The Evolution of Any Layer IVH Structure PWB

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Abstract
With the advent of digitisation, networking, broadband telecommunication, and miniaturization in electronic set products, electronic devices are essentially required to deliver high electrical and mechanical performance that correspond with this trend. From its first introduction in 1996, Any Layer IVH structure ALIVH has been serving the mobile phone application as its core business market but has since diversified into several other markets. Therefore, I would like to give an introduction, along with an update on the status of ALIVH for motherboard use and the technological development and trends of our extended range of new products such as ALIVH -B, ALIVH (G-type), etc

Introduction
In recent years, with electronic products becoming smaller and lighter with more features and higher operating speeds, electronic parts such as semiconductors are rapidly becoming miniaturized and gaining in number of pins, as shown in Figure 1. Accompanying this, printed wiring boards on which those parts are mounted need to feature high wiring capability, easy design performance, thin size, light weight and excellent electrical and mechanical performance. (See Figure 2.)

To meet the above needs, our company succeeded in 1996 in mass production of ALIVHTM (Any Layer Interstitial Via Hole Structure PWB) multi-layer resin printed wiring board which has a build-up structure for all layers and has, as of this year, attained a total sum of 100 million shipments for use in mobile phones.

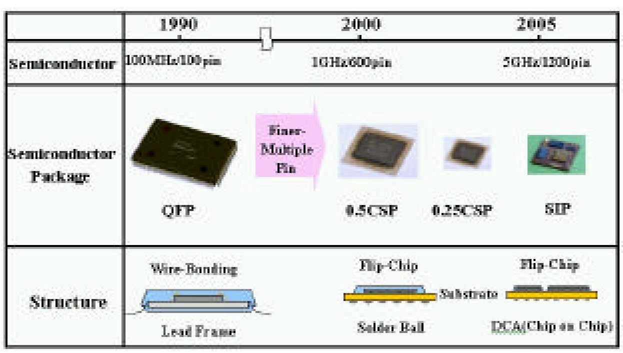


Figure 1 - Downsizing and Weight Reduction for Semiconductor

Further, we have succeeded in the development of ALIVH-B (ALIVH for Bare-chip mounting) leading to improved density and reliability of the ALIVH motherboard. We are now preparing its mass production for interposer substrates for mounting bare-chips small-sized semiconductor packages such as CSPs and MCMs.

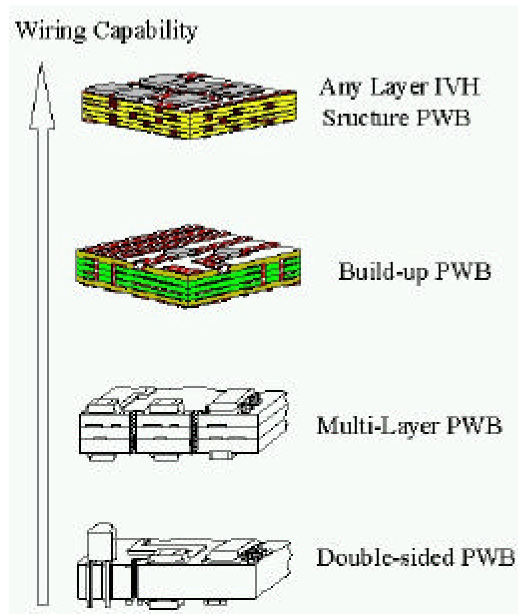


Figure 2 - Evolution of PWB

We also succeeded this year in developing ALIVH (G-type) boards (G is the acronym for Glass epoxy substrate, hereafter ALIVH-G) characterized by improved surface strength and rigidity and reduced moisture absorption compared with current ALIVH motherboards, and have started their mass production.

In the following, we describe general ALIVH technology, the results of performance evaluation of ALIVH-B and the development process of ALIVH-G.

Overview of ALIVH technology
For conventional multi-layer PWB, interconnection between layers is achieved through copper plating on NC machined holes as seen in Figure 3. With this structure, wiring has to be extended from component land to the land of these plated holes for connection with other layers. This significantly restricts the potential for further downsizing and improvement in wiring density.

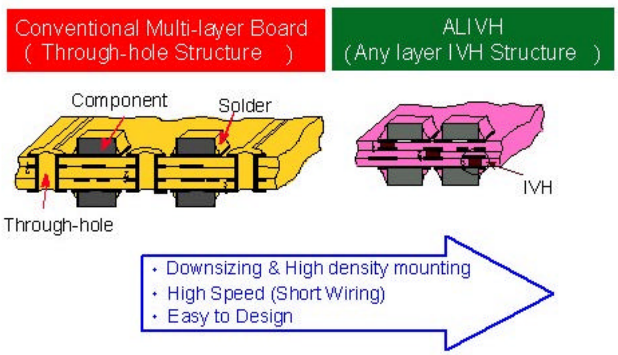


Figure 3 - Comparison with Multi-Layer Structure

Contrary to conventional multi-layer PWB, ALIVH does not require plated through holes for interlayer connection. This is because of its unique structure that can enable the use of IVH at any place on any layer. In contrast with conventional multi-layer PWB, ALIVH does not require wiring to be extended from its component lands and 100% of its surface area can be fully utilized for mounting of components, thus enabling a possible reduction in size and an optimization in wiring density. Moreover with this structure, wiring length can be shortened for faster signal transmission. On the whole, this wiring versatility can also allow 100% automatic wiring with custom-designed CAD software.

As for build-up multi-layer PWB with fine wiring feasible on build-up layers only, the use of conventional multi-layer structure as its core poses a certain constraint for downsizing and weight reduction when compared with ALIVH.

Features of ALIVH

As opposed to most other high-density multi-layer PWB that use glass epoxy resin, ALIVH employs aramid prepreg as its insulation material. Besides its application in electronics, aramid has also been known for its use in products such as bulletproof vest and fireproof jacket for its toughness and high heat resistance. The inherent properties of aramid includes low coefficient of thermal expansion (CTE), low dielectric constant, high toughness, and lightweight, which are highly regarded for use as insulating material in PWB. For hole processing, ALIVH uses pulse-oscillated CO_2 gas laser to ablate fine microvia holes with high speed and accuracy. Instead of using copper plated holes for its electrical conduction, these microvia holes are plugged with special conductive paste. Thin copper foils whose uniform thickness is desirable for forming fine wiring patterns is used in place of conventional plating process, which has poor surface evenness. Please refer to Figure 4 for the concept and technology features of ALIVH.

Manufacturing Process

A schematic representation of ALIVH manufacturing process is as shown in Figure 5.

