Development of Miniature Quad SAW Filter Bank based on PCB Substrate

Young-Jin Lee[a], Chang-Il Kim, and Jong-Hoo Paik
Electronic Components and Materials Division, Korea Institute of Ceramic Eng. & Tech., 233-5 Gasan-dong, Guemcheon-gu, Seoul 153-801, Korea

[a]E-mail : yjlee@kicet.re.kr

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This paper describes the development of a new 5.0×3.2 mm SAW filter bank which is consist of 12 L, C matching components and 4 SAW bare chips on PCB substrate with CSP technology. We improved the manufacturing cost by removing the ceramic package through direct flip bonding of $LiTaO_3$ SAW bare chip on PCB board after mounting L, C passive element on PCB board. After that we realized the hermitic sealing by laminating the epoxy film. To confirm the confidentiality and durability of the above method, we have obtained the optimum flip bonding & film laminating condition, and figured out material property and structure to secure the durability & moisture proof of PCB board. The newly developed super mini 5.0×3.2 mm filter bank shows the superior features than those of existing products in confidence, electrical, mechanical characters.

Keywords : SAW, Filter bank, PCB, Quad, CSP

1. INTRODUCTION

Miniaturization & modularization are the main trends of current components market of handhelds machineries, particularly, because of multi-functionalization of camera, blue tooth, etc., the modularization & miniaturization of various components has become big issues in electronic components market[1]. In particular, in case of SAW (Surface Acoustic Wave) filter used in GSM handheld terminal, as the Quad-band supporting mobile phone has become the main stream, the application of module type components has been growing drastically in order to reduce the space of the internal RF components. Specifically, instead of reducing the application of FEM(Front End Module) which is composed of antenna switch & multifold SAW filter modules, SAW filter bank, made in single package, has been increasing as shown in Fig. 1[2].

Since the size of filter bank that has been currently using is 7.0×3.5 mm, which is manufactured by packaging 4 of SAW single filters with the size of 1.4×1.1 or 2.0×1.4(1.6) mm and 12 L.C passive elements after mounting them on PCB or LTCC(Low Temperature Co-fired Ceramic) board, its manufacturing cost is still high, the No. of process is too much, while the total size reduction effect is not so much[2,3].

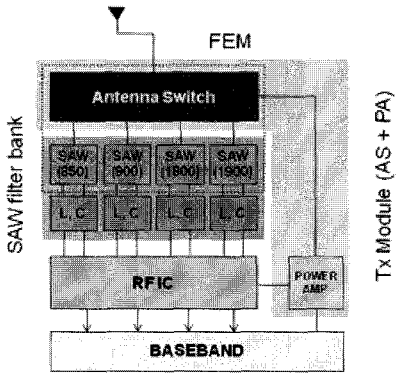


Fig. 1. RF stage of the GSM Quad-band handset.

In this article, we are going to improve the manufacturing cost of the current 7.0×3.5 mm quad-band SAW and suggest a new type of 5.0×3.2 mm size filter bank. First of all, the new filter bank can improve the manufacturing cost by removing the ceramic package through direct flip chip bonding of $LiTaO_3$ SAW bare chip on PCB board, after mounting L, C passive element on PCB board. After that we tried to obtain the hermitic sealing by laminating and coating the epoxy film. To confirm the confidentiality and durability of the above method, we have tried to get the optimum flip bonding &

film laminating condition and to design and ensure the property of materials & multi-layered structure for securing the durability & humidity proof of PCB board.

Different from the existing SAW filter bank to which the SAW end product using ceramic package is applied, by using only PCB, we can have various merits as follows; First, PCB is much cheaper compared with the ceramic package, more than 40 % of material cost reduction effect can be expected, even comparing with the total cost of SAW filter material cost. Second, since PCB has smaller manufacturing errors compared with ceramic package, the size of sheet can be realized largely, so, in the manufacturing process of chip scale package, in which the workings are conducted by sheet unit, more than 400 % increase of productivity is expected. Also, compared with the ceramic package in which abrasion of dicing blade is excessive, the dicing processing cost can be cut down substantially. Third, quality improvement is expected through minimizing the chronic inferiority, such as opening & crack inferiority occurred by heat impact[4]. Fourth, compared with ceramic package, as the development & manufacturing cost is much inexpensive, the development lead time is much shorter, we can expect that the quick responding capability to the mass production of machinery type will be increased, and even in case of development failure, the charge from the cost of development failure will be decreased[5]. In addition to these, we can expect the same effect when applying it to the products such as SAW duplexer or SAW module.

