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The document is designated as: JP3207174B2

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November 13, 2024

(19) [Issuing Country] Japan Patent Office (JP)
(12) [Publication Name] Patent Gazette (B2)
(11) [Patent Number] 3207174 (P3207174)
(24) [Registration Date] July 6, 2001 (2001.7.6)
(45) [Publication Date] September 10, 2001 (2001.9.10)

(51) [Int.Cl.^{7}] H05K 3/46
H01L 23/12
H05K 1/18
[FI] H05K 3/46 Q
N
1/18 J
H01L 23/12 N
[Number of Claims] 2
[Total Number of Pages] 6

(21) [Application Number] H11-24425
(22) [Filing Date] February 1, 1999 (1999.2.1)
(65) [Disclosure Number] 2000-223837 (P2000-223837A)
(43) [Disclosure Date] August 11, 2000 (2000.8.11)
[Examination Request Date] June 16, 1999 (1999.6.16)
[Preliminary Examination Request]
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(56) [Cited Documents]
[Document] H10-154874 (JP, A)
[Document] H10-275966 (JP, A)
[Document] H10-51150 (JP, A)
(58) [Searched Fields] (Int.Cl.^{7}, DB Names)
H05K 3/46
H05K 1/18

(54) [Title of the Invention]

Wiring Substrate With Mounted Electrical Element and Manufacturing Method Therefor

(57) [Claims]

[Claim 1]

A wiring substrate with a mounted electrical element comprising an insulating substrate obtained by laminating a plurality of insulating layers containing at least a thermosetting resin, a wiring circuit layer formed on the surface and inside of the insulating substrate, and an electrical element mounted in a sealed void inside the wiring substrate provided with via-hole conductors filled with metal powder, and the electrodes of the electrical element electrically connected to the via-hole conductors,
the wiring substrate with a mounted electrical element characterized in that the via-holes connected to the electrodes contain a mixture of a low melting point metal having a melting point that is at least 10°C lower than the thermosetting temperature of the thermosetting resin, and a high melting point metal having a melting point higher than the thermosetting temperature of the thermosetting resin, the volume ratio of the low melting point metal and the high melting point metal is 10:90 to 90:10, and the electrodes of the electrical elements are electrically connected and secured to the via-hole conductors by heating and melting the low melting point metal in the via-hole conductors.

[Claim 2]

A method for manufacturing a wiring substrate with a mounted electrical element, the method comprising: step A of forming via-holes in an uncured insulating sheet containing at least a thermosetting resin, and filling the via-holes with a conductor paste containing a mixture of a low melting point metal having a melting point at least 10°C lower than the thermosetting temperature of the thermosetting resin and a high melting point metal having a melting point higher than the thermosetting temperature of the thermosetting resin, with the low melting point metal and the high melting point metal having a volume ratio of 10:90 to 90:10; step B of mounting a predetermined electrical element on a surface of the insulating sheet and bringing the electrodes of the electrical element into contact with the exposed portion at the end of the via-hole conductors; step C of layering another insulating sheet on the surface of the insulating sheet with the mounted electrical element so that the electrical element is stored and mounted inside a sealed void; and step D of heating the laminate to the thermosetting temperature of the thermosetting resin to cure the insulating sheet, while at the same time melting the low melting point metal in the via-hole conductors and electrically connecting the electrodes of the electrical element to the via-hole conductors using the melted low melting point metal.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention is suitable for a multilayer wiring substrate and semiconductor element packages, etc., and relates specifically to a wiring substrate with a mounted electrical element, in which the electrical element is built into an insulating substrate, and to a manufacturing method for such a wiring substrate.

[0002]

[Prior Art]

Electronic devices are becoming smaller and smaller, and in recent years, the development of mobile information terminals and the spread of mobile computing, in which computers are used while being carried around, have created a trend towards even smaller, thinner, and higher-definition multilayer wiring substrates. In addition, a method has been adopted in which, when a semiconductor element, capacitor element, resistor element, or other electrical element is mounted on a conventional multilayer wiring substrate, the element is bonded to the surface of a pre-fabricated printed wiring substrate and connected to a wiring circuit layer on the wiring substrate by wire bonding, directly mounted on the surface of the wiring substrate using solder, etc. before the mounted element is molded using a resin. Another method has been adopted in which a recess is formed in the surface of an insulating substrate, the element is stored inside the recess, and then the recess is resin-molded or covered with a lid to seal the recess airtight.