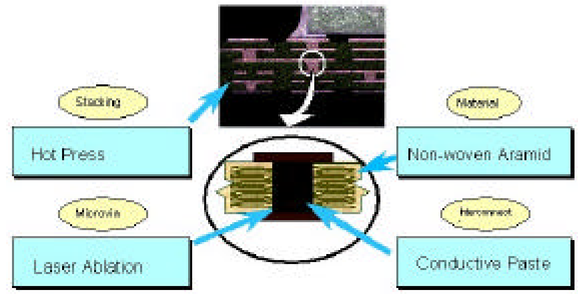


Figure 4 - Concept and Key Technology

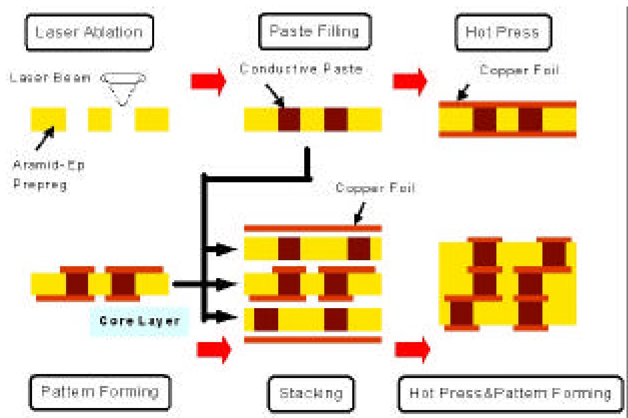


Figure 5 - Manufacturing Process of ALIVH

Microvia holes of approximately 200(µm in diameter are first ablated using CO_2 laser on a B-stage aramid epoxy prepreg formed by impregnating epoxy resin into non-woven aramid fiber paper. These microvia holes are then plugged with conductive paste consisting of copper powder particles interspersed in epoxy resin. After which 18 µm thick copper foils are aligned on both sides of the prepreg in a stacking process. The stacked layers are then pressed between the hot plates of hot press laminator furnace to form a single composite layer under suitable heat, pressure, and vacuum. During the hot pressing, bonding between the copper foils and prepreg, and interconnection within the copper paste is simultaneously achieved. Upon cooling, the blank copper on both side of the board then undergoes conventional patterning and etching to form a basic double-sided PWB structure with paste-filled IVH.

The prepregs for the build-up layers on both side of the basic double-sided board are then process in the same way as described above. CO_2 laser ablated microvia holes on the prepregs are plugged with conductive paste and aligned with copper foils on the outer-facing surfaces on both sides of the double-sided board. Under heat and pressure in the hot press laminator furnace, a multi-layer board is formed. Surface pattern is then etched from the external blank copper foil to form the conductive wiring pattern. This process is then repeated when building up 6 or 8 layers ALIVH.

From the above, it can be seen that ALIVH manufacturing process is relatively simple. A high-density uniform layer structure with pad-on-via and via-on-via features can thus be easily realized.

ALIVH-B Technology

Technology Approach

The structure of ALIVH-B is fundamentally congruent to ALIVH, inheriting some of its core features. Figure 6 below shows the strengths of ALIVH-B along with some of its characteristic values.

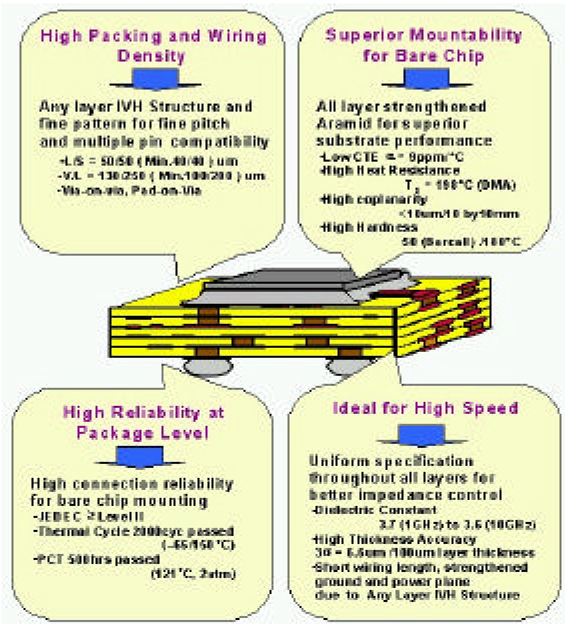


Figure 6 - Advantages of ALIVH for Bare Chip Mounting

The ensuing sections outline the development and evaluation of ALIVH-B in the following:

i. Fine pattern forming
ii. Fine microvia ablation
iii. High reliability realization
iv. Bare chip mountability evaluation
v. Package evaluation
vi. 2nd mounting evaluation

i. Fine Pattern Forming

For ALIVH motherboard, the minimum standard line and space (L/S) of its conductor pattern is 100/100µm with selective area at 60/70µm. To realize a fine wiring suitable for bare chip mounting, this design value was subsequently reduced to 50/50µm for standard wiring pattern and 40/40µm for wiring in chip mounting area. In consideration of manufacturing cost-effectiveness, subtractive method for the forming such fine conductive pattern is adopted. The following sections below shall describe the material and process development associated with such fine pattern forming.

– Thin High-resolution Dry Film

ALIVH manufacturing uses a 40µm thick dry film to form the resist pattern on the blank copper foil for the etching process. This dry film thickness may be well suited for a L/S of 100/100µm but is incapable of realizing the finer and denser pattern requirements of ALIVH-B. The aspect ratio of the film does not sufficiently allow the etchants to remove the unwanted copper defined by the resist pattern, making pattern forming for L/S of 50/50µm inadequate. Thus the thickness of the dry film was reduced to 15-µm so as to attain an ideal aspect ratio for higher etching efficiency. Also, for a finer pattern, the contact surface area of the remaining dry film resist with the blank copper surface is reduced, leading to a weakened adhesion and increased occurrence of delamination which causes short or incomplete forming of the copper. Thus the adhesive performance of the dry film was also improved. Figure 7 shows the etching results of the new dry film for fine pattern forming.

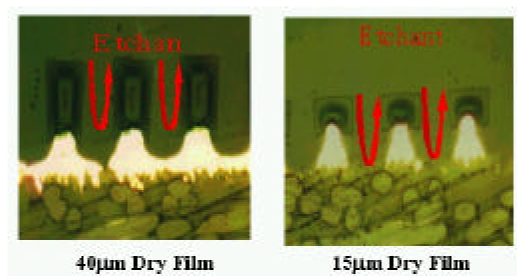


Figure 7 - Etching Result with 40mm and 15mm Dry Film

– Etching System

The etchant used for the chemical removal of copper was changed to achieve a consistent etch quality of the copper pattern.

High-pressure spray with properly chosen and configured nozzles is used for the introduction of a controlled, reproducible, constantly refreshed spray of etchant to expose away the PCB in a conveyorized chamber. Such a set-up, with the new etchant, is critical for obtaining high quality etching of fine copper patterns with straight sidewalls.

Figure 8 shows the efficiency of modified etching system while Figure 9 shows SEM photographs of etched pattern with this modified system.

Etching speed (m/min)			1.5	1.6	1.7
Etchant & Equipment	Current system	Cp	1.57	1.42	1.40
		*d value	0.32	0.34	0.33
	Modified system	Cp	1.47	1.58	1.58
		*d value	0.14	0.16	0.15

*d value = (B – T)/T

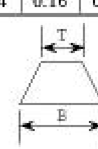


Figure 8 – Efficiency of Modified Etching System

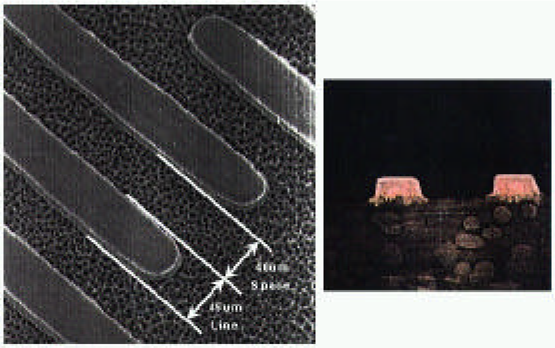


Figure 9 SEM Cross-Section Photographs

ii. Fine Microvia Ablation

In order to produce fine via holes while realizing a high manufacturing yield and cost-effectiveness, CO_2 gas laser was adopted. This process is capable of ablating via holes on the prepreg with high speed and accuracy through the use of an interchangeable mask in a series of optics system. The schematic diagram in Figure 10 shows the set up of the optical imaging system for ablating microvia holes as small as 100µm.

