A Bonding Structure with Low Return Loss and High Transmission Bandwidth for Microwave Circuit

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Abstract: In this paper, we present a bonding interconnect structure based on multi-stub impedance matching. The proposed structure has excellent high-frequency performance with 3dB bandwidth of 65.9 GHz and return loss of -15.533dB at 40 GHz.

1. Introduction

In microwave multi-chip modules (MCM), wire bonding is usually used to realize the interconnection of monolithic microwave integrated circuits (MMIC) and the interconnection between transmission lines [1]. It has the advantages of low cost, mature processing technology and strong thermal stability. However, in the microwave and millimeter wave band, bonding wire interconnection will cause serious impedance mismatch due to the introduced parasitic effect [2]. It will affect the transmission performance of the entire system. Therefore, it is necessary to optimize the structure of the bonding wire interconnection. Previously, a variety of structures of bonding wire interconnect technology have been reported, such as inserting a microstrip tuning stub, constructing a 5th-order low-pass filter and adjusting the pad width. These designs improve high-frequency performance of bonding interconnects [3-5]. However, these structures are difficult to design when used to compensate for specific frequency bands.

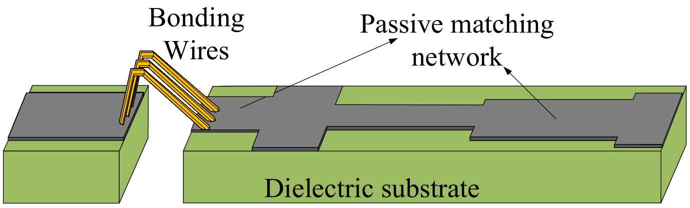
In this paper, we propose a novel a bonding wire interconnection model based on the principle of multi-stub impedance matching. We use Smith chart to design the structure with multi-stub to achieve impedance matching and reduce the damage to the transmission performance of the impedance mismatch. The proposed model can achieve impedance matching up to 40 GHz. It has an excellent high-frequency performance with 3dB bandwidth of 65.9 GHz and return loss of -15.53327dB at 40 GHz. The proposed structure can accurately compensate for specific frequency bands and be used to microwave circuit.

2. Bonding interconnect design

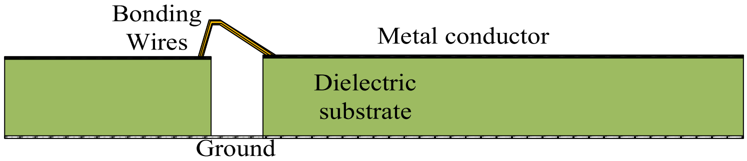
2.1 Impedance matching structure design

In the microwave and millimeter wave band, interconnecting wires will introduce serious parasitic effects. In this paper, the Smith chart tool in the commercial software ADS is used to design a multi-stub impedance matching structure. That is, ADS and HFSS are used to calculate the length and width of each stub to obtain a passive matching network, which is placed between the bonding wires and the transmission line to achieve impedance matching on both sides. The optimized structure diagram is shown in Fig.1(a) and (b).

Due to the introduction of a passive matching network, the optimized model can achieve impedance matching in the specified frequency band. Compared with the quarter-wavelength converter impedance matching, this method has a wider matching bandwidth and better compensation performance for undesirable effects in multi-chip microwave circuit.



a. Front view of the optimized structure



b. Side view of the optimized structure

Fig.1. Insert transport model of the matching network.

2.2 Model parameters design

We use microstrip line as the transmission line of this model. The distance between the microstrip lines on both sides is 300 μm. The metal conductor is made of copper. The dielectric substrate uses single-layer FR-4, the thickness is 150μm. Impedance of both ports are set to 50Ω. The microstrip lines on both sides are connected by golden bonding wires. For interconnected bonding wires, the larger the number, the larger the diameter, the lower the arch height, and the larger the spacing, the better the microwave characteristics. However, if the diameter is too large, or the arch height is too low, the golden bonding wire will easily break and reduce reliability [6]. Based on the comprehensive consideration of cost, reliability, volume, and transmission performance, the process parameters of interconnected golden wires are set to 25 μm in diameter, 200 μm in arch height, three in number, and 70 μm apart from each other.

