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LTCC를 이용한 RF MEMS 소자의 실장법

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LTCC-Based Packaging Technology for RF MEMS Devices

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Abstract - In this paper, we have proposed low temperature co-fired ceramic (LTCC) based packaging for RF MEMS devices. The packaging structure is designed and evaluated with 3D full field simulation. 50 Ω matched coplanar waveguide(CPW) transmission line is employed as the test vehicle to evaluate the performances of the proposed package structure. The line is encapsulated with the LTCC packaging lid and connected to the via feed line. To reduce the insertion loss due to the packaging lid, the cavity with via post is formed in the packaging lid. The performances of the package structure is simulated with the different cavity depth and via-to-via length. Simulation results show that the proposed package structure has reflection loss better than 20 dB and insertion loss lower than 0.1 dB from DC to 30 GHz with the cavity depth and via-to-via length of 300 μm and 350 μm, respectively. To realize the designed package structure, the cavity patterning is tested using the sandblast of LTCC.

Key Words : RF MEMS packaging, LTCC, 3D field simulation, via post, sandblasting

1. Introduction

RF MEMS devices have been researched for many years because of their low loss characteristics at high frequency bands, compact size, and low cost. However, there are some obstacles in commercializing RF MEMS devices, such as reliability of the device, production cost, and packaging techniques[1]. Among these, the packaging occupies a large mount of production cost and the overall device size.

RF MEMS packaging should provide electro mechanical shielding from harsh environment, electrical interface connected to other circuitries, and thermal interface that removes heat generated by the inner device of the package. Moreover, multichip module (MCM) packaging is needed for higher performance and smaller size[2,3]. These requirements of the packaging lead us to a careful choice of packaging material and packaging method.

Materials used for RF packaging are high resistive silicon, glass, ceramic and plastic, which are chosen in each cases of production cost, ease of processing, low loss. Among these materials, ceramic have been used for high performance due to its low loss property, better thermal properties and ease of MCM packaging. As a result, low temperature co-fired ceramic (LTCC) packaging have been commercially established packaging technology in RF system[4]. However, it is difficult to apply conventional LTCC machining for the micro-scale machining, and it prevented LTCC packaging technology from being applied for RF MEMS packaging so far. Furthermore, packaging designer faces a lack of design rules on the proper placement of the via interconnections that are formed in LTCC[4,5].

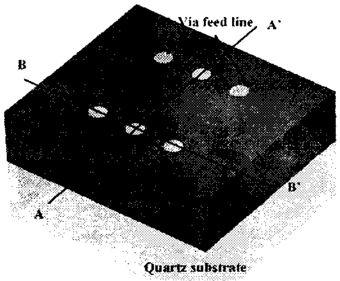
In this paper, LTCC-based packaging structure is designed and simulated for the application to the RF MEMS device. The RF performance degradation relates to the field distribution into the packaging material. To improve the RF performance, via post structure of the package has been proposed. This novel LTCC-based package with via post shows the improved packaging performance. To realize the proposed package structure, the LTCC micromachining to form the cavity and via post in LTCC is experimented using the sandblasting.

2. Packaging Design

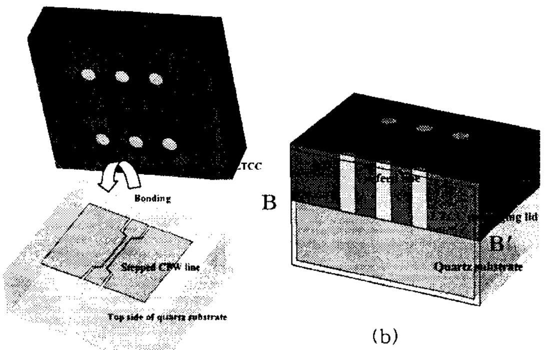
It is very difficult to expect the RF characteristics of 3D structure used in RF application because the loss increases drastically and the RF performance of the application is related to its geometry. Hence, the RF system designer conducts 3D field simulation to design the RF system of 3D geometry. We have conducted 3D full field simulation of Microwave Studio of Computer Science Technology, Co. Ltd. to design LTCC-based packaging.