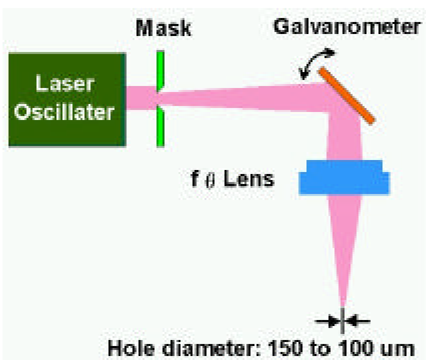


Figure 10 – Setup of New Laser Machine

Figure 11 shows the relationship of the corresponding resistance change to varying via sizes for a series of 500 via connection.

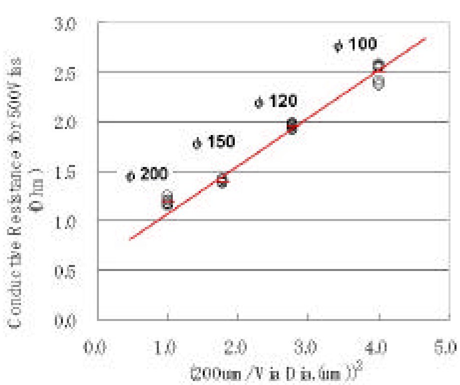


Figure 11 – Relationship of Resistance to Via Size

The measured value of the conductive resistance is found to be close to the theoretical value calculated based on the area of via. This illustrates the good electrical conductivity of ∅100µm via despite the small via size.

iii. High Reliability Realization

Compared with the PWB used as motherboards, the level of reliability expected of PWB substrate for semiconductor packages is significantly higher.

Thus in order to fulfill such strict reliability requirements of interposer substrates at package level, materials such as the insulating material, conductive paste, and copper foil were developed and adopted for use in ALIVH-B manufacturing.

The insulating material used is an improved non-woven aramid epoxy resin that exhibits excellent hole processability with laser ablation at a processing rate of approximately 200 holes per second. In addition, the impregnating resin was improved to obtain a high T_g of 198°C (DMA method), thereby attributing a high heat resistance characteristic to ALIVH-B. Also, its CTE (which is also dependent on the copper ratio) at approximately 9ppm/°C is much closer to that of silicon when compared with conventional glass epoxy (FR-4), making ALIVH-B a more suitable substrate for flip chip mounting.

In developing the insulating material for ALIVH-B use, the moisture absorption and hygroscopic expansion rate was improved, thereby enhancing the overall moisture resistance of the board.

Similar to ALIVH, ALIVH-B achieves it interlayer connection by means of a special conductive paste, consisting of copper powder particles interspersed in an epoxy resin acting as a binder. However, in seeking a higher reliability of the paste, heat resistant and moisture resistant binder was developed and used. As its microvia hole size is comparatively smaller than ALIVH, an optimum size and form of the copper powder particles is derived for attaining a quality plugged via for such fine hole sizes so as to ensure the continued high reliability performance of the connection.

After developing the above, ALIVH-B bare board was tested for its reliability under standard test requirements specified by semiconductor packaging industry. Table 1 shows the results of these reliability tests while Figure 12 shows its PCT results. Figure 13 shows the measured electrical resistance for 300 series connected via after thermal shock test.

From these test results, we can conclude that ALIVH-B bare board is sufficiently reliable for mounting with semiconductor chips.

Table 1 - Reliability Test Results of ALIVH-B Substrate

Evaluation Item	Condition	Results
Storage at High Temperature	150°C for 2000hrs	Passed
Storage at Low Temperature	-65°C for 2000hrs	Passed
Storage at High Temperature & Humidity	85°C/85%RH for 2000hrs	Passed
Storage at High Temperature & Humidity with Bias	85°C/85%RH with DC5.5V for 2000hrs	Passed
PCT Test	121°C at 2atm for 500hrs	Passed
Thermal Shock (Liquid Phase)	-65°C to 150°C for 1000cyc	Passed
Thermal Shock (Vapour Phase)	-65°C/Room temp/150°C for 2000cyc	Passed
Reflow after Moisture Ingression (Popcorn Level II)	(85°C/60%RH for 168hrs + Reflow×3) for 5 cyc	Passed
Reflow after Moisture Ingression and Heat Shock (Popcorn Level II + Heat Shock)	(85°C/60%RH for 168hrs + Reflow×3 → -65°C to 150°C (Liquid phase) for 500cyc	Passed

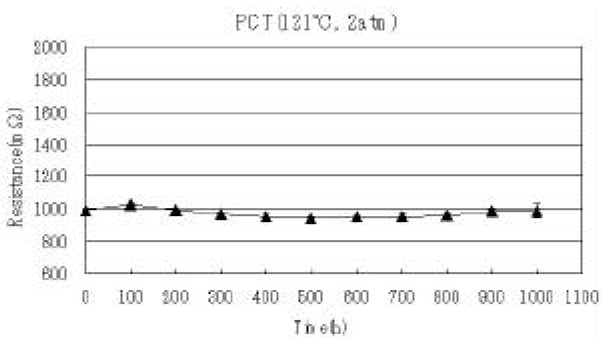


Figure 12 - Results of Pressure cooker test

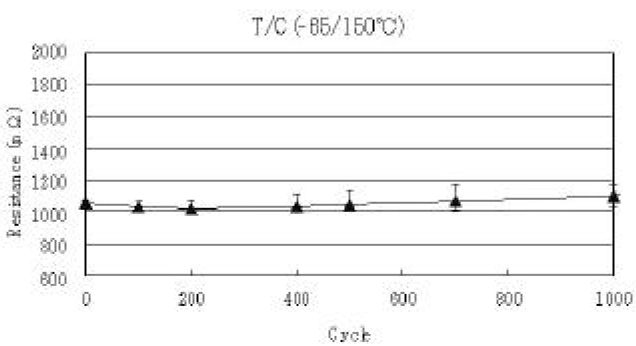


Figure 13- Results of Thermal Cycle Test

iv. Bare Chip Mountability Evaluation

With the diversification of surface mounting technology for high-density IC chip, the interposer substrate to be used should not only possess high reliability as a bare board but also exhibit befitting properties and characteristics for the various mounting conditions.

For instance in wire bonding, heat and ultrasonic energy is used to form a metallurgical bonding between the chip and interposer substrate. The typical operating temperature ranges from 130°C to 190°C. Thus, substantial substrate hardness is required at such high temperature to ensure an efficient transfer of the ultrasound energy. Similarly in ACF mounting, the applied temperature of the hot press tool operates between high temperatures of 180°C to 220°C. When such pressure is applied on the bare chip, depression on the substrate might occur if the substrate is not sufficiently rigid and hard. Also in down-facing chip mounting, a high surface coplanarity of the substrate will ensure that the IC pad not be damaged.

Figure 14 shows the temperature-dependency of ALIVH-B barcall hardness.

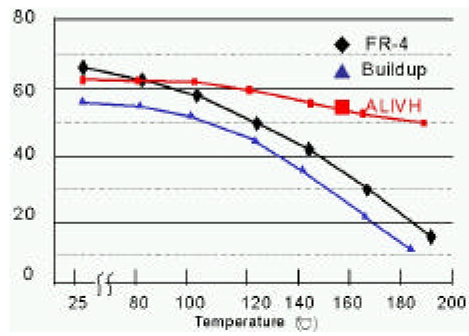


Figure 14 - Barcall Hardness of Various Material with Temperature Change

At room temperature, ALIVH-B and glass epoxy or FR-4 equivalent substrate demonstrates approximately the same hardness. However at elevated temperature, due to its high T_g, ALIVH-B is able to maintain relatively high hardness with only a slight drop as compared to FR-4. Additionally, the co-planarity in the chip mounting area is maintained at 10µm for a 10 by 10mm area (Figure 15), thereby making it suitable for wire bonding or flip chip mounting methods such as ACF, NCP, or SBB.

