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RF MEMS 소자 실장을 위한 LTCC 및 금/주석 공융 접합 기술 기반의 실장 방법

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LTCC-based Packaging Method using Au/Sn Eutectic Bonding for RF MEMS Applications

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Abstract - This paper reports on an LTCC-based packaging method using Au/Sn eutectic bonding process for RF MEMS applications. The proposed packaging structure was realized by a micromachining technology. An LTCC substrate consists of metal filled vertical via feedthroughs for electrical interconnection and Au/Sn sealing rim for eutectic bonding. The LTCC capping substrate and the glass bottom substrate were aligned and bonded together by a flip-chip bonding technology. From now on, shear strength and He leak rate will be measured then the fabricated package will be compared with the LTCC package using BCB adhesive bonding method which has been researched in our previous work.

1. INTRODUCTION

Packaging is one of the most important issues for stable and reliable performances in radio frequency microelectromechanical system (RF MEMS) devices. RF MEMS devices containing three-dimensional movable fragile parts should be protected from an external environment. Therefore, a number of researchers have been focused on the development of various packaging methodologies with applicable to RF MEMS devices.

The main requirements for the MEMS package are hermeticity and high mechanical strength. In RF MEMS packages, electrical interconnection to apply a bias voltage and a RF signal is also an important factor. Interconnection methods can be generally classified into vertical and coplanar-buried feedthroughs in RF MEMS applications [1, 2]. However, the vertical feedthrough has several advantages such as lower feed line loss and smaller packaging areas over the coplanar-buried type in high frequency applications. Although diverse studies were proposed to achieve vertical feedthroughs, there are few perforation methods with simple fabrication processes [3, 4].

However, LTCC substrates make it possible to overcome this problem by its simple manufacturing process for achieving vertical via feedthroughs. Furthermore, the LTCC substrate also has a merit as a good RF characteristic in high frequency, thus it can be regarded as such a suitable material for applications in RF MEMS packages.

Among various bonding processes, eutectic bonding process can guarantee hermetic sealing, strong bonding strength and freedom of the substrate selection in processes without any restriction by bonding mechanism. Especially, since Au/Sn-based eutectic bonding can be performed at low temperature of around 285 ℃, structural deformations of the devices can be prevented during bonding process. From these merits, various packaging methods using Au/Sn eutectic boding were explored [5, 6].

This paper proposed a new RF MEMS packaging method to satisfy all the requirements in RF MEMS packages by using LTCC capping substrates and Au/Sn-based eutectic bonding process.

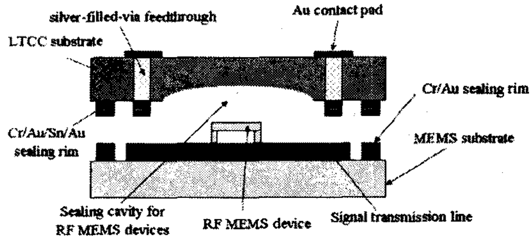

Figure 1. *Cross-sectional view of the proposed package*

2. DESIGN

The proposed packaging structure consists of an LTCC capping substrate with Au/Sn sealing rim patterns and bottom MEMS substrate. Cross-sectional view of our packaging structure is described in Figure 1.

On the capping substrate, two pairs of via feedthrough groups are mechanically perforated and filled with silver epoxy. There are three via feedthroughs in each groups for vertical interconnection between the capping substrate and coplanar waveguide (CPW) on the bottom substrate. Therefore, one group of via feedthrough pairs acts the role of an input port, while the other acts the role of an output port. The diameter of each via feedthrough and the distance between the via feed through pairs are designed to be 150 μm and 400 μm, respectively. A cavity for location of RF MEMS devices is defined in order to improve RF characteristics as shown in Figure 1 [1].

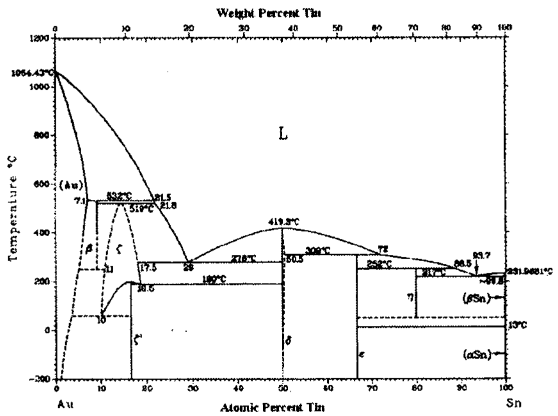

Figure 2. *Au–Sn equilibrium phase diagram* [5]

Au/Sn sealing rim for eutectic bonding consists of two kinds of multi-layers. One kind of sealing rim consists of Cr/Au/Sn/Au multi-layer and is patterned on the capping substrate. The other consists of Cr/Au multi-layer, and is patterned on the bottom substrate. Each layer was designed using equilibrium phase diagram between Au and Sn as described in Figure 2 [5, 7]. The determined total Au/Sn alloy has a composition of 80 wt.% Au (71 at. %) and 20 wt.% Sn (29 at. %).

