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Modeling and Co-Design of Novel Packaging Interposer with IPD Layers

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1. Introduction

Through silicon via (TSV) technology is thought to be the essential technology of the next generation high-end semiconductors such as 3-D packaging interposer for fan out. TSV technology is proposed to solve the interconnect problem to reduce process area [1][2][3].

Two innovations topics will be presented in this research. First, structure of packaging interposer with IPD layers is proposed and broad-band equivalent model of TSV will be extracted too. Second, co-design case, coplanar waveguide transfer layers from top to bottom by TSV, is simulated by equivalent model we performed and compared with full wave EM simulation.

2. Structure and Modeling

Figure 1 shows the novel structure of interposer with IPD layers. It consists of dielectric layers, through silicon via and three redistribution layer. Top redistribution layer (RDL1), and two redistribution layers below the silicon substrate (RDL2 & RDL3) were Copper. The dielectric layers (BCB1 to BCB5) were SINx. The thickness of each layer is shown in table.1. The integrated passive components circuit could be designed in Copper layers (RDL1.RDL2.RDL3).

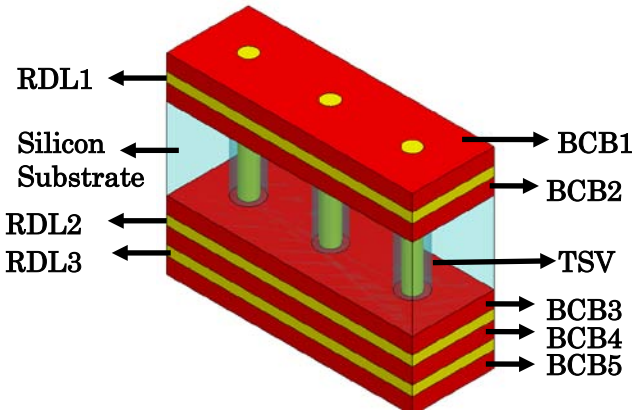

Fig.1 Novel Structure of Interposer with IPD Layers.

Table 1. The thickness of each layer

Layer	Thickness	Layer	Thickness
BCB1	5 μm	Silicon	150 μm
M1	3 μm	BCB4	3 μm
BCB2	5 μm	M3	3 μm
M2	3 μm	BCB5	5 μm
BCB3	5 μm		

The equivalent model of TSV in packaging interposer can be established by transmission line theorem. Figure 2 shows the simulation structure and proposed equivalent model of TSV by transmission line theorem [4]. The structure we used to simulate is Ground-Signal-Ground (GSG), including three through via, one for signal, and two for grounding. Two exciting ports, port1 and port2, are placed in RDL1 and RDL2 layers, typical TSV length when co-design with IPD circuits.

By the equivalent model shows in Figure 2, unbalance RLCG model of transmission line is used to perform TSV model. Series resistance (RofTSV) and series inductance (LofTSV) in the middle of the model present the trace loss and magnetic flux of grounding-return paths of TSV individually. And shunt capacitance (Csil) presents electric coupling between each TSV or to ground capacitance. This equivalent model is made to simulate the electrical characterization of TSV and used to co-design with IPD later.

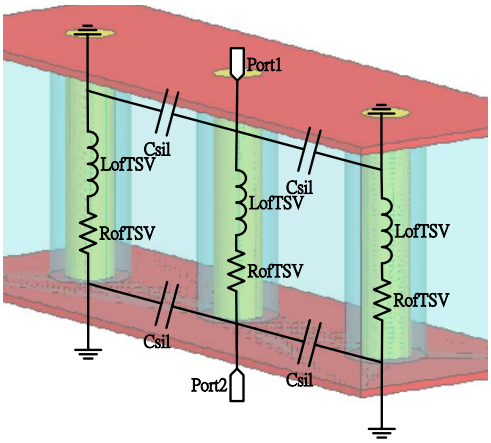

Fig.2 Equivalent Model of TSV in GSG Type

To find correct equivalent model of TSV [5], full wave 3D EM simulation result is extracted to perform broad band equivalent model of TSV, each parasitism values of model components are shown in Table 2.

Table 2 The parasitism values of Model Components

Component name	Value
Csil	3 fF
LofTSV	0.25 nH
RofTSV	6 mOhm

Once we created the equivalent model, we made the simulation of the model to find the S parameter and phase. Figure 3 and figure 4 show the comparison result between the TSV structure and the equivalent model. In these figures, we could discover that the results both 3D structure EM simulation and equivalent model to correspond exactly.