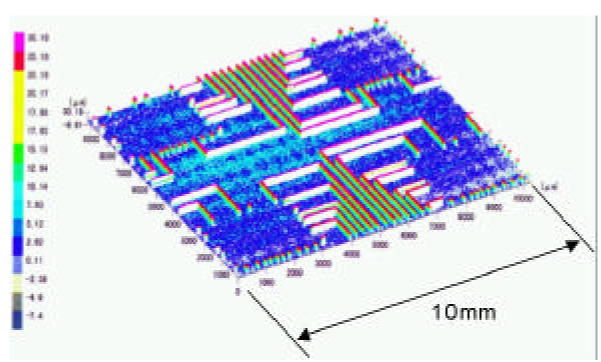


Figure 15 - Surface Co-Planrity of ALIVH-B

v. Package Evaluation

The reliability of a package is a combination of many factors such as structure, material, and the mounting method used. For the different mounting methods, the qualities needed of its interposer substrate varies with each set of mounting conditions. Thus, test packages fabricated with ALIVH-B using wire bonding, and flip chip mounting methods such as ACF and SBB, were tested and examined in an attempt to determine its package reliability. Examples of such package evaluation with solder flip chip and ACF mounting methods are shown in Figure 16.

From the results shown in the figure, ALIVH-B has displayed high reliability at package level with minimal resistance change in the assembly.

vi. 2nd Mounting Evaluation

As the pitch size of CSP gradually decreases from 0.8mm to 0.5mm, package mountability in a 2nd level interconnection becomes increasingly significant. Figure 17 shows the reliability results of ALIVH-B package assembly mounted on ALIVH motherboard.

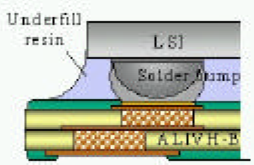
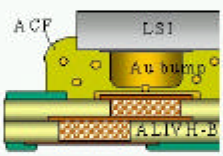
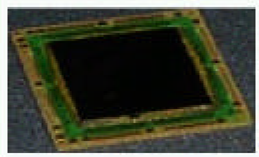
Method	Structure	Sample	Reliability Results			
			Layer Count		6	4
Solder FC			Moisture Absorbed Reflow Test (JEDEC Level Ⅲ)	HT	Pass	Pass
				LF	Pass	Pass
			PCT :121℃, 2atm, 100%, 240hrs	HT	Pass	Pass
				LF	Pass	Pass
			Thermal cycle : -65 to 150℃, Dry, 1000cyc	HT	Pass	Pass
				LF	Pass	Pass
	10X10mm² Area Array TEG Chips (400um Pitch × 265 pads) HT-High Temp Solder ; LF- Lead Free Solder Bump		Temp & humidity : 85℃, 85%, 2000hrs	HT	Pass	Pass
				LF	Pass	Pass
ACF			Moisture Absorption Reflow Test (JEDEC Level Ⅱ × 5 times)		Pass	Pass
			PCT :121℃, 2atm, 100%, 168hrs		Pass	Pass
			Thermal cycle : -65 to 150℃, Dry, 1000cyc		Pass	Pass
	10X10 mm² Peripheral TEG Chip, (160um Pitch × 208 pads)		Temp & humidity : 85℃, 85%, 2000hrs		Pass	Pass

Figure 16 - Summary of Package Reliability Results with ALIVH-B Substrate

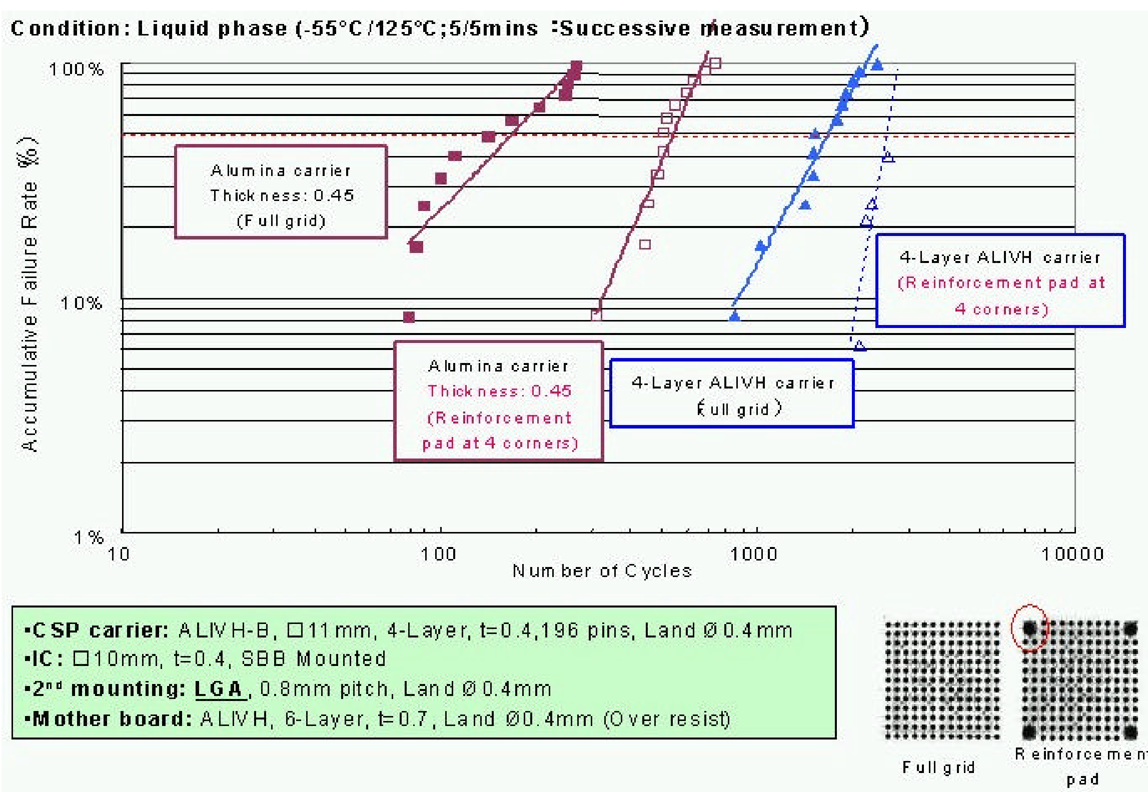


Figure 17 - Results of 2nd Mounting Evaluation

The package assembly was fabricated on a 6-layer ALIVH motherboard with solder ball LGA used for its CSP mounting. No underfill was used between the motherboards and package assemblies.

From the obtained results, ALIVH-B has proven itself to be reliable for 2nd level interconnection.

Electrical Characterization for ALIVH

The current trend in high-performance systems is towards achieving higher speeds and capacities. As the operating speed and frequencies of communication system rapidly increases, electrical performances of PWB become increasingly significant.

As such, dielectric constant of ALIVH (same as ALIVH-B) between 1 to 10GHz was extracted by ring resonator method. The test set-up for this ring resonator method is as shown in Figure 18.

