Organic Substrate and Flip-Chip Bonding on It Technology, “Chip on ALIVH” Suitable for GHz System Packaging

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1. Introduction
The current trend in high-performance system level packaging is toward achieving higher speeds above GHz. In such situation, electrical parastics of wiring in a substrate and interconnection between chips and the substrate are becoming critical issues to realize it. Therefore, substrate and interconnection technologies having much less parastics are strongly required. To satisfy this requirement, we have developed an organic substrate and flip-chip bonding on it technology, “Chip on ALIVH: COA” operable at GHz.

“ALIVH™ Any Layer Inner Via Hole” is the organic high density multi-layered printed circuit board with an any layer inner via hole structure. [1] Because of the structure, the wiring in the substrate can be made with shortest length. In the COA, stud bump bonding, “SBB™” is engaged as the flip-chip bonding of LSI chips on the substrate. [2][3] The COA can realize both much less electrical parastics at GHz and high reliability in spite of organic substrates.

In this paper, the COA, its electrical characteristics at GHz, and its applications to a CSP (Chip Size Package) and an MCM (Multi-Chip-Module) are described.

2. ALIVH, SBB and COA Technology
The ALIVH substrate is the organic substrate having a dielectric constant much lower than those of ceramic substrates, so that it is suitable for GHz operation. It does not consist of glass-epoxy as conventional but epoxy impregnated non-woven aramid. Its via hole interconnection is not performed by copper electroplating as conventional but copper conductive paste.
The SBB is the flip-chip interconnection technique using stud bumps made of an Au on LSI chips and conductive adhesives. The epoxy under-fill resin is inserted to fill a gap between the LSI chip and the substrate.

![Fig. 1 The typical structure of SBB and ALIVH](image)

Figure 1 shows the typical structures of the SBB and the ALIVH substrate.

The COA technology is the combination of the improved and optimized processing of the SBB and materials of the ALIVH to realize both high performance at GHz and high reliability.

3. Electrical Characteristics of ALIVH at GHz
In order to design packaging at GHz, material constants of the substrate and the equivalent circuit of the via hole at GHz must be characterized. The dielectric constant, transmission line losses in a GHz frequency range of the ALIVH substrate were evaluated using a microstrip line resonator. Figure 2 shows the frequency dependence of ε (relative dielectric constant) and the transmission line losses of the ALIVH substrate. The ε of the ALIVH substrate was about 3.5 and constant from 1 to 10 GHz. The loss tangent was about 0.024 and also constant from 1 to 10 GHz. In comparison with a conventional FR-4 substrate, the ε of ALIVH was 19% smaller and the loss tangent was almost same.

![Fig. 2 Frequency dependence of the dielectric constant and the transmission line losses of the ALIVH substrate](image)

The equivalent circuit of the via hole in the ALIVH substrate was also evaluated using the resonant method [4]. The structure and the equivalent circuit of the via hole are shown in Fig.3. In order to evaluate the influence of the via clearance, the clearances were changed from 0.1mm to 5mm. The capacitance and inductance values at 0.1mm and 5mm are shown in Fig.3. At 0.1mm clearance, the inductance was 0.1nH and the capacitance was 0.12pF. These values were
constant from 1 to 10GHz. At 5 mm clearance, the inductance and capacitance changed from 1GHz to 10GHz. One choice of the via clearance to be recommended for signal transmission at the frequency is 0.5mm. In this case, the equivalent inductance and capacitance of the via are 300pH and 50 fF, respectively.

![Equivalent Circuit](image)

**Fig.3** The structure and the equivalent circuit of the via hole of the ALIVH substrate

**Fig.4** The capacitance and inductance values from 1 to 10GHz

4. SBB Interconnection

The equivalent inductances of the SBB interconnection and wire bonds were also measured using the resonant method. Figure 5 shows the relationship between frequency and the equivalent inductance. The measured values of the SBB were less than 0.1nH.

![Inductance vs Frequency](image)

**Fig.5** The relationship between frequency and the equivalent inductance of the SBB

5. CSP

One of the typical applications of the COA is a CSP for digital LSI. In the high-speed digital operation, the equivalent inductance of the power and ground line is important. We evaluated the power or ground line of the CSP at GHz. Three types of the line configuration in the CSP were evaluated. Type 1 was microstrip line configuration without any ground in the CSP. Type 2 was microstrip line configuration with ground in the CSP. Type 3 was stripline configuration with ground in the CSP. The evaluation method was same as that of the via and the SBB.

Figure 6 shows the equivalent inductances up to 2GHz on type 1, type 2 and type 3 structures when the line length was 14 mm. Type 3 showed lowest equivalent inductance of 0.5nH/mm.

![Inductance vs Frequency](image)

**Fig.6** The equivalent inductances of type 1, type 2 and type 3 structures

6. MCM

One of the typical applications to system level packaging of the COA is the MCM for high-speed microprocessor. Figure 7 shows the application to the MCM consisting of 4 LSI chips including 1 MPU on 8 layer ALIVH substrate using the COA technology. The MCM showed high-speed operation and high reliability.

![MCM with MPU](image)

**Fig.7** The outlook of the MCM with a MPU using the COA

7. Conclusions

We have developed the organic substrate and flip-chip bonding on it, “COA” operable at GHz. We evaluated the high frequency electrical characteristics of the COA and the equivalent circuits. The COA was found to be good enough to apply to high-speed digital systems up to 1GHz.

References


