Design of a Vertical Interconnection Based on Micro-additive Manufacturing Technology

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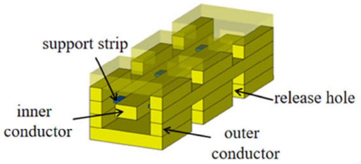
ABSTRACT

- The design of a rectangular-coaxial vertical interconnection structure based on micro-additive manufacturing technology is presented in this paper. This vertical interconnection is realized with quasi-coaxial structure with square cross section composed of Sn-based solder balls and is designed to connect coaxial transmission lines at different layers. Simulation results show that the insertion loss is <0.2 dB and the return loss is better than 20 dB from 0.1-110 GHz. In addition, the isolation between two vertical interconnections is higher than 50 dB.

DESIGN AND ANALYSIS

Rectangular coaxial line structure



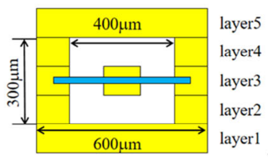


Fig.1 The schematic diagram of an air-filled rectangular coaxial transmission line.

Fig.2 The cross-section of an air-filled rectangular coaxial transmission line.

- The coaxial structure was fabricated through the electroforming of thick copper layer by layer (similar to 3D printing) and the release holes on the outer conductor are used to wash out the photoresist.
- Due to the inner and outer conductors are filled with air, the insertion loss of the coaxial line is minimized and the cutoff frequency can be extended at the same time. This feature makes the coaxial line very suitable for MMW and terahertz signal transmission.
- A typical coaxial line has an internal cross-sectional size of 400×300 um, and the corresponding TE11 mode appears above 314 GHz. Therefore, the operating frequency of the TEM mode can theoretically cover the DC to WR-2.8 frequency band.
- In practice 2 to 3 layers of coaxial structures (10-15 layers of copper) becomes more difficult as the internal stress of the structure grows rapidly when more layers are used. Hence, the vertical integration structure is very important for future micro-systems with several layers.

Quasi-coaxial vertical interconnection structure

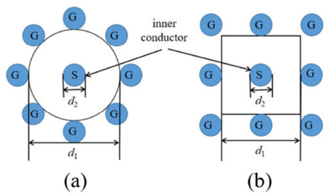


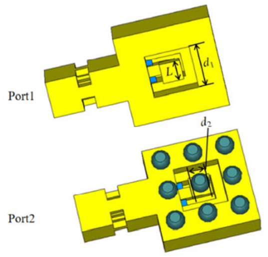
Fig.3 Vertical transmission line patterns:(a) quasi-coaxial with circular cross section; (b) quasi-coaxial with square cross section.

- The available Sn-based solder ball diameter is approximately 300 um, which equals to the size of the inner conductor (d2) in the solder balls layer . For a typical coaxial line , the characteristic impedance of 50Ω corresponds to the size of the inner conductor, which is about 178 um.
- It is necessary to enlarge the size of the inner and outer conductor of the fifth layer of the coaxial line to better place the solder balls while keeping the characteristic impedance constant. In addition, the fourth layer acts as an impedance transition to minimize reflection.

$$f_{TE_{11}} = \frac{2c}{\pi\sqrt{\varepsilon_r}(d_1+d_2)} \qquad (1)$$

- Considering the shape of the outer conductor of the coaxial line, we choose the quasi-coaxial form of the square. The calculated outer diameter dimension is d1=700 um. Its cut-off frequency can be roughly estimated by (1), which is approximately 190GHz.

SIMULATED RESULTS AND FABRICATION



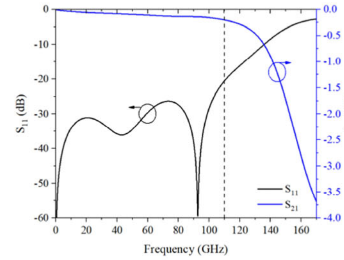


Fig.4 The schematic illustration of vertical interconnection between air-filled rectangular coaxial transmission lines.

Fig.5 The simulation results of vertical interconnection between air-filled rectangular coaxial transmission lines.

- From the above analysis, the size of the inner conductor of layer 5 should be greater than or equal to 300 um, which can be optimized in CST. The final optimum size is L=320 um.
- It can be seen from simulation results that the introduction of vertical interconnection structure has little effect on coaxial transmission. The insertion loss is < 0.2 dB and the return loss can be maintained below -20 dB over a wide frequency range (from 0.1 GHz to 110 GHz).

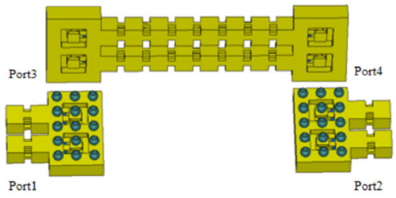


Fig.6 The schematic illustration of the B2B interconnection.

- In order to verify isolation performance of the above structure and also to enable the measurement, a back-to-back interconnection is presented, as shown in Fig. 6.
- As can be seen from Fig.7, the isolation between two adjacent vertical interconnections can reach -50dB, which shows that the structure has good isolation performance.

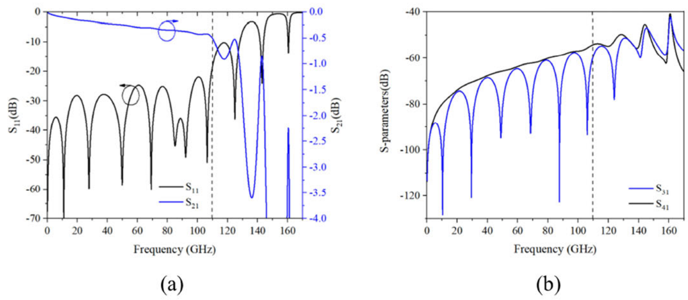


Fig.7 The simulation results of the B2B interconnection: (a): transmission coefficient and reflection coefficient; (b): isolation coefficient between ports.

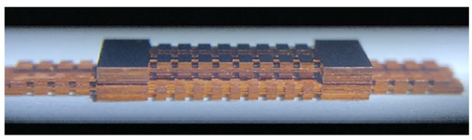


Fig.8 Photograph of the fabricated B2B interconnection.

- Fig. 8 shows the photograph of B2B vertical interconnection fabricated by M-MAM technology.At the time of the completion of this paper, the B2B vertical interconnection has not been tested because the test platform has not been set up yet.

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