2. DESIGN & MANUFACTURING PROCESS OF SAW FILTER BANK

2.1 Structure of the existing SAW filter bank

The quad-band SAW filter bank used in handheld terminal are all composed of mounting & packing structure of the existing SAW completed product filter and additional L, C elements on PCB board. In case of F company in Japan, they developed the 7.0×3.5×1.5 mm size filter bank by mounting 2 dual SAW filters and 12 L, C elements on PCB board. In case of E company in Germany, it takes the plastic molding structure by mounting 4 completed product 2.0×1.4 mm size SAW filters, while 12 L, C elements are imbedded in LTCC. But, all of the two existing products have almost no size decreasing effect, not so much merits in manufacturing cost compared with the product using completed product elements.

2.2 Structure of SAW filter bank and manufacturing process

The SAW filter bank that we want to develop through this research is different from the products mentioned above. The purposes are to reduce the manufacturing cost and the total size of the product drastically through flip bonding the SAW bare-chip directly on PCB board.

2.2.1 Structure of SAW filter bank

While the existing filter bank is that the completed SAW is mounted on PCB or LTCC, the new SAW filter bank, as shown on Fig. 2, the bare chip of SAW is directly mounted on PCB. After that, as film laminating is conducted using epoxy film, the hermetic sealing structure can be realized. For protection against external moisture and electrostatics, metal coating is conducted to the most exterior to have humidity proof and electricity prevention effects. When we use these kinds of technology, the existing SAW ceramic package becomes unnecessary, the No. of processes decreases drastically, as the results, we can expect that the manufacturing cost will be cut off to the below level of 50 % of existing one[6].

To realize the above SAW filter bank structure, we can summarize the most important technology into three; First of all, the flip chip bonding technology to realizing fitting the SAW bare chip to PCB board, the hermetic sealing using epoxy film and material quality and structure design to secure moisture proof of PCB board.

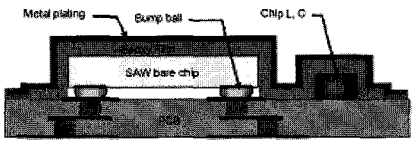


Fig. 2. Structure of SAW filter bank.

2.2.2 Manufacturing process of SAW filter bank

The manufacturing process of chip, scale, and package is shown as Fig. 3. After mounting the chip L,C on the sheet type array board, coating the upper part of sheet with laminating film and flip chip bonding the SAW bare chip on which IDT pattern & metal bump are formulated, then, formulate external shape of package using heat expression method. After then, conduct grooving process between chips at appropriate intervals using laser. At this moment, it is important to remove the

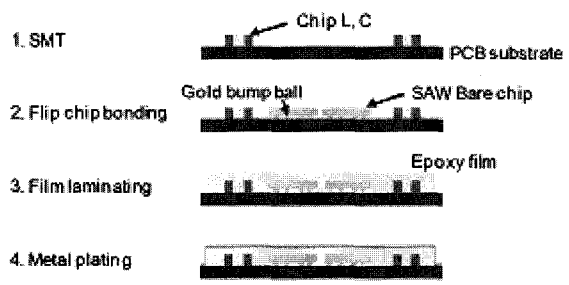


Fig. 3. Manufacturing process of the SAW filter bank.

laminating film from the wanted part clearly. Then conduct metal coating using sputtering and electrolysis coating method, the role of which are not only to screen electro-magnetic field, but also, to screen moisture from infiltrating from outside. Lastly, the manufacture will be completed through dicing process.

a) Flip chip bonding

The flip chip bonding conducted in usual manner is easy to enhance the adhesiveness strength, as it is conducted in high solidity ceramic package, but in case of application to the PCB board having comparatively smooth solidity such as in this study, it is very important to configure bonding power, surrounding temperature, etc. So, we formulated the thickness of electrode pad more than 50 um to increase the bump ball adhesiveness between the metal coating face and the metal fitting face of SAW chip. Also, we can enhance the adhesiveness through embossing treatment & cleaning of pad.

b) Film laminating

Epoxy laminating process is important process to secure hermetic sealing, which effects greatly to the confidence of moisture proof of completed product. The most high heart impacted process is film hardening process conducted by long time heat treatment at more than 180" after laminating. During hardening process, the film shrinking situation occurs, which caused to increase the internal stress to make confidence problem.