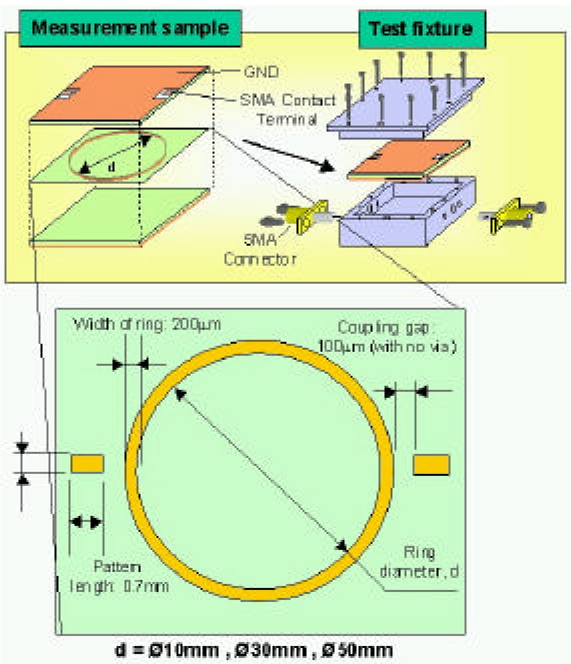


Figure 18 – Ring Resonator Method for Dielectric Extraction

For this ring resonator measurement, the dielectric value can be calculated from the measured resonant frequencies and geometry of microstrip ring by Equation.1:

$$e_r = \left(\frac{n.c_o}{f_n pd}\right)^2 \qquad (1)$$

where

εr - relative dielectric constant
n - order of harmonics
c_o - velocity of wavelength propagation in vacuum
d - diameter of ring resonator stripline
f_n - resonant frequency at nth harmonics

Since the resonant frequencies is calculated assuming that the mean length of the strip forming the resonator is a multiple of the guide wavelength on the microstrip, 3 different ring diameters of ∅10mm, ∅30mm, and ∅50mm are used to ascertain the reproducibility of the results. When the results of ALIVH is compared with that of FR-4 measured with the same method, it was found that ALIVH substrate has relatively low and stable dielectric performance over a wide bandwidth, showing a high of 3.8 and low of 3.6 (Refer to Figure 19).

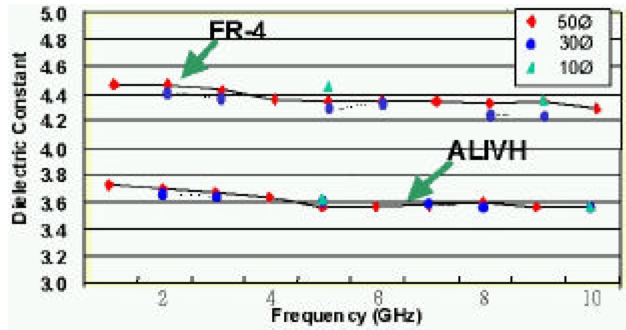
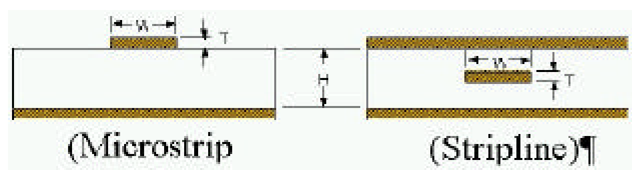


Figure 19 – Dielectric Constant of ALIVH and FR-4

As for characteristic impedance of ALIVH, as in most other PWB, it can be defined by KAUPP's equation as shown in Equation 2.

$$Z_o = \left(\frac{60}{\sqrt{e_r}}\right)\ln\left(\frac{5.98H}{0.8W+T}\right) \qquad (2)$$



where
W - Pattern width
T - Pattern thickness
H - Insulation thickness

From KAUPP's equation, it can be seen that the characteristic impedance is predominantly a function of pattern width, insulation thickness, and dielectric properties. These parameters are essential for the effective control of characteristic impedance in maintaining the electrical integrity of its circuit. In keeping within a small impedance variation, if the dielectric constant of the insulating material is high, the width of the conductive pattern will have to be extremely fine and accurate. The improvement in the patterning process of ALIVH-B as covered in part i Fine Pattern Forming has shown to be capable of producing a consistent pattern width of an average value of 64µm with a standard deviation value of 2.1µm. (See Figure 20)

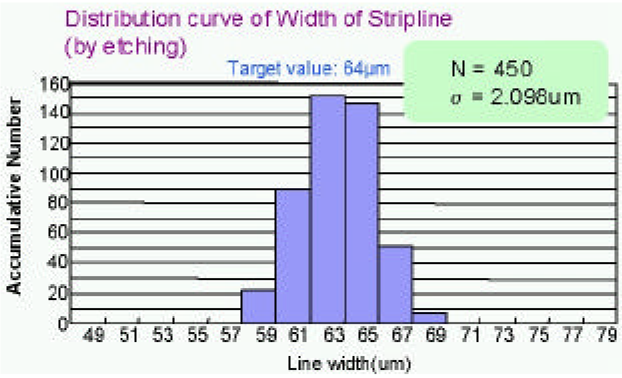


Figure 20 - Distribution Curve of Width Stripline (by Etching)

Also the thickness variation between each layers of ALIVH (Same as ALIVH-B) structure is small and well controlled as it uses the same prepreg material to press process. Figure 21 shows the average thickness value of the insulation layer to be 112.2µm with a standard deviation value of a mere 2.2µm.

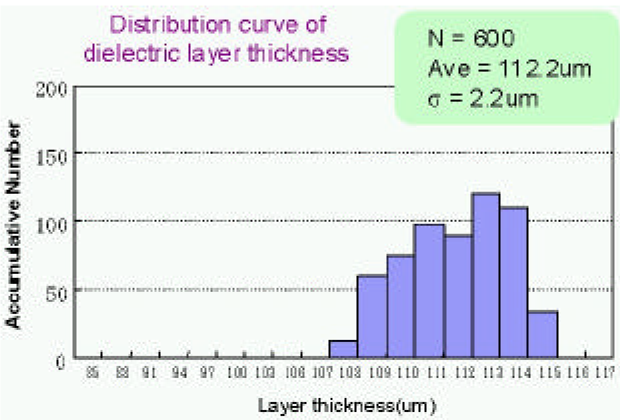


Figure 21 – Distribution Curve of Dielectric Layer Thickness

The characteristic impedance of ALIVH from 10 production lots were obtained and plotted as shown in Figure 22. ALIVH has exhibited good control of its characteristic impedance with little deviations.

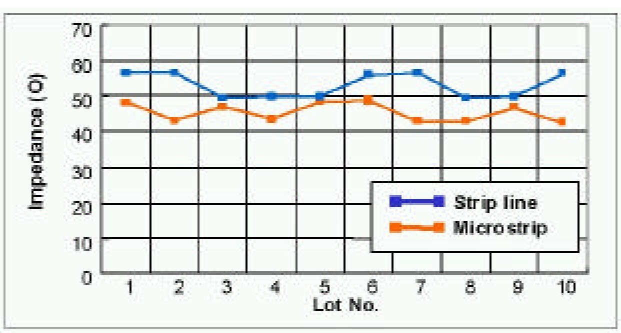


Figure 22 - Characteristic Impedance Control

ALIVH-G Technology

Background of the Development

As explained above, ALIVH and ALIVH-B use non-woven aramid epoxy as the substrate. Although this material has good heat resistance, dimensional stability, surface evenness and suitable electrical properties for high speed circuitry, there is market demand for improvements specific to motherboard applications, such as greater adhesive strength of surface lands, greater substrate bending strength, and measures during the mounting process to prevent absorption of humidity.

