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5.4 GHz Lamb Wave Resonator using $LiNbO_3$ Crystal Thin Plate and Application to Tunable Filter

$LiNbO_3$ 単結晶薄板を用いた 5.4GHz ラム波共振子とその応用

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1. Intorduction

In recent years, a high-frequency device of 3 GHz or more, for instance, for a fourth generation mobile phone system in Japan, has been required[1]. It is proper to use the a 1-st anti-symmetric (A1) mode of a Lamb wave with a high velocity in order to realize a high frequency acoustic device and to use a substrate with large electromechanical coupl-ing factor in order to realize a wide band acoustic device. As such device, authors realized a 4.5 GHz high frequency Lamb wave resonator on an elect-rode/c-orientated twin epitaxial $LiNbO_3$ thin film /air gap/base substrate structure like MEMS depo-sited by chemical vapor deposition method (CVD) in 2008[1,2]. Conventionally it is considered that it is difficult to realize a very thin crystal plate for a high frequency Lamb wave device. This time, the author tried to fabricate a high frequency Lamb wave resonator on a very thin Z-$LiNbO_3$ crystal plate instead of a thin $LiNbO_3$ film and apply it to a ladder type of tunable filter.

2. Lamb wave resonator

A Z-$LiNbO_3$ substrate glued on a Si substrate was ground and polished to be a very thin Z-$LiNbO_3$ plate. After an air-cavity was fabricated on the back side of Si substrate by chemical etching, an Al-interdigital transducer (IDT) and Al-grating reflectors at both side of the IDT were formed on the surface of the Z-$LiNbO_3$ thin plate/Si substrate structure. The Lamb wave one-prt resonator com-posed of the Al-electrodes/ZX-$LiNbO_3$ crystal thin plate/air cavity/Si substrate is shown above in Fig.1. The IDT of a wavelength λ of 2.63 has 60 pairs and each grating reflector has 20 fingers. The thickness of the $LiNbO_3$ single crystal plate is 0.15λ (actual thickness of 395 nm). Figure 1 shows the frequency characteristics of the Lamb wave resonators. It shows a good characteristic such as high resonant frequency (fr) of 5.44 GHz, which corresponds to a high velocity of 14,000 m/s, a high anti-resonant frequency (fa) of 6.09 GHz, a wide relative band width of 12 %, and an large impedance ratio of 62 dB at fr and fa. On the other hand, though the mechanical Qr at fr and Qa at fa are not high as 70 and 560, respectively, because the electromecha-nical coupling factor is large and the relative band width is wide. Figure of merits Mr at fr and Ma at fa are 18 and 140, respectively. Compared with Qa and Ma, Qr and Mr are small, because the Al thickness is thin and resistance loss is large. They could be improved by thickening the Al-electrode. This resonator has a large spurious response due to a 0-th shear horizontal (SH0) mode at 1.5 GHz, though the Lamb wave resonator composed of the twin epitaxial $LiNbO_3$ film reported by the authors does not have[1,2]. Because the latter resonator is composed of the twin epitaxial $LiNbO_3$ film[1,2]. In the several applications of the Lamb wave on the ZX-$LiNbO_3$ crystal thin plate, this spurious respo-nse should be suppressed. The authors have reported the 5.4 GHz high frequency Lamb wave device on the $LiNbO_3$ crystal thin plate for the first time. It is considered that this is the first report concerning a high frequency Lamb wave device using a crystal plate higher than 5 GHz.

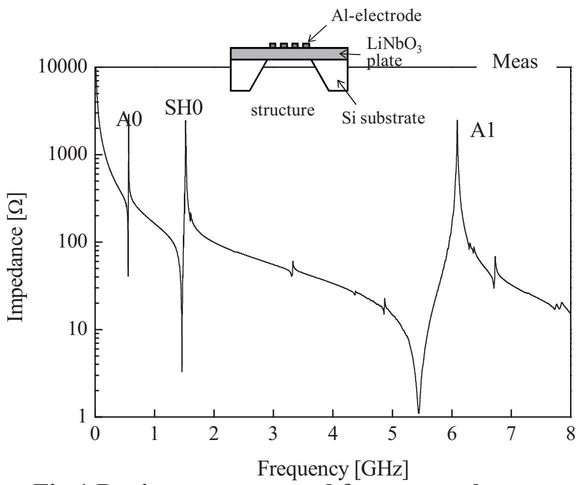

Fig.1 Device structure and frequency charac-teristic of Lamb wave resonator on $LiNbO_3$ plate/Si.

3. Application to tunable filter

Tunable filters composed of the band pass type or the ladder type structures using SAW resonators with the relative wide bandwidth of 12-17 % were reported[3,4,5]. They were operated lower than 2 GHz. In this paper, the authors simulate the characteristic of the tunable filter composed of the ladder type shown in Fig.2 using the Lamb wave resonators on

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the $LiNbO_3$ thin crystal plate/Si. An usual ladder type filter is designed as shown in Fig. 3(a) by corresponding the resonant frequencies (fr) of the series arm resonators to the anti-resonant ones (fa) of parallel arm resonators. In this case, the ladder filter with a very wide band is obtained as shown in Fig.3(a). This time, the ladder type filter has the frequency arrangement shown in Fig.3(b). Each resonant and anti-resonant frequencies shift by changing the values of the addition capacities shown in Fig.3(b). As a result, the tunable filter changing a center frequency is composed. Figure 4 shows the frequency characteristics. As a result, tunable filter having tunable ranges of 9 % at the center frequency 5.8 GHz and 3 dB bandwidths of 60 to 100MHz (1.1 to 1.9%) have been realized theoretically. The insertion loss could be improved by optimizing the impedance matching.