As this kind of package is a structure adhered by more than two kinds of materials, it has principle structural weakness because of the difference of thermal expansion coefficient. While the thermal expansion coefficient value of HTCC series has less than 7.5(ppm/K), LTCC series has less than 5, but the PI(polyimide) series has more than 80 value. So, in every heating processes, bending caused by increasing internal stress has been great problems. Comparing to hereupon, in case of PCB board of BT series, the value of thermal expansion coefficient is about 15, from which we can expect relatively increased confidence features comparing to that of ceramic package.

c) Design PCB board

Compared with ceramic package, some weaknesses are expected in PCB board having polymer material as basic, with moisture infiltration in moisture proof confidence. In order that moisture infiltration is not be occurred, in case of two layers structure, we prevented moisture infiltration through interface between PCB material and metal via hole by treating via hole using plugging process. In case of 4 layers structure, moisture infiltration is prevented by maximizing interface path between metal electrode & via hole structure and PCB material. Also, in order to increase the adhesiveness between epoxy film and PCB board, we improved the interface adhesiveness through adhesion of coating film during coating process by adding 150 μm width of wide metal line on the edge of upper top face of PCB in circular form. At the same time, as the result of review of commercial materials to find out optimum material quality for PCB board, among the materials having properties of material shown on Table 1 showed the best adhesiveness, moisture proof, and high temperature confidence.

Table 1. Material properties of the PCB substrate.

Property	Item		Value
Thermal	Tg		174
	Decomposition Temperature		334.5
	CTE (ppm/°C) RT→Tg, Tg→260 °C	x-axis	15
		y-axis	15
		z-axis(MD/TD)	35/198
Electrical	Dielectric Constant (1 GHz)		4.85
	Dissipation Factor (1 GHz)		0.013
	Volume Resistivity		264.53
	Surface Resistance		2.61
Physical	Tensile Strength(MD/TD)(Mpa)		290-310
	Young's Modulus (Gpa)		25-27
	Peel Strength (kN/m)		0.88

3. OPTIMIZATION OF PROCESS CONDITION AND RESULTS OF MANUFACTURING

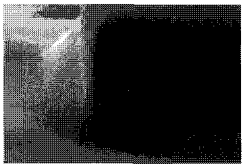
3.1 Optimization of process condition

a) Flip bonding condition

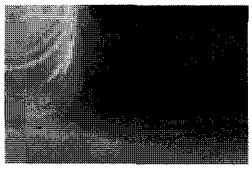
First, we figure out optimum condition for flip bonding of SAW bare chip on PCB. The major factors determining the optimum condition for flip bonding can be divided into pre-heating temperature when working, pressure impacted to bare chip, and power of ultrasonic wave bonding. Based on the results of testing, the optimum flip bonding conditions shows that the flip bonding adhesive power is 880 g when the surrounding temperature is 120 °C, load pressure is 0.5 MPa, and ultrasonic bonding power is 2.2 watt, which represented more than equal results comparing to the adhesiveness strength of ceramic packages.

b) Lamination film condition

During epoxy film hardening, because of the film shrinking situation, internal stress increases, and package bending problem is occurred, which caused confidence problem. So, we reviewed various conditions to figure out the temperature and expression time that occurs minimum stress when epoxy film laminating, the results shows the best features.



Load pressure = 0.5 MPa



Load pressure = 0.6 MPa

Fig. 4. Folded situation caused by laminating pressure.

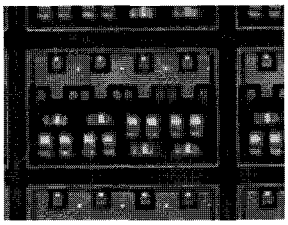
The thermal treatment condition seriously influences the reliability of the humidity-proofing of the finished product. Thermal treatment at the highest temperature in the CSP process occurs in film hardening process, when it is thermally treated for a long time at more than 180 °C after film lamination. Film contraction occurs during the hardening process, increasing the inner stress of the package and causes reliability problems. The thermal expansion coefficient of HTCC is 7.5 (ppm/K) whereas LTCC is under 5 (ppm/K), but epoxy film is over 250, showing that each thermal process causes serious bending problems from the rise of the package's inner stress. The BT system PCB substrate used in this study has a thermal expansion coefficient of less than 15, which presents improvement in quality compared with that of the ceramic package.

