Modeling and Characterization of the Bonding-Wire Interconnection for Microwave MCM

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Abstract

The 3-D electromagnetic software Ansoft HFSS is adapted to modeling analysis and simulation optimization about the microwave characteristics of bonding interconnection in the MMCM. The gold bond model contained micro strip is set up to emulate and optimize for insertion loss (IL) and return loss (RL), according to the major parameters such as arch highness, span and the root of the number of gold. Micro strip model of three roots copper wire connection is established to analyses the difference between microwave characteristics of the golden and copper. The results showed that arch highness of bonding gold wire is the lower the better in the case of singles gold and the same span. The span of bonding gold wire is the shorter the better in the case of singles gold and the same arch highness. It should be as far as possible bond 2 or 3 roots gold if the chip welding area allowed. Copper wire has shown better microwave properties than gold in the area of return loss and insertion loss.

1 Introduction

In the microwave multichip module (MMCM), the bonding interconnect line is generally used to realize the interconnection between pad. As frequency increases, the bonding of interconnect is more and more obvious influence to the microwave circuits, sometimes even become major factors. There are several parameters to decide bonding characteristic, such as the length of bonding line, arch highness, the span and root number of gold. These differences of parameters can also affect the consistency of bonding line microwave characteristics. In this paper, 3-D electromagnetic software Ansoft HFSS is adopted to modeling analysis and simulation optimization about the microwave characteristics of bonding interconnection wire in the MMCM. In the HFSS, physical model of gold wire bonding interconnection of micro strip is established, in accordance to several cases: (1) single wire, different high arch and the same span; (2) single wire, same high arch and different span; (3) same high arch, same the span, different number of roots of gold, to emulate and optimize the main performance parameters insertion loss (IL) and return loss (RL) which can affect microwave characteristic of bonding interconnect.

2 model of bonding interconnect in the MMCM

Bonding interconnect is the key technology to realize the electrical interconnection of MMCM. The high arch, span and number of gold wire the bonding interconnection have a great influence on the microwave characteristics. Normally the structure of bonding between micro strip lines is shown in figure 1. The equivalent circuit model can simply use a low-pass filter network consisting the shunt capacitance C1, series inductance L, series resistor R and the shunt capacitance C2, as shown in figure 2.The main role in this model is the bonding series inductance L, and the shunt capacitance C1, C2 is small, which is similar to open circuit stubs [1].

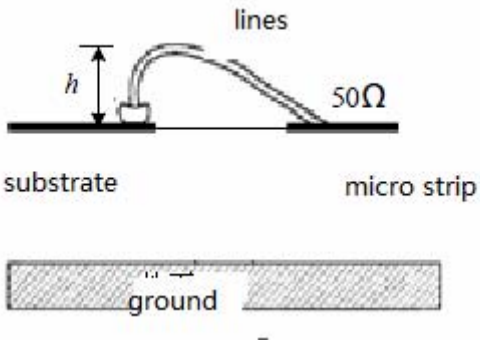

Figure 1 the structure of bonding between micro strip

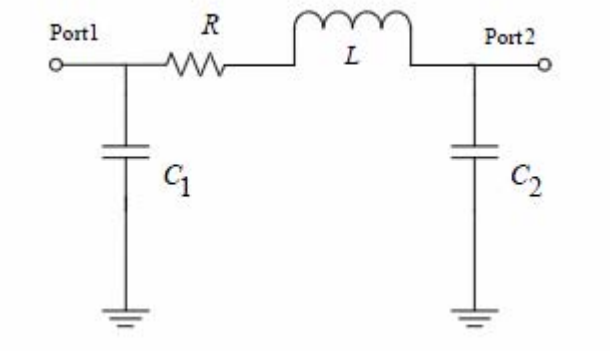

Figure 2 the equivalent circuit model of bonding

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In the low temperature co-fired ceramic (LTCC) microwave multichip module (MCM), gold-rimmed bonding is usually adopted to realize the interconnection between the monolithic microwave integrated circuit (MMIC), lumped type resistance and capacitance and micro strip and coplanar waveguide, as well as the interconnection between the micro strip or RF grounding. The arch height, span and the gold number of roots of gold wire bonding interconnection have a great impact on the microwave characteristics of microwave MCM. Unlike low-frequency digital circuits, microwave characteristics of gold bonding interconnection is the major factor which affect the microwave performance of the LTCC MMCM, the wire length, arch height and span, solder joint location and the consistency and repeatability of bonding parameters have great influence on the microwave transmission. Previous, gold bonding interconnection microwave characteristic analysis usually adopt lumped elements such as inductance to equivalent bonding gold-rimmed [3], or adopt quasi-static analysis method [4]. However, gold bonding interconnection is an open structure, and there is media boundary and gold curve. So using the above method to analyze the microwave properties of gold wire bond interconnection will lead to decrease analysis accuracy with the increase of frequency and length of gold wire [5]. This article uses the commercial 3D electromagnetic analysis software HFSS to give modeling analysis and simulation optimization on the microwave characteristics of the gold wire bonding interconnection, which is equivalent to the low-pass filter network model composed of a series resistance, a series inductance and two parallel connection capacitance. A typical structure of gold bonding interconnects shown in Figure3.