[0003]

Recently, a method known as tape automated bonding (TAB) as been applied to substrates used in applications in which there is demand for smaller, lighter, and thinner mobile information devices. In the TAB connection method, metal foil is affixed to the entire surface of a film made, for example, of polyimide resin, which has holes in prescribed locations for storing semiconductor elements, a lead wiring layer consisting of inner leads and outer leads for connecting semiconductor elements is formed by photo-etching, and the bumps and inner leads of semiconductor elements are connected to so-called TAB tape.

[0004]

[Problem to Be Solved By the Invention]

However, in the conventional method for mounting an electrical element, a step of mounting an electrical element on a surface of a pre-fabricated wiring substrate and then electrically connecting the element to a wiring circuit layer is required. As a result, several manufacturing steps are required before an electrical device including the electrical element can be completed, which leads to high costs. Moreover, because the only place that electrical elements can be mounted is on the surface of the wiring substrate, it keeps substrates from being made thinner and smaller, and prevents high-density mounting of a plurality of electrical elements.

[0005]

Also, in the connecting method, when a semiconductor element is mounted by wire bonding, a connection pad must have a pitch of approximately 200 μm, which makes it difficult to make connections with a smaller pitch, impeding further miniaturization. In addition, connections between individual terminals are required, which increases the time required to establish connections and, thus, reduced productivity. Moreover, because the wires used in wire bonding have to be routed in a loop shape, clearance of around 0.5 mm is inevitably required in the thickness direction of the silicon chip, which impedes the creation of thinner semiconductor devices.

[0006]

In contrast, the TAB connection method enables connection of a semiconductor element to leads in a single connection step, thereby establishing connections in a shorter period of time, and conferring the advantage of excellent productivity. However, this connection method can only be realized by using a polyimide resin film with copper foil affixed to one surface, also known as TAB tape. As a result, handling an increased number of terminals on a silicon chip is not possible. For example, if the number of connection terminals exceeds 500, a wiring width of 20 μm or less is required, etc. Thus, the method cannot be adapted to handle an increase in the number of terminals on an silicon chip.

[0007]

Therefore, an object of the present invention is to provide a wiring substrate with a mounted electrical element that can be used to mount electrical elements such as semiconductor devices and electronic components (capacitor elements, resistor elements, filter elements, oscillator elements, etc.) on a substrate, in a manner the enables the miniaturization of substrates and an increase in element mounting densities. Another object of the present invention is to provide a method for manufacturing a wiring substrate with a mounted electrical element, which can be easily used to fabricate a wiring substrate that can incorporate an electrical element inside.

[0008]

[Means for Solving the Problem]

As a result of extensive research conducted to make wiring substrates smaller by mounting electrical elements in sealed voids and to simplify the manufacturing process for such wiring substrates, the present inventor discovered that by including a mixture of a low melting point metal having a melting point lower than that of a thermosetting resin included in an insulating substrate and a high melting point metal having a melting point higher than that of the thermosetting resin included in the insulating substrate at a prescribed ratio, and by connecting the electrodes of the electrical element to via-hole conductors by heating and melting the low melting point metal, an electrical element could be easily built into the wiring substrate. The present invention is a result of this discovery.

[0009]

Specifically, the present invention is a wiring substrate with a mounted electrical element comprising an insulating substrate obtained by laminating a plurality of insulating layers containing at least a thermosetting resin, a wiring circuit layer formed on the surface and inside of the insulating substrate, and an electrical element mounted in a sealed void inside the wiring substrate provided with via-hole conductors filled with metal powder, and the electrodes of the electrical element electrically connected to the via-hole conductors, the wiring substrate with a mounted electrical element characterized in that the via-holes connected to the electrodes contain a mixture of a low melting point metal having a melting point that is at least 10°C lower than the thermosetting temperature of the thermosetting resin, and a high melting point metal having a melting point higher than the thermosetting temperature of the thermosetting resin, the volume ratio of the low melting point metal and the high melting point metal is 10:90 to 90:10, and the electrodes of the electrical elements are electrically connected and secured to the via-hole conductors by heating and melting the low melting point metal in the via-hole conductors.