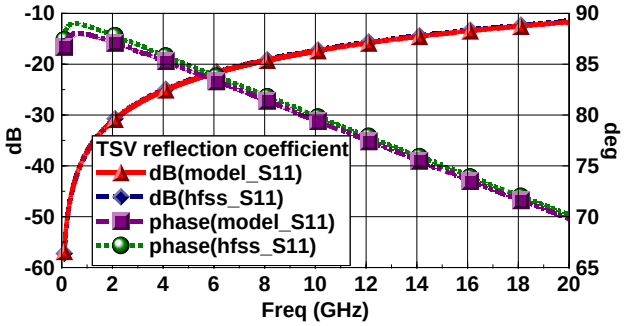

Fig.3 Compare reflection coefficient of the 3D EM Structure simulation and the Equivalent Model

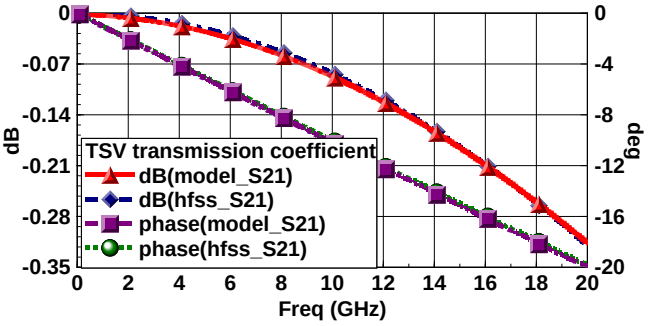

Fig.4 Compare transmission coefficient of the 3D EM Structure simulation and the Equivalent Model

3. Co-Design Example of CPW-TSV-CPW

For verify the model of TSV correct or not and perform IPD co-design characterization, a interposer with IPD co-design structure, coplanar waveguide transfer layers from top to bottom by TSV, is created and simulated. Figure 5 shows the full structure of CPW-TSV-CPW.

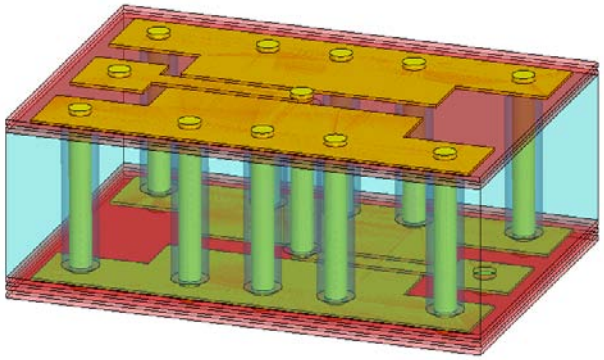

Fig.5 Structure of CPW-TSV-CPW

At last, compare with the simulation result between model and 3D EM simulation. Figure 6 and Figure 7 show the simulation result comparison with EM extracting by the CPW-TSV-CPW structure and circuit simulation by TSV equivalent model. Curve is fit and very similar or equal exactly too.

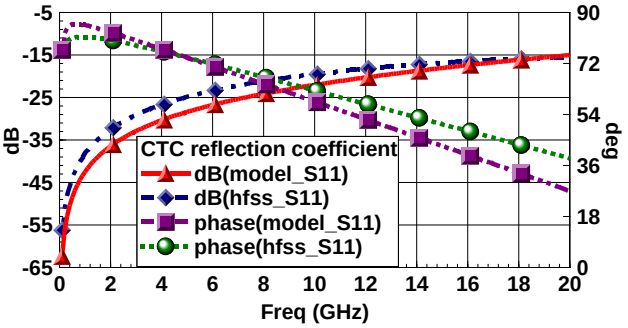

Fig.6 Compare reflection coefficient of the C-T-C Structure and the Equivalent Model

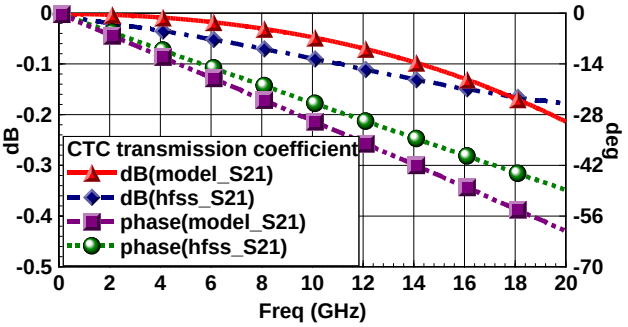

Fig.7 Compare transmission coefficient of the C-T-C Structure and the Equivalent Model

4. Conclusions

In this study, we presented the equivalent model by transmission line theorem in TSV and verified it by co-design case. Although we only have simulation results and don't have relative process technology, we can use simulation result to predict the electrical characterization of TSV. Therefore, we don't have any measurement results in this paper. The TSV can replace the vertical connection in PCB. This way can decrease the area of PCB board. The goals of the slight, thin and small product can be achieved.

References

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