In the HFSS, the physical model of gold bonding included in the micro strip is established, to calculate in the needed frequency range with the same boundary conditions, and the results will get into S parameter file. This model shown in figure 4, substrate sizes for 8mm*8mm*0.2mm, BT resin, wire bonding for gold, 1mil diameter, distance between micro strip 0.2 mm, wide of micro strip 0.6 mm, using the wave port, the incentive for waveport1, the right to waveport2.

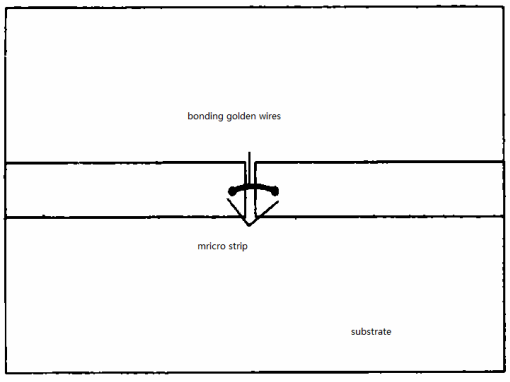

Figure 3 the structure of gold bonding interconnects

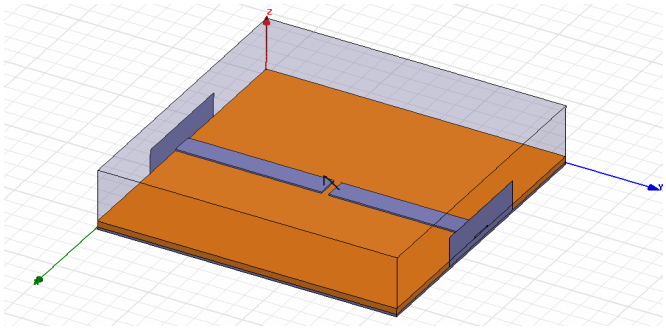

Figure 4 HFSS model of gold bonding

3simulation analysis of microwave characteristic of bonding interconnection

The main performance parameters such as insertion loss (IL) and return loss (RL), which can affect the microwave characteristics of bonding, are emulated and optimized in accordance to several cases: (1) single wire, different high arch and the same span; (2) single wire, same high arch and different span; (3) same high arch, same the span, different number of roots of gold silk.

3.1 Analysis of gold silk bonding with single golden, the same span but different arch height.

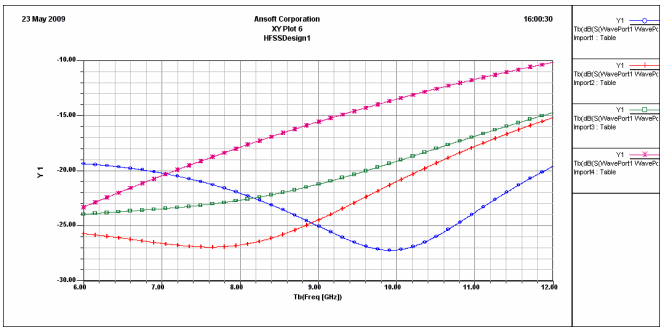

Figure 5 S11 curve with single golden, the same span but different arch height

Figure 5 is the S11 curve with single silk, in the span d = 0.4 mm, different arch height (blue: h = 0.01 mm, red: h = 0.1 mm, green: h = 0.2 mm, purple: h = 0.3 mm). It can be obtained from S parameter figure that: lower the arch

height is, smaller the db value is with high frequency, in the same span and single golden. The microwave characteristics is better when the return loss (RL) is smaller, namely the energy reflected from port 1 is smaller.

