유리 기판과 패인 홈 모양의 홀을 갖는 웨이퍼를 이용한 웨이퍼 레벨 패키지

論 文
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Wafer Level Package Using Glass Cap and Wafer with Groove-Shaped Via

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Abstract - In this paper, we propose a new wafer level package (WLP) for the RF MEMS applications. The Film Bulk Acoustic Resonator (FBAR) are fabricated and hermetically packaged in a new wafer level packaging process. With the use of Au-Sn eutectic bonding method, we bonded glass cap and FBAR device wafer which has groove-shaped via formed in the backside. The device wafer includes a electrical bonding pad and groove-shaped via for connecting to the external bonding pad on the device wafer backside and a peripheral pad placed around the perimeter of the device for bonding the glass wafer and device wafer. The glass cap prevents the device from being exposed and ensures excellent mechanical and environmental protection. The frequency characteristics show that the change of bandwidth and frequency shift before and after bonding is less than 0.5 MHz. Two packaged devices, Tx and Rx filters, are attached to a printed circuit board, wire bonded, and encapsulated in plastic to form the duplexer.
We have designed and built a low-cost, high performance, duplexer based on the FBARs and presented the results of performance and reliability test.

Key Words : wafer level package (WLP), RF MEMS, Au-Sn eutectic bonding, FBAR (Film Bulk Acoustic Resonator).

1. Introduction

According to the recent trend wherein mobile communication terminals have tended to become much leaner, enhanced and diversified in their quality and functions. Moreover, techniques related with constituent components of the mobile communication terminals, for example radio frequency (RF) components, are rapidly being developed [1]. Among the RF components, especially, an FBAR (film bulk acoustic wave resonator) is in the spotlight as an essential passive filter component of the mobile communication terminals by virtue of its advantages in that it has a lower insertion loss than other filters, and it can achieve a desired level of integration and miniaturization. In order to achieve miniaturization in mobile communication products, it is necessary to reduce the overall size of a micro device package [2].

When comparing SAW (on $LiTaO_3$, $LiNbO_3$, Quartz, etc.) with FBAR (on Silicon), FBAR is a very useful solution of duplexers and RF filters because the wafer level package structure can be made by etching away the silicon substrate. By using device etch process, via connector could be fabricated, which can improve an overall yield by simplifying a process related with wafer level package such as a cap wafer. [3].

We developed the wafer level package using glass cap and silicon wafer with grooved shaped via to prevent the increase of size and cost. One major benefit is that other MEMS components can be integrated on the newly developed WLP.

2. Concept

The cross sectional schematic view of Fig. 1 shows the new package with glass cap. The packaging process is proceeded as wafer level using an Au-Sn bonding between glass cap and FBAR device wafer. The glass cap wafer prevents the FBAR device wafer from being exposed and ensures excellent mechanical and environmental protection. The cap wafer can be made of various materials, such as high resistance silicon, quartz, but a glass wafer is very useful to observe a device

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wafer after bonding process. The device wafer includes electrical bonding pads and groove-shaped via for driving the device [4].

The grooves onto the FBAR device wafer backside achieve a complete protective enclosure for each die. Contacts and pads are deposited by gold. The reliability of the glass cap and bonding material is good, as it allows to withstand conventional back-end processing, such as dicing, wire bonding and transfer molding.

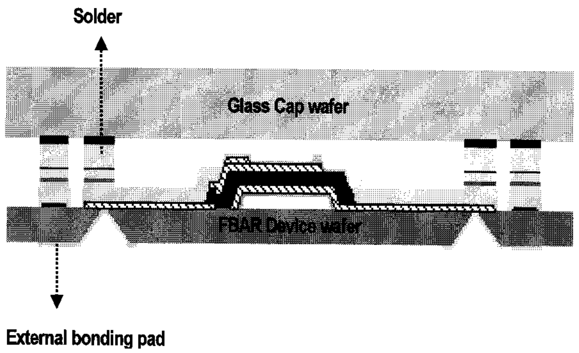


Fig. 1 Cross-sectional view of the FBAR WLP with electrical bonding pads and via connectors

3. Fabrication

The schematic view of the process flow of WLP with glass cap is shown in Fig. 2.

The fabrication process begins by glass wafer as cap wafer without forming a cavity, as shown in Fig. 2 (a). To eliminate the etching process of cap wafer, the solder material is deposited and lifted off (> 6um thick), as shown in Fig. 2 (b). The solder material including Au and Sn is a good solution for commercial production because it has a large process window.