[0010]

The present invention is also a method for manufacturing a wiring substrate with a mounted electrical element, the method comprising: step A of forming via-holes in an uncured insulating sheet containing at least a thermosetting resin, and filling the via-holes with a conductor paste containing a mixture of a low melting point metal having a melting point at least 10°C lower than the thermosetting temperature of the thermosetting resin and a high melting point metal having a melting point higher than the thermosetting temperature of the thermosetting resin, with the low melting point metal and the high melting point metal having a volume ratio of 10:90 to 90:10; step B of mounting a predetermined electrical element on a surface of the insulating sheet and bringing the electrodes of the electrical element into contact with the exposed portion at the end of the via-hole conductors; step C of layering another insulating sheet on the surface of the insulating sheet with the mounted electrical element so that the electrical element is stored and mounted inside a sealed void; and step D of heating the laminate to the thermosetting temperature of the thermosetting resin to cure the insulating sheet, while at the same time melting the low melting point metal in the via-hole conductors and electrically connecting the electrodes of the electrical element to the via-hole conductors using the melted low melting point metal.

[0011]

[Embodiments of the Invention]

The present invention will now be described with reference to the drawing. FIG. 1 is a process diagram used to describe the method for manufacturing a wiring substrate with a mounted electrical element in the present invention.

[0012]

In FIG. 1, first, as shown in FIG. 1 (a), a soft (B-stage state) insulating sheet 1 containing a thermosetting resin with thermosetting temperature T_1 is formed and via-holes passing through in the thickness direction are formed in the insulating sheet 1. Among these via-holes, the via-holes that are connected to the electrodes of the electrical element are filled with an conductive paste while performing screen printing or suctioning to form via-hole conductors 2a for connecting the electrical element. This conductive paste contains a low melting point metal having low melting point T_2, which is equal to or lower than thermosetting temperature T_1 of the thermosetting resin, and a high melting point metal having a melting point that is higher than the thermosetting temperature of the thermosetting resin. Also, as shown in FIG. 1 (a), general via-hole conductors 2b are also formed in addition to the via-hole conductors 2a for connecting electrical elements.

[0013]

The insulating sheet 1 used herein is prepared by thoroughly mixing thermosetting resins or a thermosetting resin and filler composition using a kneading machine or three-roll mill, etc., and forming the resulting material into a sheet using rolling, extrusion, injection, or a doctor blade, and semi-curing the material at a temperature slightly lower than the curing temperature, if desired.

[0014]

The via-holes and voids can be formed in the insulating sheet using any method known in the art, such as drilling, punching, sandblasting, or exposure to a carbon dioxide gas laser, YAG laser, or excimer laser, etc.

[0015]

Note that the thermosetting resin forming the insulating sheet is not particularly limited as long as the thermosetting resin has electrical characteristics, heat resistance, and mechanical strength as an insulating material. For example, an aramid resin, phenol resin, epoxy resin, imide resin, fluororesin, phenylene ether resin, bismaleimide-triazine resin, urea resin, melamine resin, silicone resin, urethane resin, unsaturated polyester resin, or allyl resin, etc. can be used alone or in combination.

[0016]

Furthermore, a filler can be compounded with an organic resin in the insulating sheet 1 described above to increase the strength of an insulating substrate or wiring substrate as a whole. An inorganic filler such as SiO_2, Al_2O_3, ZrO_2, TiO_2, AlN, SiC, $BaTiO_3$, $SrTiO_3$, zeolite, $CaTiO_3$, aluminum borate, etc. is preferably used as the filler compounded with the organic resin. A woven fabric, non-woven fabric composed of glass or aramid resin, etc. impregnated with one of the resins described above may also be used. Compounding the organic resin and filler at a volume ratio of 15:85 to 50:50 is appropriate.

[0017]

Among these, a mixture of at least one type of thermosetting resin selected from the group consisting of epoxy resins, imide resins, and phenylene ether resins and silica or an aramid nonwoven fabric as a filler component is most preferred from the standpoint of ease of processing by punching or a laser, etc.

