Ultra-low profile and high heat dissipation multi-layered SAW device employing sapphire substrate

Ryohei Komiyama1[1†], Takayuki Suzuki, Masayuki Kitajima, and Motoi Yamauchi
([1]TAIYO YUDEN Mobile Technology Co., Ltd.)

1. Introduction

Recently, the increasing complexity of telecommunication systems requires surface acoustic wave (SAW) filters further improvement of performance and integration. The power handling is one of the most important performance. However, miniaturization of devices means a decrease in a heat dissipation due to a decrease in the surface area of the devices. Therefore, it is becoming more and more important to develop a structure that can achieve both miniaturization and heat dissipation. Our group developed $LiTaO_3$/sapphire bonded substrate technology [1)] to improve temperature coefficient of frequency (TCF) and heat dissipation. We also developed metal sealed package named chip size saw device (CSSD) [2,3)], a high heat dissipation and compact package technology. Furthermore, the combination of $LiTaO_3$/sapphire bonded substrate and CSSD has shown improved power durability [4)].

Then the purpose of this paper is to propose direct-mount type ultra-low profile multi-layered SAW device employing a sapphire substrate. First, we describe the use of high-strength multi-layered sapphire substrates to achieve a low profile. Then, we fabricated the direct-mount type multi-layered SAW device and performed power linearity tests to demonstrate the improvement of heat dissipation and power durability.

2. Structure of the direct-mount type package

Firstly, we show the differences between the direct-mount type package and conventional CSSD. Fig. 1 (a) shows a cross-sectional view of the CSSD on printed circuit board (PCB). It is a face-down package consists of a ceramic package and a metal sealing. The direct-mount type package is face-up type as shown in Fig. 1 (b). SAW resonators are covered with a metal sealing.

3. Realization of ultra-low profile by utilizing sapphire substrate

We have developed a multi-layered SAW device consisting of a thin $LiTaO_3$, a sapphire support substrate and an intermediate layer. Fig.2 shows cross-sectional view of the multi-layered SAW substrate. The thinner LT (less than 1um) improves the die resistance to cracking, since most of the die volume is made up of rigid sapphire. We simulated the die break pressure to demonstrate the advantage of a sapphire substrate over a silicon substrate using finite element simulation. The die break pressure is calculated from maximum tensile stress of $LiTaO_3$, intermediate layers and a support substrate using the simulation model shown in Fig. 3. Fig. 4 shows the simulation results. For all thicknesses, $LiTaO_3$ failed first when silicon substrate is used, while sapphire failed first when sapphire substrate is used. From the simulated die break pressure, it can be predicted that sapphire can be made 36.2% thinner than silicon.

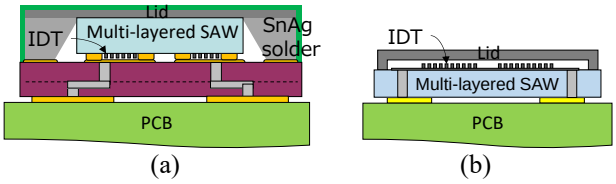

Fig. 1 Cross-sectional view of (a) conventional SAW device (CSSD) and (b) proposed multi-layered SAW device on printed circuit board

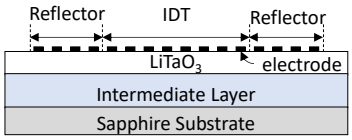

Fig. 2 Cross-sectional view of the multi-layered SAW substrate.

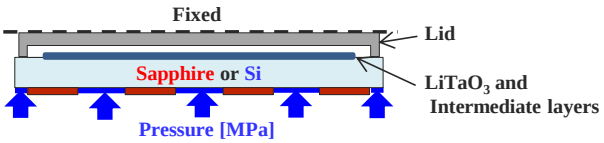

Fig. 3 Schematic diagram of cross-sectional view of simulation model.