Figure 4 is package external picture according to approved pressure. We can identified that folded situation is occurred by focusing stress on film when more pressures than appropriate amount is approved.

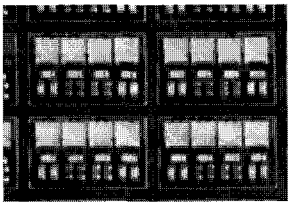
Also, experimental result of vapor pressurization in which the thermal treatment time varied from 1 to 4 hours at 200 °C in the thermal treatment of the laminating film. It was not quite dependent on the thermal treatment time, but the best result was obtained in the 2-hour process.

c) Manufacturing SAW filter bank and features

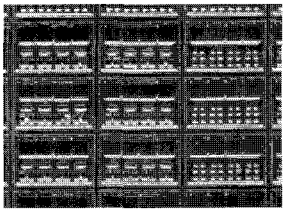
Based on the above results of testing, we manufactured the SAW filter bank and reviewed the features. In Fig. 5, the pictures of each process are displayed. First of all, after mounting L, C chip elements, proceed with cleaning process, and mount 4 GSM Quad-band SAW bare chip by flip bonding, and then conduct hermetic sealing process through film laminating process. At final stage, packaging was conducted using injection molding to formulate external shape.



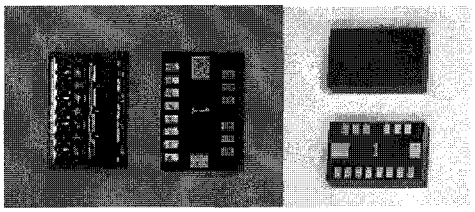
(a) After SMT of chip L, C



(b) After flip bonding of SAW bare chip



(c) After film laminating & Metal plating



(d) 5032 SAW filter bank

Fig. 5. Manufacturing process of the SAW filter bank.

d) Comparison of characteristics with existing SAW filter bank

Among the tests conducted to ensure reliability, the most important one is thermal shock test, which examines performance according to the variation in external temperature to install on the set or module of portable devices, and the high-temperature, high-humidity test or PCT(Pressure Cooker Test), which examines the level of hermetic sealing. Thermal shock reliability experiment condition was -65~150 °C and 100 times, which was more severe than that of the normal condition mass-produced SAW filters are subjected to. Electrical characteristic error occurred from thermal shock in ceramic package SAW filter, which resulted from the separation of the mechanical bump ball. On the other hand, there was no electrical characteristic error in PCB substrate, which shows that PCB SAW filter has better characteristics in terms of thermal shock reliability

than that of ceramic package SAW filters.

4. CONCLUSION

In this article, we are going to improve the manufacturing cost of the current 7.0×3.5 mm quad-band SAW and suggest a new type of 5.0×3.2 mm size filter bank. We improved the manufacturing cost by removing the ceramic package through direct flip bonding of $LiTaO_3$ SAW bare chip on PCB board after mounting L, C passive element on PCB board. After that we realized the hermitic sealing by laminating the epoxy film. To confirm the confidentiality and durability of the above method, we have obtained the optimum flip bonding & film laminating condition, and figured out material property and structure to secure the durability & moisture proof of PCB board. The newly developed super mini 5.0×3.2 mm filter bank shows the superior features than those of existing products in confidence, electrical, mechanical characters.

REFERENCES

[1] S. Entwistle, N. Mawston, and S. Robinson, "Wireless & portable enabling technology strategies analysis showcase", Strategy Analytics, Electronica., p. 10, 2004.

[2] P. V. Wright, "Integrated front-end modules for cell phones", IEEE Ultras. Symp. Proc., p. 564, 2005.

[3] P. Selmeier, R. Grunwald, A. Przadka, H. Kruger, G. Feiertag, and C. Ruppel, "Recent and advances in SAW packaging", IEEE Ultras. Symp. Proc., p. 283, 2001.

[4] S. Yoshimoto, Y. Yamamoto, Y. Takahashi, and E. Otsuka, "Multi-band RF SAW filter for mobile phone using surface mount plastic package", IEEE Ultras. Symp. Proc., p. 113, 2002.

[5] K. W. Baik, "Electronic packaging technology", The J. of KIEEME(in Korean), Vol. 16, No. 7, p. 3, 2003.

[6] Y. J. Lee, J. I. Im, and S. H. Lee, "Development of the RF SAW filters based on PCB substrate", IEEE Freq. Cont. Sym. Proc., p. 334, 2006.