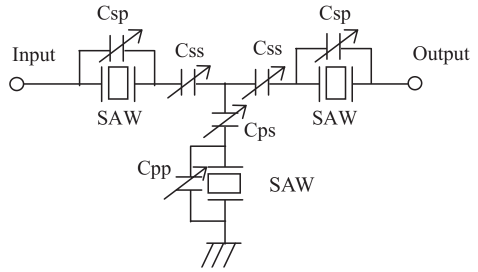

Fig.2 Ladder type filter to construct tunable filter.

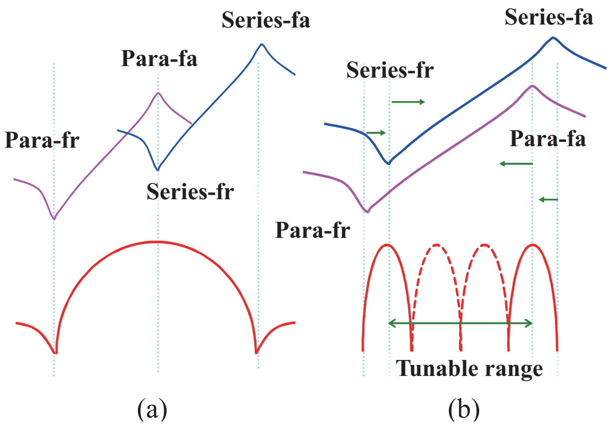

Fig.3. Frequency arrangement for ladder type filter (a) conventional arrangement and (b) arrangement for tunable filter.

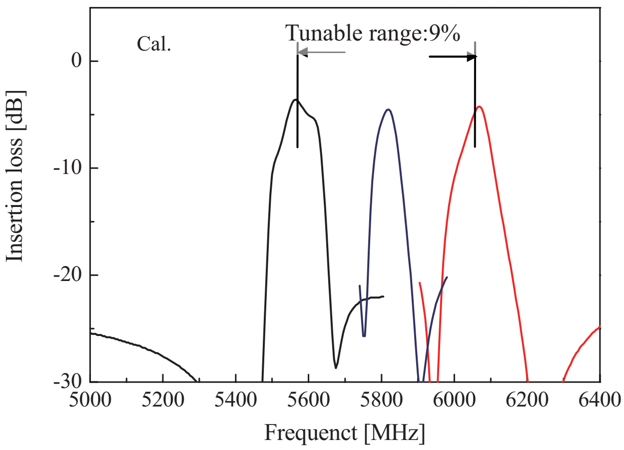

Fig.4 Frequency characteristics of tunable filter composed of ladder type.

4. Conclusion

The 5.4 GHz high frequency Lamb wave resonator composed of the MEMS structure was fabricated by using the $LiNbO_3$ crystal thin plate on Si substrate for the first time. It shows good frequency characteristics such as a high fr of 5.44 GHz, a high fa of 6.09 GHz, a large impedance ratio at fr and fa of 62 dB, a wide band of 12 %, and figure of merit of Mr of 18 and Ma of 140. Though the 4.5 GHz Lamb wave resonator composed of the epitaxial twin crystalline $LiNbO_3$ thin film reported by the authors doesn't have the spurious response due to the SH0 mode, the 5.4 GHz Lamb wave resonator on LiNbO3 crystal thin plate/air cavity/Si has the large spurious response. Because the former resonator is composed of the twin epitaxial $LiNbO_3$ film. In the several applications of the Lamb wave on the ZX-$LiNbO_3$ crystal thin plate, the spurious response due to the SH0 mode should be sup-pressed.

As a result applying the Lamb wave resonators to the tunable filter, the tunable filter having tunable ranges of 9 % at the center frequency 5.8 GHz and 3 dB bandwidths of 60 to 100 MHz (1.1 to 1.9 %) have been realized theoretically.

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Reference

1) M. Kadota, T. Ogami, K. Yamamoto, and H. Tochishita: Proc. IEEE Ultrasonic. Symp.,p.1940 (2008).
2) M. Kadota, T. Ogami, K. Yamamoto, H. Tochishita and Y. Negoro: Jpn. J. Appl.Phys., vol.48, 07GG08-1-4, 2009.
3) M. Kadota, T. Kimura and Y. Ida: Proc. IEEE Ultrasonic. Symp., p.2668(2009).
4) M. Kadota, T. Kimura and Y. Ida: Jpn. J. Appl.Phys., vol.49, 07HD26, 2010.
5) T. Komatsu, K. Hashimoto, T. Omori, and M. Yamaguchi: Jpn. J. Appl.Phys., vol.49, 07HD24, 2010.