The packaging design has been focused on the low transmission loss to develop high performance of RF packaging. To achieve this goal, each element of the package should be matched to characteristic impedance of 50Ω. The elements of the packaging are via feed lines and a packaged device. The vias are filled with silver paste for the electrical interconnection with the packaged device. However, there is a difficulty that no analytic model for the feed line exists. Thus, the impedance of via feed line formed in LTCC was tuned through a simulation. The impedance of via feed line is related with the diameter of vias and via-to-via distance. We have taken minimum via size of 150μm diameter, which ensures smaller overall package size and the stable process to form the vias in LTCC. The via feed line matches with 50Ω when vias are 350μm apart form each other. Also, we have employed a coplanar waveguide(CPW) line as a test vehicle, which is matched with 50Ω impedance.

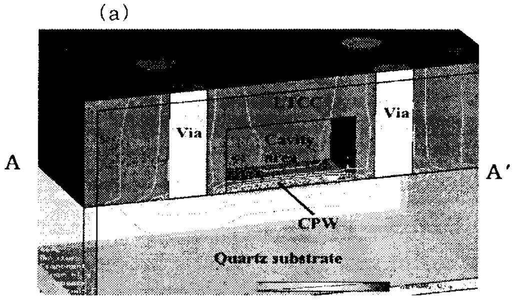
As a consequence, the CPW is encapsulated with the cavity-formed LTCC packaging lid. The cavity formed in the packaging lid allows the MEMS device movement (fig. 1). Fig. 2(a) shows the schematic view of the simple



packaging model. The cavity is formed only in

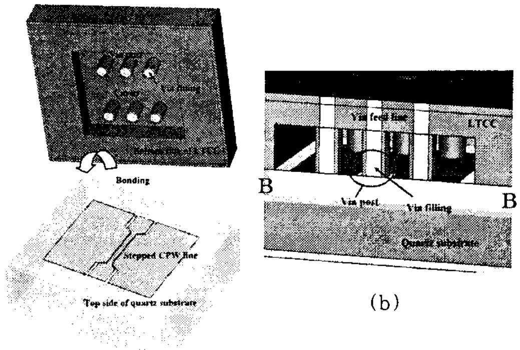


(a) (b)



(c)

the area for the device movement. As shown in fig.2(c), the field distributes into LTCC packaging lid. This comes to increased loss.

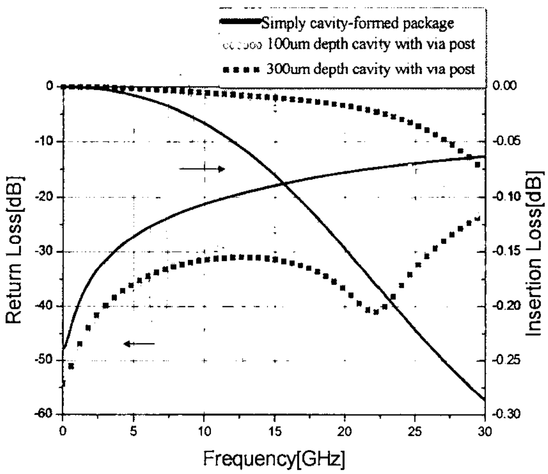


(a) (b)

Thus, the modified design that reduces the field distribution into LTCC has been proposed (fig. 3). The modified structure that has the via posts shows improved RF performance. Depending on the length of via post, the RF performance of the package is different. Longer via post gives more improved RF performance to the package. However, longer via post follows many process limitations such as undercut of the etch process. The simulation results of the modified design with via post of 300 μm length show reflection loss better than 20 dB and insertion loss lower than 0.1 dB from DC to 30 GHz, respectively (fig. 4).

Fig. 1. Schematic view of the packaged structure.

Fig. 2. Simply cavity-formed packaging model (a) Schematic view (b) BB′ cross-sectional view



(c) E-field distribution of AA′ cross-section.

Fig. 3. Improved packaging model with via post (a) schematic view (b) BB′ cross-sectional view (c) E-field distribution of AA′ cross-section.

Fig. 4. Simulated results with different pac structures

3. LTCC micromachining

To realize the proposed packaging design, we have investigated LTCC micromachining using sandblasting. The dry film is used for etch mask for sandblasting and patterned with UV-lithography. Then, the LTCC is air-blasted with sands (fig. 5). Fig. 6 shows etched profile of sandblasted LTCC. After sandblasting, the etched area of 300 × 300 μm^2 square opening enlarged by 400×400 μm^2 due to undercut. The etch depth was measured to be 290 ± 10 μm for 300 μm target depth. Via posts were also made by sandblasting (fig. 6). The etched depth in the process of forming via post was 180 μm. The undercut was measured to be 15 μm.