E-mail: †komiyama.ryohei@jmty.yuden.co.jp

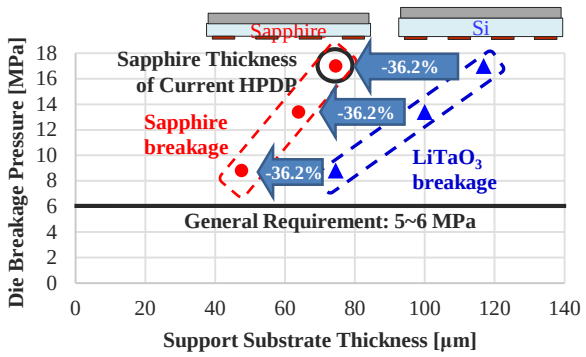

Fig. 4 Simulation result of load die breakage pressure

4. Heat dissipation improvement by direct mount type package

The direct-mount type device also increases a heat dissipation when a high power electric signal is applied. In addition, the thinner substrate further enhances heat dissipation by shortening the heat dissipation path. To demonstrate the heat dissipation, we fabricated ladder filters with the same inter digital transducers (IDTs) design with both the conventional and the proposed structure, and conducted power linearity tests. CP-OFDM, 100% duty cycle signal applied to the high-frequency edge of the passband at ambient temperature of 50 degrees Celsius. Fig. 5 shows the measured passband characteristics and the estimated temperature rise from frequency drifts and TCF in each input power. Frequency drift is suppressed in the proposed structure compared to the conventional structure. The Pin-Pout characteristic is improved, and while the conventional structure shows breakdown at 32dBm, the proposed structure does not breakdown even at 35dBm.

5. Conclusions

We demonstrated the height reduction and the heat dissipation improvement of the direct-mount type multi-layered SAW device employing sapphire substrate. By using this structure, ultra-low profile SAW device and the power linearity with no breakage up to 35dBm are confirmed.

Acknowledgment

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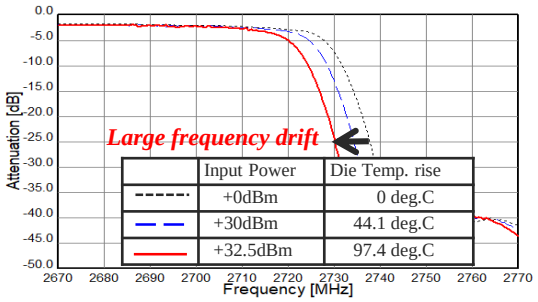
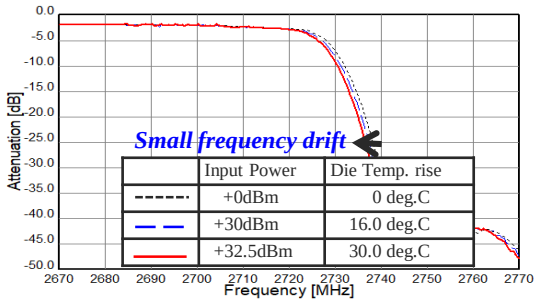


(a)



(b)

Fig. 5 Measured passband characteristics and estimated die temperatures of (a) CSSD and (b) proposed structure.

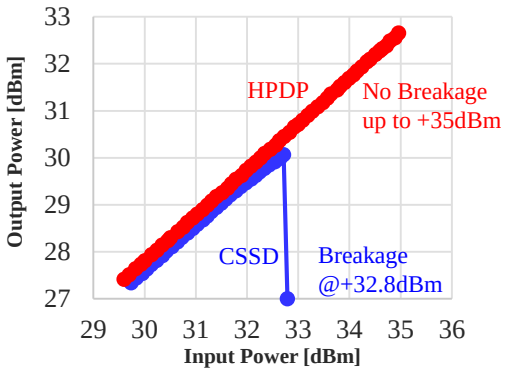


Fig. 6 Measured power linearity test results.

References

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