3P3-7

Proceedings of Symposium on Ultrasonic Electronics, Vol. 30 (2009) pp. 489-490
18-20 November, 2009

Development of High Coupling Coefficient SAW Resonator on Ta_2O_5/Al/$LiNbO_3$ Structure

Ta_2O_5/Al/$LiNbO_3$ 構造を用いた高結合係数 SAW 共振器の開発

Hidekazu Nakanishi‡, Hiroyuki Nakamura, and Rei Goto (Panasonic Electronic Devices Co., Ltd.)
中西秀和‡，中村弘幸，後藤令　(ﾊﾟﾅｿﾆｯｸ ｴﾚｸﾄﾛﾆｯｸﾃﾞﾊﾞｲｽ㈱)

1. Introduction

The surface acoustic wave (SAW) duplexer is a key device of mobile phones for miniaturization and high performances. In the universal mobile telecommunication system (UMTS), Band IV system has the largest duplex gap of 355 MHz. Therefore, to realize the duplexer with small size, low insertion loss, and high attenuation, the SAW resonator having very high coupling coefficient (K^2) is required. Recently, a combination of the low cut angle Y-cut $LiNbO_3$ substrate and SiO_2 film[1)] and a combination of a 15°YX-$LiNbO_3$ substrate and a Cu electrode[2)] for wideband applications are reported. For the duplexers with wide duplex gap, a flattened SiO_2 film /Cu electrode/$LiNbO_3$ structur[3)] and a shape controlled SiO_2 film /Al electrode/$LiNbO_3$ structure[4,5)] were reported. On the other hands, the approach of using Ta_2O_5 film has never been reported. In this report, we developed the high K^2 SAW resonator on a Ta_2O_5/Al/$LiNbO_3$ structure.

2. Structure of SAW resonator with Ta_2O_5 film

We employed the 1-port resonator as a test device. **Fig.1** shows a cross-sectional view of the Ta_2O_5/Al/$LiNbO_3$ structure. Above the IDT electrodes, the Ta_2O_5 film is deposited by RF sputtering. The piezoelectric substrate is a 5°YX-$LiNbO_3$ substrate. The IDT electrodes consist of Al-alloy. The Al electrode thickness is 160 nm (0.08λ). Regarding the SAW resonator structure, a pitch of the IDT electrodes is 1.0 μm. The number of the IDT electrodes and the reflector electrodes are 150 and 30, respectively. And, aperture length is 25 μm.

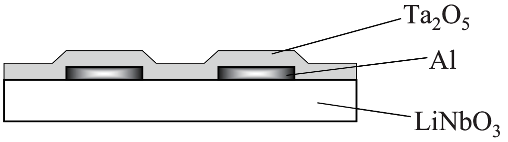

Fig. 1 Cross sectional view of Ta_2O_5/Al/$LiNbO_3$ structure

3. Characteristics of SAW resonator with Ta_2O_5 film

Fig.2 shows the admittance (Y_{11}) of SAW resonator dependence of Ta_2O_5 thickness. Some spurious responses appearing between the resonant and the antiresonant frequencies are due to transverse-mode in Fig.2. **Fig.3** shows the dynamic range of Y_{11} as a function of the Ta_2O_5 thickness. **Fig.4** shows the phase velocity at resonant and antiresonant frequency as a function of the Ta_2O_5 thickness. The phase velocity is calculated by multiplying resonant or antiresonant frequency by IDT pitch on each resonator. And, dashed-line is the phase velocity of slow shear wave of the $LiNbO_3$ substrate.

As shown Fig.2, the characteristic of SAW resonator without Ta_2O_5 film degrades. Especially, an attenuation at antiresonant frequency degrades. And, as shown Fig.3, the dynamic range of Y_{11} is very small. On the other hand, the characteristic of SAW resonator with Ta_2O_5 film does not degrade at antiresonant frequency. Because, as shown Fig.4, when the Ta_2O_5 thickness becomes more than 0.0125λ, the phase velocity at antiresonant frequency becomes slower than the phase velocity of slow shear wave of the $LiNbO_3$ substrate. So, the bulk radiation does not occur. However, the dynamic range of Y_{11} decreases as the Ta_2O_5 thickness increases. Therefore, the optimum thickness of Ta_2O_5 is determined in views of the dynamic range of Y_{11} and the Rayleigh-mode spurious response.