To make FBAR, we used an aluminum nitride (AlN) as a piezoelectric material and molybdenum (Mo) as electrode material and poly silicon is used as a sacrificial material for the air gap, which was removed by XeF_2 dry gas, as shown in Fig. 2 (c).

A glass cap wafer is bonded to the active side of device wafer with the Au-Sn eutectic bonding method. Lapping and polishing is used to make about 250 μm thickness [Fig. 2 (d) ~ (e)].

After wafer bonding, to etch away silicon material, we used silicon oxide as masking material. The groove-shaped via are fabricated by KOH wet etch. Dry etching process was applied to remove the oxide layer to allow an electrical via contact serially. And then, external bonding pads are formed by lift off process on the backside of the FBAR device wafer and were connected to the bonding pads through the groove-shaped via, respectively. The created metal pads can serve as pads for wire bonding. After dicing, the WLP filters are ready for assembly [Fig. 2 (f) ~ (h)].

Two dice, Tx and Rx packaged filters, are attached to a printed circuit board, wire bonded, and encapsulated in plastic to form the duplexer.

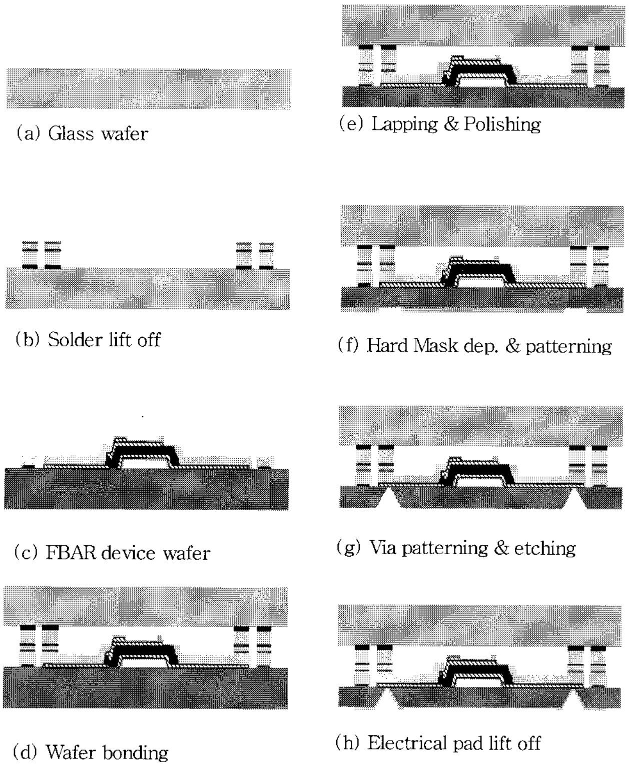
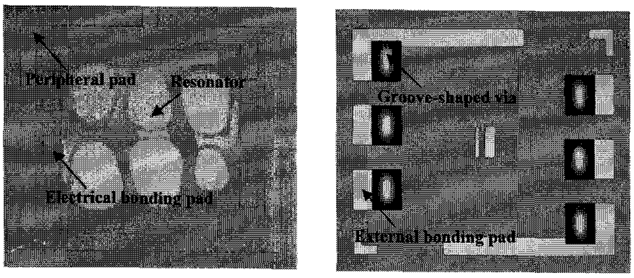

(a) Glass wafer
(b) Solder lift off
(c) FBAR device wafer
(d) Wafer bonding
(e) Lapping & Polishing
(f) Hard Mask dep. & patterning
(g) Via patterning & etching
(h) Electrical pad lift off

Fig. 2 Fabrication process of the FBAR WLP with electrical bonding pads and via connectors

3. Results and discussion

Optical microscope images of a real packaged filter with a glass cap can be seen in Fig. 3. The transparent glass cap encases the filter die in a solid protecting optically clear enclosure. An Tx filter used in the USPCS duplexer is about 900×750×250 μm^3 and is composed of four bonding pads and a peripheral pad. The inspection of bonding alignment has been performed by microscope. Fig. 3(a) shows a good alignment after wafer level packaging process.

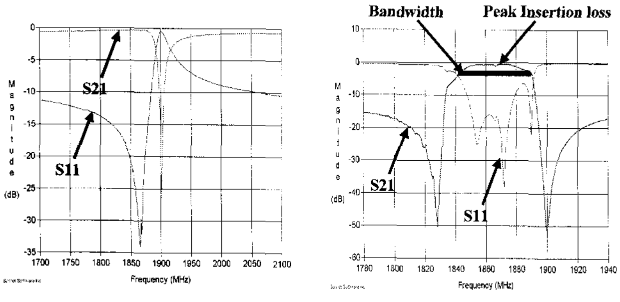
To analyze the fabricated resonator and filter, the measurement is performed using an 8510C vector network analyzer, GGB Picoprobe 200 μm pitch coplanar, and GGB CS-5 SOLT calibration standard.