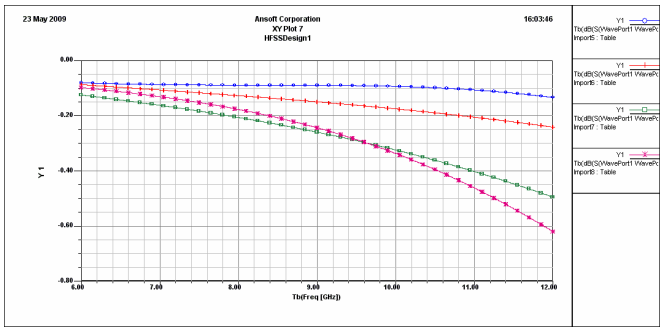

Figure 6 S21 curve with single golden, the same span but different arch height

3.2 Analysis of gold silk bonding with single golden, the same arch height but different span.

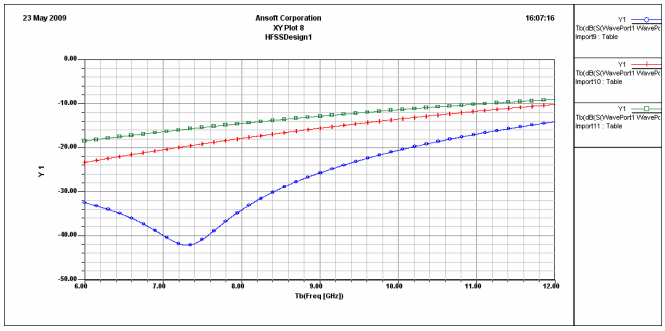

Figure 7 S11 curve with single golden, the same arch height but different span

Figure 7 is the S11 curve with single silk, in the arch height h = 0.3mm, different span (blue: d = 0.3mm, red: d = 0.4mm, green: d = 0.5mm). It can be obtained from S parameter figure that: lower the span is, smaller the db value is with high frequency, in the same arch height and single gold silk. The microwave characteristics is better when the return loss (RL) is smaller, namely the energy reflected from port 1 is smaller.

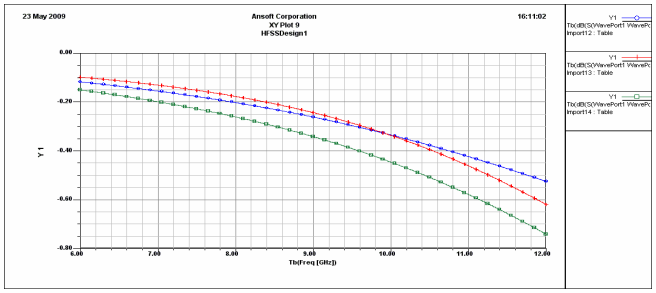

Figure 8 S21 curve with single golden, the same arch height but different span

Figure 8 is the S21 curve with single silk, in the arch height h = 0.3mm, different span (blue: d = 0.3mm, red: d = 0.4mm, green: d = 0.5mm). It can be obtained from S parameter figure that: lower the span is, smaller the db value is with high frequency, in the same arch height and single gold silk. The microwave characteristics is better when the insertion loss (transmission coefficient) is larger, namely the energy transmitted from port 1 to 2 is larger.

3.3 Analysis of gold silk bonding with the same arch height and span, but different number of roots of gold wire.

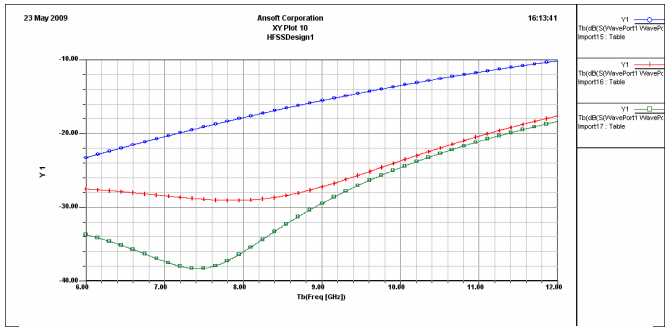

Figure 9 S11 curve with same arch height and span but different number of gold wire

Figure 9 is the S11 curve in the span d=0.4mm, arch height h = 0.3mm, different number of roots (blue: one roots, red: two roots, green: three roots). It can be obtained from S parameter figure that: the more roots of gold silk are, smaller the db value is in the same arch height and span. The microwave characteristics is better when the return loss (RL) is smaller, namely the energy reflected from port 1 is smaller.

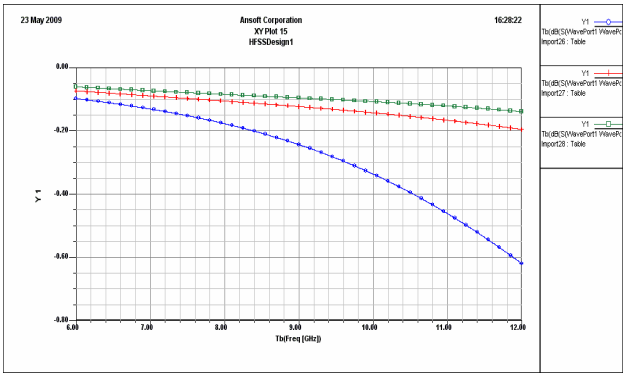

Figure 10 S21 curve with same arch height and span, but different number of gold wire

Figure 10 is the S21 curve in the span d=0.4mm, arch height h = 0.3mm, different number of roots (blue: one roots, red: two roots, green: three roots). It can be obtained

from S parameter figure that: the more roots of gold silk are, larger the db value is in the same arch height and span. The microwave characteristics is better when the insertion loss (transmission coefficient) is larger, namely the energy transmitted from port 1 to port 2 is larger.