So, to solve these challenges, we have developed a motherboard (ALIVH-G) that uses woven glass epoxy instead of non-woven aramid epoxy, and have successfully mass-produced it. In addition, in response to growing public demand to preserve the environment, we made it a prerequisite to adopt halogen-free materials.

Figure 23 shows the structure of the products. The only structural difference is in the prepreg material.

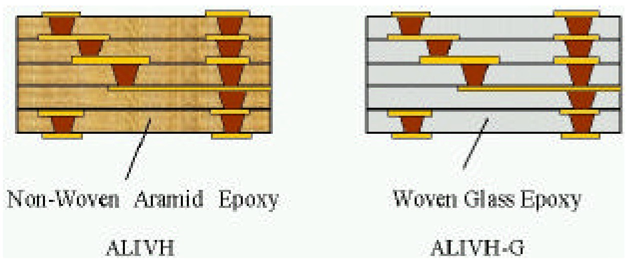


Figure 23 - Structure of ALIH and ALIVH-G

The main problems we encountered during development were as follows:

(1) Processing technology of via holes
(2) Connection reliability of vias

The following describes how we approached and solved these problems.

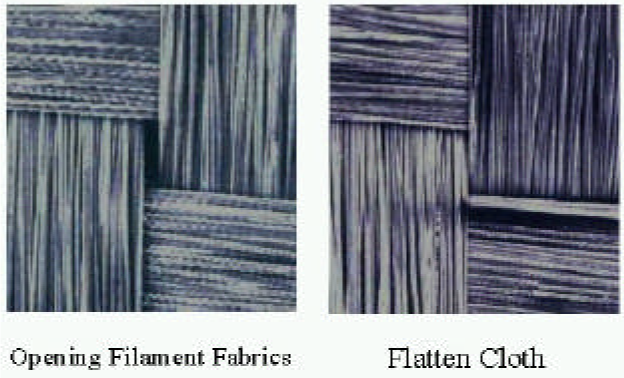
Development of a processing technology for via holes

Woven glass epoxy has up to now been regarded as being very difficult to process using lasers. This is because of its structural complexity: the variation in density of glass cloth results in variation in the diameters of the via holes if processed using a constant-power laser. Similarly for ALIVH-G, the variation in density of glass cloth also results in variation of the compression rate of the substrate, depending on position, causing variations in connection resistance (see Figure 25). To resolve these problems, we worked mainly on the following two issues:

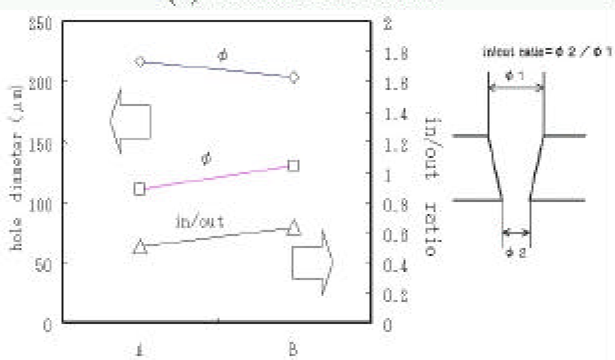
(1) Study of glass cloth material
(2) Study of laser ablation conditions

As for (1), concerning the unravel process (the process of unraveling and widening the glass cloth), we introduced a highly unraveled (further widened) type of glass cloth (Flatten cloth) instead of the conventional type (Opening Filament Fabrics) (see Figure 24a).By using this highly unraveled type of glass cloth, we were able to reduce the variations in hole diameter and resin thickness.

As for (2), by optimizing the ablation conditions, such as the laser intensity and the pulse width, we were able to improve the in/out ratio of holes, as shown in Figure 24b.



(a) Woven Glass Cloth



(b) Improvement of the processing conditions

Figure 24 - The improvement of Laser Hole Processing

Improvement of via connection reliability

Figure 25 shows the mechanism of via connection in ALIVH. After the conductive paste is filled into the vias, substrates are compressed using a hot press so that the copper foil and the conductive paste are fused together. The compression rate is an important factor that determines the connection reliability of vias.

The compression rate of woven glass cloth is lower than that of non-woven aramid epoxy. However, by changing the content of fire retardant and resin composition in the ALIVH-G substrate, we were able to reduce the coefficient of linear expansion in the Z direction to 45 ppm (25-125 °C, ALIVH 90 ppm), and were also able to reduce the thermal expansion and contraction of substrates caused by temperature changes, thus ensuring high connection equivalent to that of ALIVH.

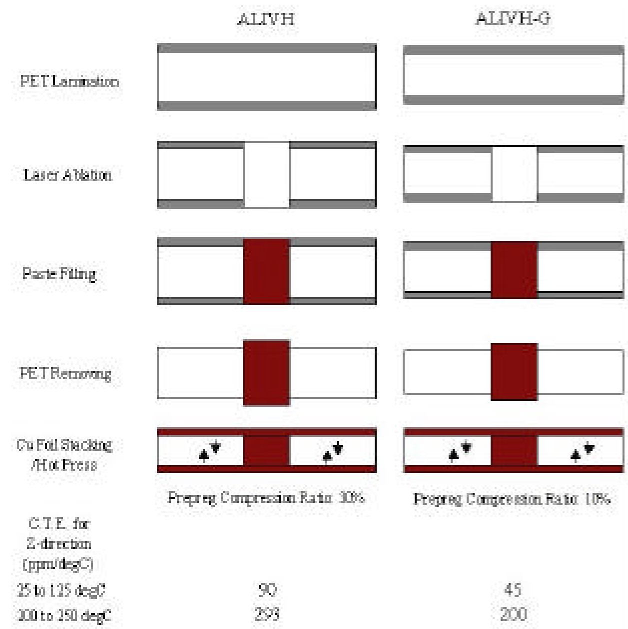


Figure 25 - Connection Mechanism of ALIVH & ALIVH-G

Table 2 shows the results of reliability tests.

Table 2 - Reliability Test Results of ALIVH-G

Evaluation Item	Condition	Results
Storage at High Temperature	150°C for 2000hrs	Passed
Storage at Low Temperature	-65°C for 2000hrs	Passed
Storage at High Temperature & Humidity	60°C/95%RH for 2000hrs	Passed
Storage at High Temperature & Humidity with Bias	60°C/95%RH withDC15V for 2000hrs	Passed
Thermal Shock (Vapour Phase)	-65°C to 150°C for 1000cyc	Passed
Thermal Shock (Vapour Phase)	-40°C/80°C for 1000cyc	Passed
Thermal Shock (Oil Dip)	260°C/20°C for 100cyc	Passed

Improvement of adhesion strength of lands

Figure 26 shows a structural comparison between cross-sections of ALIVH and ALIVH-G lands.