3. FABRICATION

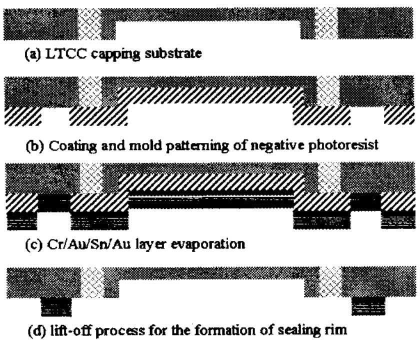

Figure 3. *Fabrication flow at the capping substrate*

The brief mechanism of the proposed packaging is that LTCC capping substrate and RF MEMS bottom substrate are bonded using Au/Sn sealing rim. Fabrication processes of the LTCC capping substrate and RF MEMS bottom substrate are described in Figure 3 and 4 respectively.

At the capping substrate, the process started with an LTCC substrate with the sealing cavity and silver-filled-via feedthroughs (Figure 3.(a)). A 3-μm-thick negative-tone photoresist (PR) is spun on the LTCC substrate, then mold patterns for lift-off process are defined using photolithography process (Figure 3. (b)). After the formation of negative sloping mold patterns, Cr/Au/Sn/Au is co-evaporated onto an LTCC capping substrate (Figure 3. (c)). In the case, Cr layer is used to improve adhesion with the LTCC substrate and Au layer on top surface of the multi-layer is utilized as the barrier layer to prevent oxidation of Sn layer during producing processes. Finally, the lift-off process is performed by dipping in acetone. Patterns are obtained (Figure 3. (d)).

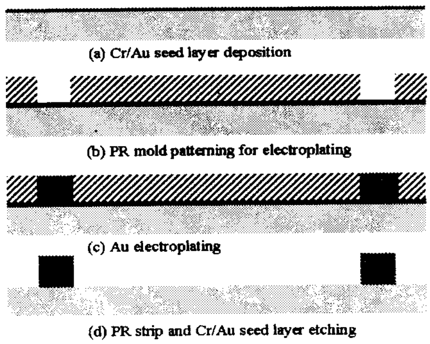

Figure 4. *Fabrication flow at the bottom substrate*

At the bottom substrate, sealing rim is fabricated (corning Pyrex #7440) glass substrate by gold electroplating technology. The process started with a glass MEMS substrate, followed by the evaporation of thin Cgr/Au seed layers (Figure 4. (a)). Then PR coating and mold patterning is progressed using photolithography process (Figure 4. (b)). The Au rim patterns are electroplated with 4 mA/cm^2 current density and 0.25 μm/min electroplating rate (Figure 4. (c)). PR mold is stripped by acetone, then Cr/Au seed layer is removed by wet etching technique (Figure 4. (d)). After the fabrication of multi-layered metal rims on each substrate is shown in Figure 5. Total bonding layers are considered for achieving the concentration as 80 wt.% Au and 20 wt.% Sn [5, 7].

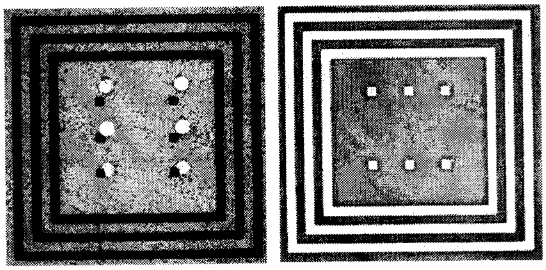

Figure 5. *Sealing rim patterned substrates. (a) LTCC capping substrate with Cr/Au/Sn/Au rim. (b) glass bottom substrate with Cr/Au rim*

After these fabrication processes, a glass bottom substrate and an LTCC capping substrate are aligned and bonded by flip-chip technology.

4. CONCLUSION

An LTCC-based packaging method using Au/Sn eutectic bonding was suggested. The Au/Sn eutectic bonding can offer a guarantee of hermetic sealing estimated by its material property, and a relatively low bonding temperature to prevent thermal deformations of 3-D structural MEMS devices.

From now on, general performances of the proposed packaging structure, hermeticity and mechanical strength, will be measured by He leak test and shear strength test, respectively and compared with the LTCC package using BCB adhesive bonding method which has been researched in our previous work.

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