4 contrast between optimization model of gold wire bonding and copper wire bonding

The optimum model obtained from the above analysis, is using three gold wires to connect microstrip, the arch height 0.1mm and span 0.3mm, as shown in figure 11:

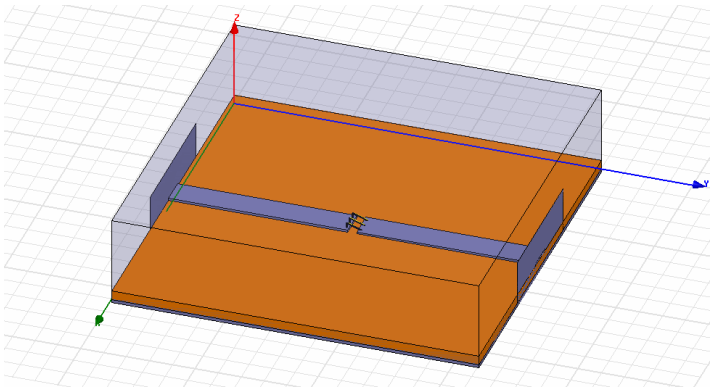

Figure 11 the optimum model of gold bonding

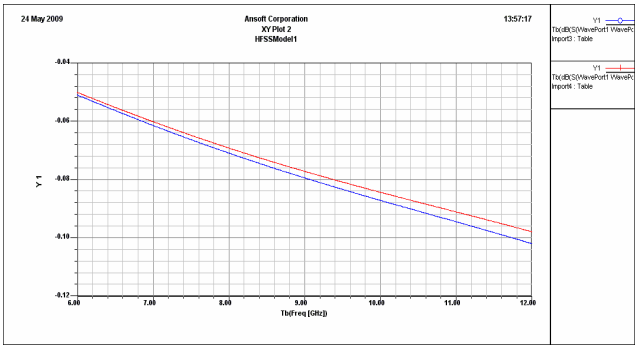

Figure 12 S11 curve of the optimum model of gold wire and copper

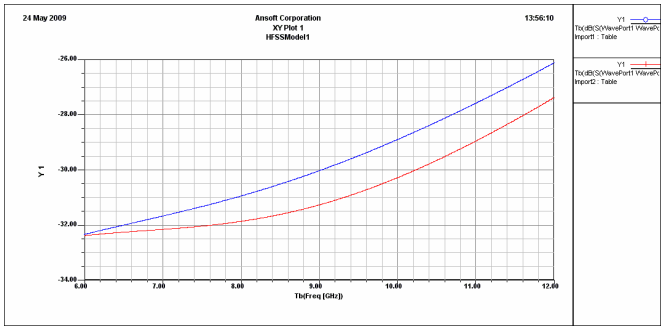

Figure 13 S21 curve of the optimum model of gold wire and copper

Now gold wire replaced by copper, we can observe the difference between microwave properties. First of all, compare their return loss, such as figure 12 shown below.

The blue line shows the S11 curve of gold and red shows copper in the figure 12. You can see the db value of the red line is smaller, and its return loss is smaller, namely the energy reflected back to port 1 smaller, the microwave properties better.

Followed their insertion loss can be compared, shown in figure 13. The blue line shows the S21 curve of gold wire and red shows copper in the figure 13. You can see the db value of the red line is larger, and its insertion loss is larger, namely the energy transmitted from port 1 to port 2 is larger, the microwave properties are better. So regardless of the return loss or insertion loss, the microwave properties of copper all showed better than gold, which is one of the reasons copper wire bonding has been widely applied.

5 conclusions

(1) Height arch of gold bonding wire is the lower the better with the singles gold and the same span. But in HFSS the high arch cannot simulation for 0, so using 0.01mm instead. It cannot guarantee the welding stability of flat bonding gold because of the characteristic of bonding process. Under the stress concentration, flat bonding gold fracture easily when suffer temperature shock or the vibration fault. It must keep proper arch height so as to both microwave characteristics and reliability

(2)The span of gold bonding wire is the shorter the better with the singles gold and the same height.

(3) If the chip welding area allowed, it should be as far as possible the same time to bond two or three roots gold wires, in particular, three roots gold. It little affects on the transmission characteristics, and improve the bonding reliability.

(4) The microwave properties of copper wire have shown better than the gold in the area of return loss and insertion loss.

Acknowledgments

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