Under the premise of selecting the key bonding wire process parameters, we use commercial simulation software HFSS and ADS to design the transmission model. After calculation, a microwave network composed of four series-connected stubs is obtained to achieve the purpose of impedance matching. The length and width of each stubs is shown in Table 1.

Table 1. The length and width of each stub

	length/μm	width/μm
Stub 1	200	250
Stub 2	200	360
Stub 3	700	135
Stub 4	700	220

3. Results analysis

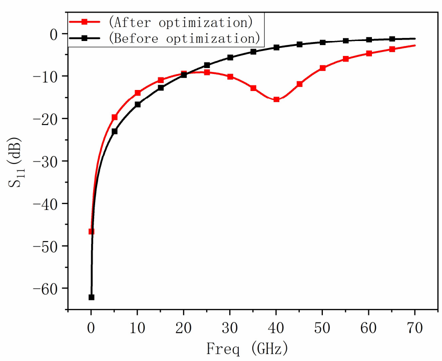


Fig.2. Reflection coefficient of the model

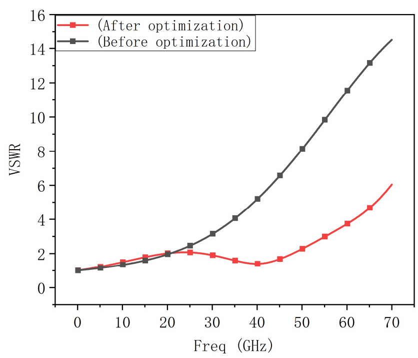


Fig.3. Voltage Standing Wave Ratio of the model

We got the comparison of the reflection coefficient S_{11}, voltage standing wave ratio (VSWR) and transmission coefficient S_{21} of the model before and after optimization, as shown in Fig. 2, Fig. 3 and Fig. 4. The reflection coefficient S_{11} and voltage standing wave ratio (VSWR) are important parameters reflecting impedance matching. Because of impedance mismatch, the reflection coefficient S_{11} of the model before optimization is -3.40191dB and VSWR is 5.17159 at 40GHz. That means a lot of energy is reflected back to the original port. At the same time, S_{11} and VSWR of the optimized model are -15.53327dB and 1.40165 respectively. It can be seen that due to the addition of the matching structure, the bonding interconnect model achieves good impedance matching at 40GHz and the return loss has been greatly reduced.

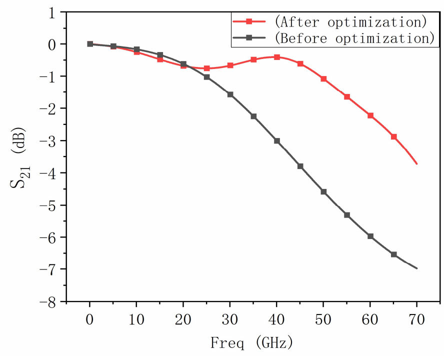


Fig.4. Transmission coefficient of the model

And the transmission coefficient S_{21} is -0.41238dB, and the 3dB bandwidth reaches 65.9GHz. The transmission performance in the microwave and millimeter wave band has been greatly improved. At the same time, due to the use of the Smith chart tool, the model obtained is less dependent on the frequency and has a wider matching bandwidth, which is more suitable for application in high-frequency circuits.

4. Conclusion

In this paper, a bonding interconnection structure with excellent high frequency performance is proposed. We optimize bonding wire process parameters that take account of reliability, cost and transmission performance. A 3dB bandwidth of 65.9 GHz and return loss of -15.53327dB at 40 GHz is achieved. The proposed structure only needs to insert a passive matching network on one side, which is flexible and suitable for application in multi-chip microwave circuits.

5. Acknowledgment

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