous one.

3. Experiment

An LLSAW resonator was fabricated by using a composite substrate comprised of a thin $LiNbO_3$ plate at Euler angle of (90°,90°,40°) with 340 nm thickness and a stacked reflector on a silicon substrate. The reflector consists of five alternating layers having a SiO_2 film with 238 nm thickness as a low acoustic impedance layer and a Pt film with 153 nm thickness as a high acoustic impedance layer.

Al-IDTs with 80 nm thickness were fabricated on the composite substrate by a lift-off process. The pitch of IDT electrodes (the pitch equals to 0.5λ) was 0.86 μm, and the number of IDT finger pairs and aperture length were 100 and 25.5 μm, respectively. Twenty grating reflectors were also placed at both sides of the IDT.

4. Results and discussion

Figure 3 shows an impedance curve of the fabricated resonator measured by a network analyzer. Spurious-free single-mode resonance is seen at 3.55 GHz, and the impedance ratio of 71 dB and fractional bandwidth of 9.5% are obtained in such a high frequency.

Figure 4 shows measured Smith-chart of the resonators. The resonator reported in the previous work[8] is also shown in the chart. Comparison between these two results reveals how the present result is superior to the previous one, even the resonance frequency of this work is 47% higher than that of previous one.

From the resonance frequency, the phase velocity of the LLSAW is estimated as 6,035 m/s, which is approximately 1.5 times larger than those of the Rayleigh SAW on the 128°YX $LiNbO_3$ and the SH-leaky SAW on 36°-48°YX $LiTaO_3$. This indicates that 3.5 GHz SAW devices can be mass produced by using conventional manufacturing facilities for 2 GHz SAW devices, and further fine pitch process is not necessary.

Conclusions

This paper proposed the new configuration for suppression of the energy leakage in LLSAW resonators. First, it was shown theoretically that the configuration comprised of the thin $LiNbO_3$ plate and the SiO_2/Pt reflector on the Si substrate exhibits excellent confinement of LLSAW energy in the vicinity of the top surface. Then the 3.5 GHz LLSAW resonator was fabricated by using conventional manufacturing facilities, and it was shown that achievable performances are much superior to those reported in the previous work. From the results, we can conclude that the structure is promising for realization of high performance SAW filters and duplexers in the 3 GHz range.

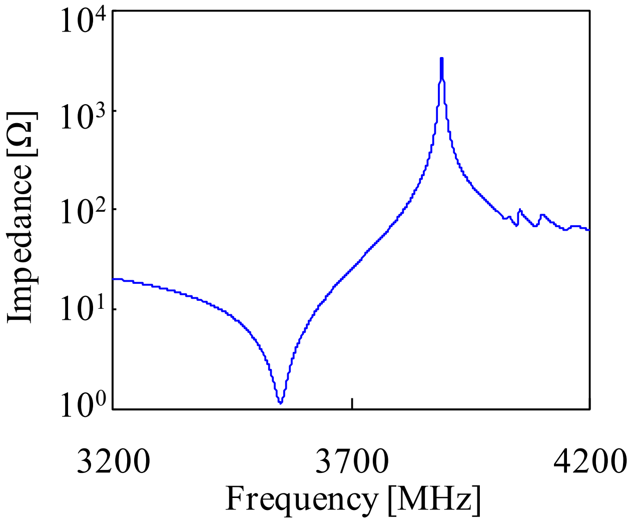

Fig. 3 Measured impedance curve

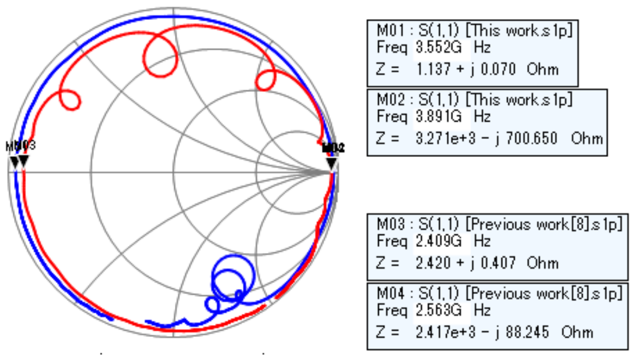

Fig. 4 Measured Smith-chart. The blue line: present result and the red line: the result given in previous work[8].

References

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