From the results, we have found that the improved packaging model in fig. 3 could be realized. The via post has the 150 μm diameter via in LTCC, which is filled with silver paste in the conventional LTCC process. In the consideration of undercut occurred in 300 μm target depth, it is expected that the etch mask pattern size is 300 × 300 μm^2 to get a via post of 200 μm diameter.

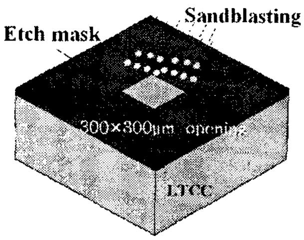


Fig. 5. LTCC micromaching using sandblasting.

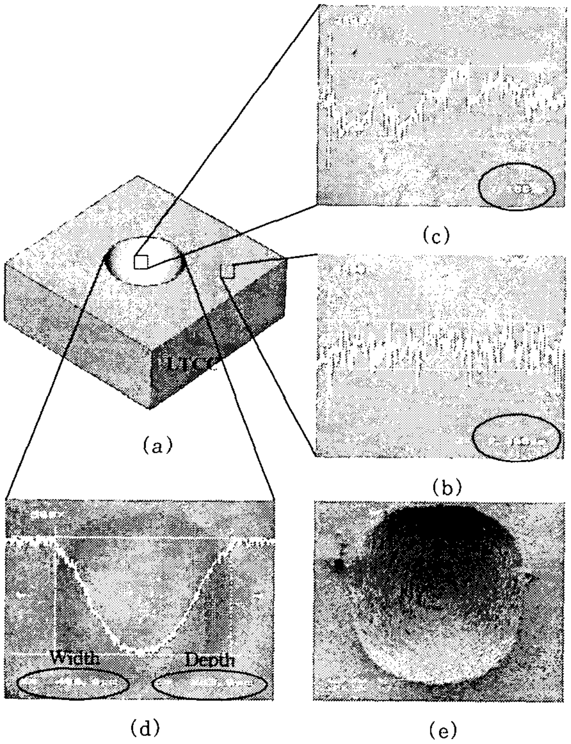
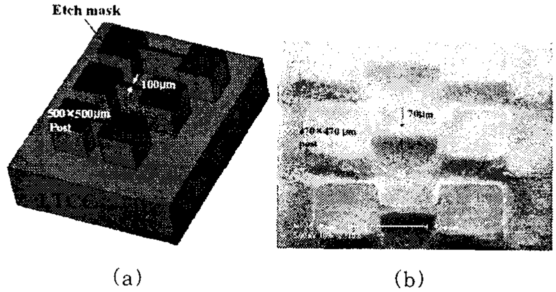
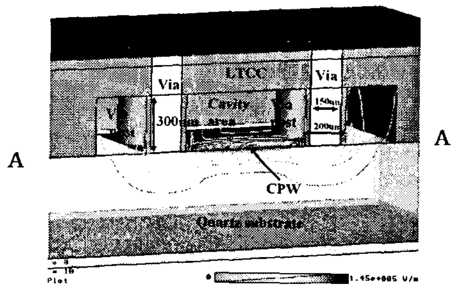


Fig. 6. Profiles of sandblasted LTCC (a) schematic view of etched profile of 300 × 300 μm^2 square opening (b) the LTCC surface (c) the sandblasted surface of LTCC (d) width and depth of etched profile (e) SEM photograph





(c)

Fig. 7. Via post (a) Designed scheme of LTCC via post (b) SEM photograph.

4. Conclusion

A novel LTCC-based RF MEMS packaging has been proposed, which has the advantages of low loss, better thermal properties, ease of MCM pacakging, ease of forming via feed line. The proposed LTCC-based packaging structure was designed and simulated through the 3D full field simulation. The packaging loss relates to the field distribution into packaging material. For the improved RF performance, not only the cavity structure for the RF MEMS device movement, but also via post should be formed in the packaging material. As shown in the simulation results, the proposed packaging that forms the via post in the LTCC shows reflection loss better than 20 dB and insertion loss lower than 0.1 dB from DC to 30 GHz, respectively. To realize the packaging, we investigated the patterning of LTCC using sandblasting. From the results, we have verified that via post structure proposed in the design could be fabricated.

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