(a) (b)

Fig. 3 Optical microscope images of a real packaged filter. (a) Top view of encapsulation (b) bottom view of FBAR

Fig. 4(a) and (b) show a performance of resonator and filter after wafer level package. Measurement of performance of a FBAR filter before and after the WLP processes is the most sensitive method to figure out if the process work well. The obtained frequency characteristics show low insertion loss (IL), high attenuation at stop band, and sharp roll off. The peak insertion loss and bandwidth of filter were -0.56 dB and 71 MHz. We meet all the required Tx filter specifications for USPCS system [5].



(a) (b)

Fig. 4 The S-parameter response of the fabricated WLP FBARs (a) resonator and (b) filter

Table 1 shows the S-parameter response of the fabricated filters. As can be seen in this table, the change of band width and frequency shift before and after bonding is negligible. The resistance of 1 grooved-shaped via seemed to be about 0.02 ohm (not shown) and insertion loss degradation of filter happened about 0.1dB. This is the reason why an increase of feed through length and contact resistance between metal layers worsen to overall characteristic

Table 1 S-parameter response of the fabricated filters (a) before, (b) after WLP

	Fl (MHz)	Fr (MHz)	P-P (MHz)	Roll-off (dB)	IL (dB)	Att. (dB)
(a)	1827.3	1898.5	71.2	7.3	-0.43	-56.2
(b)	1827.5	1899.0	71.5	7.6	-0.56	-51.3

The results of the reliability test (Temperature cycling) are shown in Fig. 5. Worst case insertion loss is 2.3 dB for the Tx filter and 2.9 dB for the Rx filter after the reliability test. The duplexers were subjected to the reliability test shown in Table 2. No failures were seen in any of the reliability test.

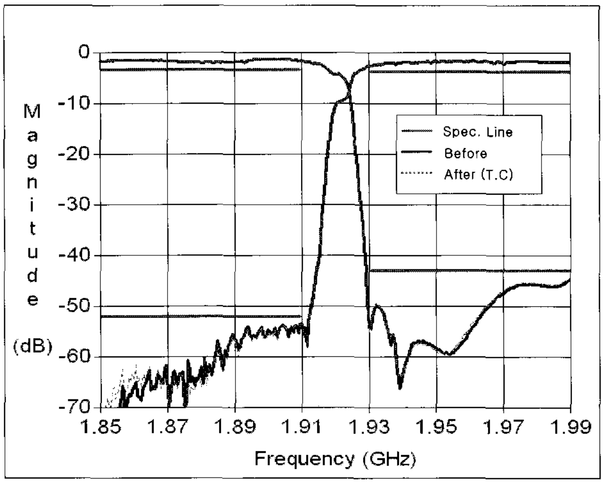


Fig. 5 The measured 3.8mm×3.8mm FBAR duplexer response before and after the reliability test (Temp. cycling)

Table 2 Reliability results for the WLP packaged duplexers

Test	Conditions	Fail	Measurement
Pre_Condition	T.C 5 times → 125 ℃ Bake → 85℃/85% 24hrs → Reflow 3times	0/33	Before and after
PCT	121℃, 100%, 2 atm, 96hrs	0/11	Before and after
Temp. Cycling	-40℃ ~125℃ 300 cycles	0/11	0 time, 300time
Storage of high temp. &humidity	85℃/85%, 120 Hrs	0/11	Before and after

4. Conclusion

We have fabricated a low cost, high performance, duplexer for handsets based on the Film Bulk Acoustic Resonator. Using glass cap and wafer with grooved shaped via was the key to reducing the size and cost. The obtained frequency characteristics show frequency shift and band width were not changed after bonding. By using the developed WLP, we can meet all the required specifications for USPCS system, and could greatly reduce the costs for the overall manufacturing process of the WLP

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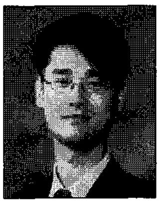

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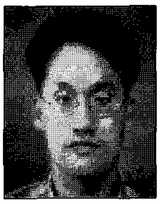

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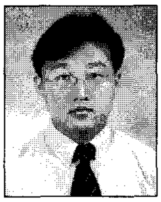

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