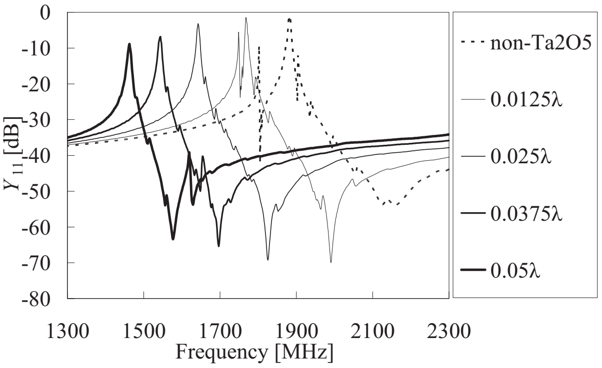

Fig. 2 The admittance (Y_{11}) of SAW resonator dependence of Ta_2O_5 thickness

---

nakanishi.hidekazu@jp.panasonic.com

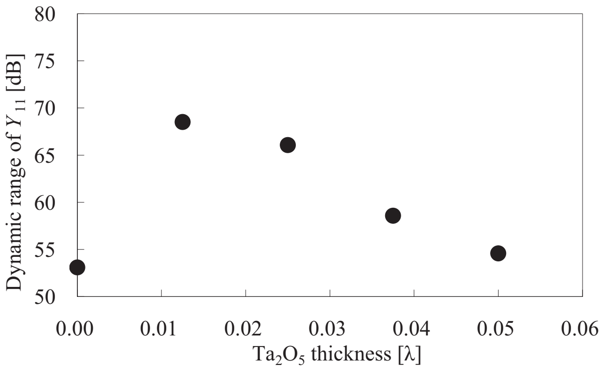

Fig. 3 Dynamic range of Y_{11} as a function of the Ta_2O_5 thickness

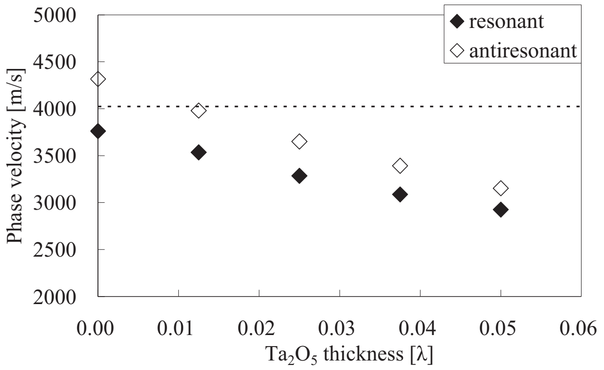

Fig. 4 Phase velocity at resonant and antiresonant frequency as a function of the Ta_2O_5 thickness

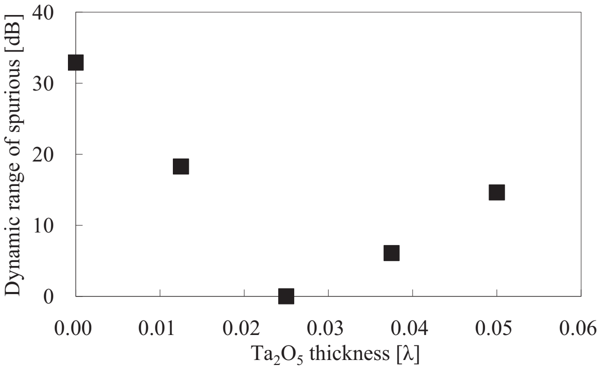

Fig. 5 Dynamic range of Rayleigh-mode spurious response as a function of the Ta_2O_5 thickness

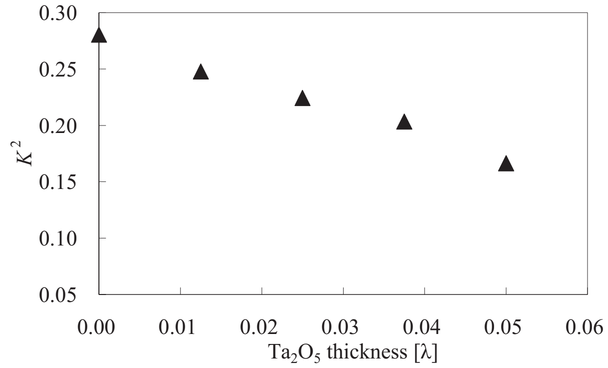

Fig. 6 K^2 as a function of the Ta_2O_5 thickness

3. K^2 and Rayleigh-mode spurious response of SAW resonator dependence of the Ta_2O_5 thickness

We investigated the level of Rayleigh-mode spurious response and the K^2 dependence of the Ta_2O_5 thickness. **Fig.5** shows the dynamic range of Rayleigh-mode spurious response as a function of the Ta_2O_5 thickness. **Fig.6** shows the K^2 as a function of the Ta_2O_5 thickness. As shown Fig.5, the dynamic range of Rayleigh-mode spurious response becomes zero when the Ta_2O_5 thickness is 0.025λ. In addition, the dynamic range of Y_{11} has sufficient value. And, as shown Fig.6, although the K^2 decreases as the Ta_2O_5 thickness increases, the K^2 is very high of 23%. We have cleared the optimum Ta_2O_5 thickness to realize the high performance SAW resonator without Rayleigh-mode spurious response.

4. Conclusion

We have established the SAW resonator on Ta_2O_5/Al/5°YX-$LiNbO_3$ structure for wide duplex gap application. The SAW resonator shows the excellent performance with high K^2. The SAW resonator could be applied sufficiency for Band IV duplexer. Moreover, the density of Ta_2O_5 is higher than that of SiO_2. So the Ta_2O_5 thickness, which the bulk radiation does not occur, is thinner comparing with the SiO_2 thickness.

References

1. K. Yamanouchi, Y. Satoh, H. Isono and D. Kawasaki: Jpn. J. Appl. Phys. **44** (2005) 4520.
2. K. Hashimoto, H. Asano, T. Omori, and M. Yamaguchi: Jpn. J. Appl. Phys. **43** (2004) 3063.
3. M. Kadota, T. Nakao, K. Nishiyama, S. Kido, M. Kato, R. Omote, H. Yonekura, N. Takada and R. Kita: Jpn. J. Appl. Phys. **46** (2007) 4714.
4. H. Nakamura, H. Nakanishi, T. Tsurunari, K. Matsunami, Y. Iwasaki, K. Hashimoto and M. Yamaguchi: Jpn. J. Appl. Phys. **47** (2008) 4052.
5. Hidekazu Nakanishi, Hiroyuki Nakamura, Tetsuya Tsurunari, Hiroki Kamiguchi, Yosuke Hamaoka, Rei Goto, and Yukio Iwasaki: Jpn. J. Appl. Phys. **48** (2009) 07GG04.