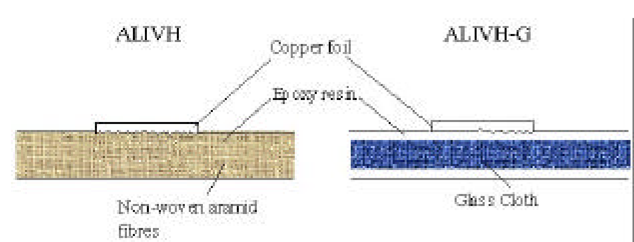


Figure 26 - Structure Comparison Between ALIVH & ALIVH-G

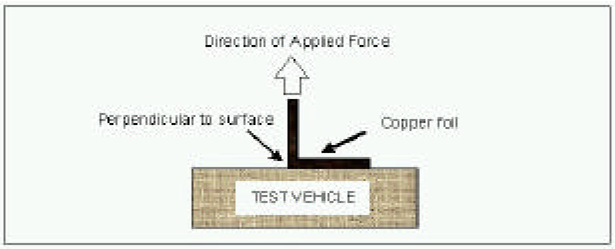
In ALIVH, aramid fibers expand to just under the land (copper foil), resulting in advantageous features that include fine surface evenness and the retainability of high hardness at high temperatures, as stated before. On the other hand, however, this aramid fiber has less internal adhesion strength and has a structural problem in that agglutinative destruction occurs between the fibers if a large mechanical stress is applied from outside to the parts soldered to the land, causing the land to peel.

In ALIVH-G, on the other hand, since epoxy resin is present between lands and the glass cloth, the lands have high adhesion strength, giving them very good resistance to externally applied mechanical stresses.

Figures 27 to 29 show the adhesion strength of ALIVH and ALIVH-G lands.

[Peel Strength]

A - Evaluation Method



i. Peel pre-determined width of copper conductor perpendicularly to the surface of the test vehicle
ii. Measure and record the peel strength of the copper conductor along the peeling edges

Evaluation Condition

Items	Units	Description
Test Circuit Pattern	-	See diagram above
Cu Conductor Thickness	um	18 (foil) + Rating
Direction of Pull	-	Vertical
Sample Size, N	-	8

B – Evaluation Results

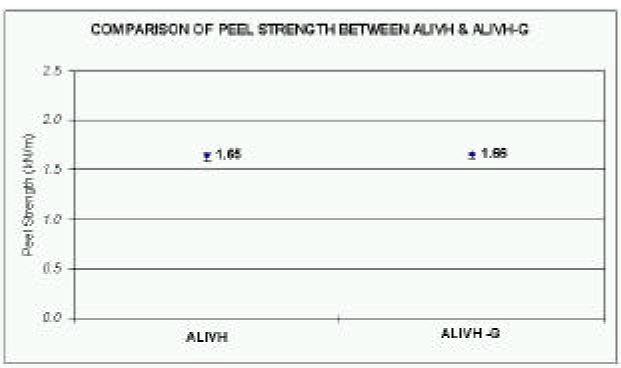
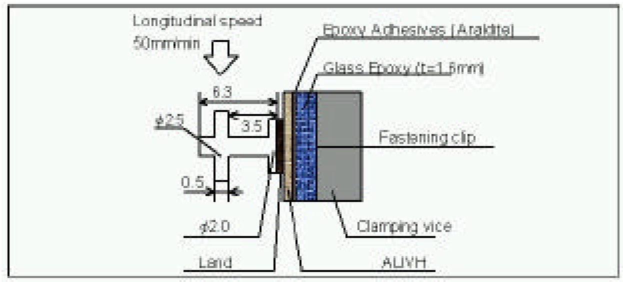


Figure 27 - Peel Strength Test

[Pin Knock-Down Strength]

A – Evaluation Method



i. Place solder ball (0.76mm dia) on pre-determined land and reflow solder test vehicle with solder ball (at peak temp. 240°C).
ii. Heat attached solder ball before puncturing it with the probe. Under cool air, lift probe upward at longitudinal speed of 300um/s.
iii. Measure and record the pull strength and its failure mode after separation.

Evaluation Condition

Items	Units	Descriptions
Test Circuit Pattern	-	See Diagram above
Land Size	Mm	∅2.0
Loading Speed	-	5mm/min
Direction of Pull	-	Vertical
Sample Size, N	-	12

B – Evaluation Results

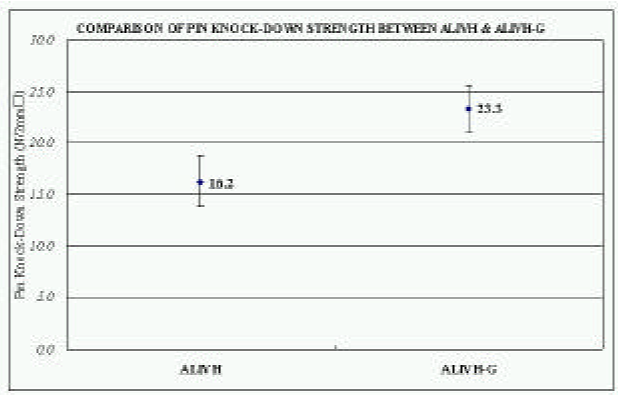
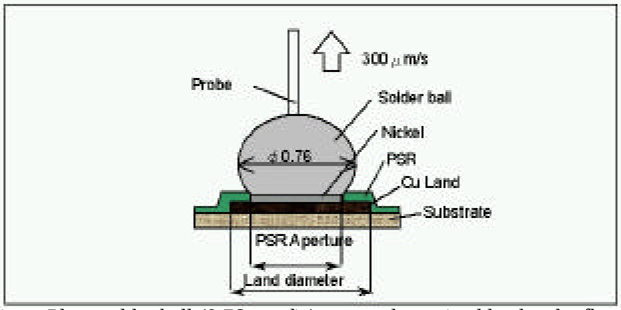


Figure 28 - Pin Knock-Down Strength Test

As Figure 27 shows, ALIVH and ALIVH-G have nearly equal peel strength, but for the test methods applying mechanical stresses to lands similar to those in actual usage, such as the Pin Knock-down Strength test (Figure 28) and the Ball Pull Strength test (Figure 29), ALIVH-G showed strength of about 140% of that of conventional ALIVH.

[Ball Pull Strength]

A – Evaluation Method



i. Place solder ball (0.76mm dia) on pre-determined land and reflow solder test vehicle with solder all (at peak temp. 240°C).

ii. Heat attached solder ball before puncturing it with the probe. Under cool air, lift probe upward at a longitudinal speed of 300um/s.

iii. Measure and record the pull strength and its failure mode after separation.

Evaluation Condition

Items	Units	Description
Test circuit Pattern	-	See diagram above
Land Size	Mm	∅0.55
PSR Aperture	Mm	∅0.45
Surface Treatment	-	Electroless Au plating
Direction of Pull	-	Vertical
Sample Size, N	-	20

B – Evaluation Results

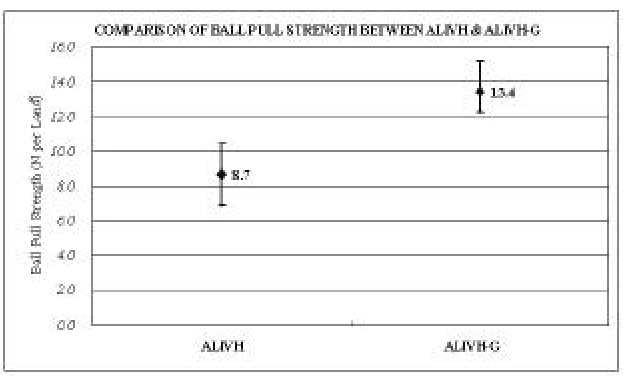
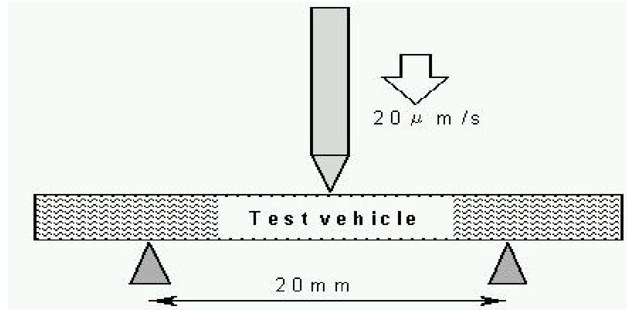


Figure 29 - Ball Pull Strength Test

Improvement of bending strength of substrate

Figure 30 shows the measurement results of bending strength tests on substrates. Because ALIVH-G uses prepreg in all the layers that contain glass cloth, its bending strength of substrate is about 150% of that of conventional ALIVH.

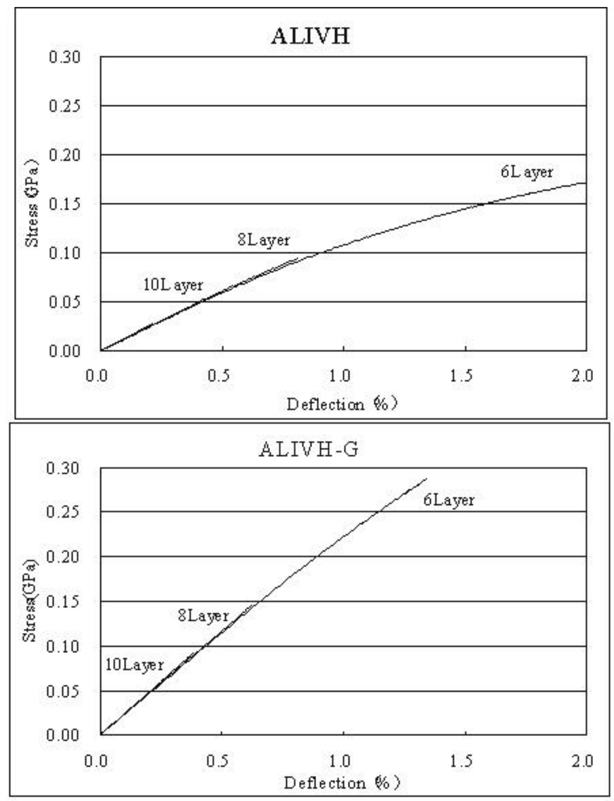
A. Evaluation Method



i) Set test vehicle 20mm apart between the supports.

ii) Set longitudinal speed of 20um/s at the centre of test vehicle between the supports. Measure and record the corresponding stress and deflection.

iii) Determine the Elastic Modulus at 0.3% deflection using its corresponding stress and board thickness.



B. Evaluation Results

Elastic Modulus (GPa)

(n=5 each)

	6 Layer	8 Layer	10 Layer
ALIVH	12.0	12.4	12.1
ALIVH-G	23.7	23.1	23.7

Figure 30 - Bending Strength Test

Elastic modulus was here determined using the following equation.

$$E_b = \frac{1}{4} \cdot \frac{L^3}{bh^3} \cdot \frac{P}{D}$$

Where,
Eb: elastic modulus
P: applied force
D: deflection
L: distance between the supports
b: width of the test piece
h: thickness of the test piece

Comparison of moisture absorption

Because the aramid used in conventional ALIVH has the property of absorbing water, as shown in Figure 31, if ALIVH is exposed humid conditions during the user's mounting process, a baking process has up to now been required before reflow soldering to prevent delamination within the board.

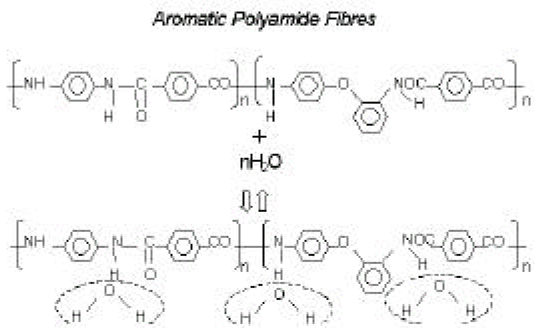


Figure 31 - Mechanism of Moisture Absorption for ALIVH

Figure 32 shows a comparison of moisture absorption by ALIVH and ALIVH-G. The moisture absorption of ALIVH-G is only about two thirds that of ALIVH and this has almost eliminated the need for the user to monitor water absorption during the manufacturing process.

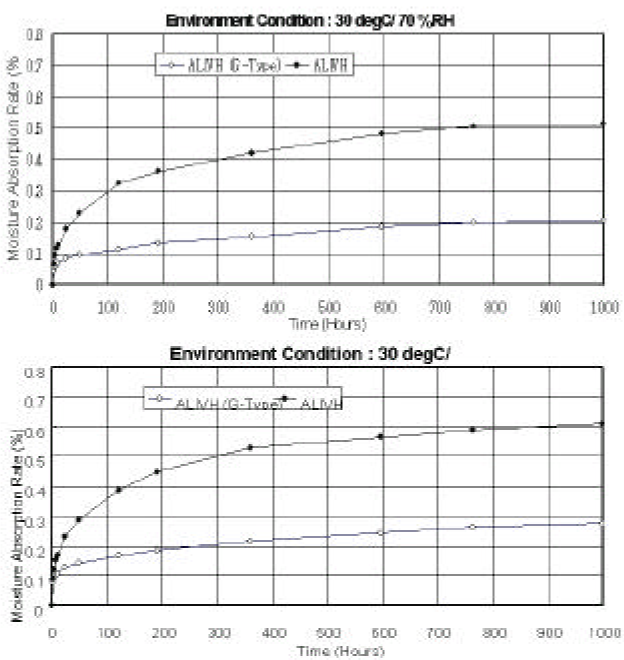


Figure 32 - Comparison for Moisture Absorption

Conclusion

Table 3 shows a comparison summary between ALIVH and ALIVH-G.

Table 3 - Comparison Summary between ALIVH&ALIVH-G

ITEM	ALIVH	ALIVH-G
1. Lead - Free Soldering	Available	Available
2. Halogen Free	Under Development	Available
3. *Moisture Absorption	100	40
4. *Surface Mechanical Strength		
Peel Strength	100	100
Pin Knock - down Strength	100	140
Ball Pull Strength	100	140
5. *Rigidity		
Elasticity Modulus	100	200
6. Dielectric Constant (at 1GHz)	3.6	4.6
7. Density (10^3 kg/m^3)	1.4	2.0
8. Design	Via on Via / Pad on Via	

* The values for ALIVH-G are relative to ALIVH = 100.

Although current aramid-type ALIVH is superior in some areas, including low dielectric constant at high frequencies and lower board weight due to its low density, these problems do not seem so serious when considering the recent progress of high-frequency circuitry design technology and the fact that the light weight of sets is no longer an important requirement.

Deployment in the future

Using the current ALIVH motherboard as our starting point, we have, as described above, succeeded in developing and mass producing ALIVH-B, which shows higher density and reliability, and ALIVH-G, which solves the problems associated with the current use of aramid substrate for motherboards by changing to a glass substrate and attaining added halogen-free properties.

In the future, we intend to continue with technical developments and accelerate the progress of this Any Layer IVH Structure PWB toward (1) further reduction of size and increased density and (2) further reduction of cost, while diversifying our product line.

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2. T.Nishiyama et al., "Development of ALIVH for High-Density Fine Pitch Applications", Proceedings of the 13th JIEP Annual Meeting, pp.205, 1999.
3. Y.Ishimaru et al., "CSP 2nd Mounting; Reliability with ALIVH Substrate", Proceedings of the 13th JIEP Annual Meeting,pp.225, 1999.
4. T.Nishiyama et al., "ALIVH-B Substrate", Matsushita Technical Journal, pp.45, August 1999.