[0018]

Use of tin (Sn), zinc (Zn), bismuth (Bi), or an alloy thereof with silver (Ag) or copper (Cu), etc. is preferred as the low melting point metal in the conductive paste filling the via-hole conductors 2a connected to the electrodes of the electrical element.

[0019]

The melting point T2 of the low melting point metal and the thermosetting temperature T_1 of the thermosetting resin must satisfy the relationship $T_1 - T_2 \geq 10°C$. This enables the low melting point metal to become hot and melt during curing of the thermosetting resin to facilitate simple and secure bonding with the electrodes of the electrical element.

[0020]

If the low melting point metal is the only metal component in the conductive paste, shape retention in the via-hole conductor will be poor when melted during thermal curing as described below. Therefore, the low melting point metal is mixed with a high melting point metal having a melting point that is higher than the thermosetting temperature of the thermosetting resin. Copper, silver, a copper-silver alloy, or any mixture thereof is preferably used as the high melting point metal having a higher melting point than the thermosetting temperature of the thermosetting resin. The high melting point metal and the low melting point metal are mixed at a volume ratio of 90:10 to 10:90.

[0021]

The via-hole conductors 2b that are not connected to the electrical element do not require a low melting point metal, and can be filled with a conductive paste containing a metal powder having a high melting point, such as ordinary copper, silver, or any alloy thereof.

[0022]

When preparing the conductive paste, the low melting point metal, or the low melting point metal along with the high melting point metal, is preferably prepared as a metal powder with an average particle size of 0.5 to 50 μm. If the average particle size of the metal powder is smaller than 0.5 μm, contact resistance between particles in the metal powder increases and the resistance of the via-hole conductors tends to be high. If the average particle size exceeds 50 μm, via-hole conductors with low resistance tend to be difficult to realize.

[0023]

The conductive paste is also prepared by adding and admixing a binding organic resin mentioned above and a solvent to the metal powder. The solvent added to the paste can be any solvent that can dissolve the binding organic resin being used, such as isopropyl alcohol, terpineol, 2-octanol, butylcarbitol acetate, etc.

[0024]

Cellulose, etc. can be used as the binding organic resin in the conductive paste, in addition to the organic resin constituting the insulating layers. The organic resin binds the particles of metal powder in contact with each other and also binds the metal powder to the insulating sheet. The organic resin is preferably included in the metal paste at a ratio of 0.1 to 40 vol%, and particularly 0.3 to 30 vol%. This is because if the amount of resin is less than 0.1 vol%, it is difficult to bind the particles of metal powder firmly together, making it difficult to firmly bind a low resistance metal to the insulating layer. Conversely, if the amount exceeds 40 vol%, the resin keeps the particles of metal powder from making sufficient contact with each other, increasing the resistance of the via-hole conductors. Next, as shown in FIG. 1 (b), a wiring circuit layer 3 is formed on the front or back surface of the insulating sheet 1, as appropriate. Examples of methods that can be used to form the wiring circuit layer 3 include: 1) affixing metal foil to a surface of the insulating sheet 1 and performing etching to form a circuit pattern; 2) depositing a resist on a surface of the insulating sheet 1 surface and then performing plating; 3) affixing metal foil to a transfer film surface, etching the metal foil to form a circuit pattern, and then transferring the circuit pattern formed of metal foil onto a sheet of the insulating sheet 1 surface. At this time, a wiring circuit layer may not be formed and connecting pads containing the low melting point metal may be provided for the via-hole conductors 2a to be connected to the electrodes of the electrical element.

[0025]

The wiring circuit layer 3 preferably contains at least one or more alloy selected from the group consisting of copper, aluminum, gold, and silver, with copper or copper alloys being preferred. In some cases, a high resistance metal such as a Ni-Cr alloy may be mixed or alloyed to obtain a conductor composition used to adjust the circuit resistance. Also, in order to lower the resistance of the wiring circuit layer, a metal with a lower melting point than the low resistance metal mentioned above, such as solder or tin, may be included in the metal component in the conductor composition at a ratio of 2 to 20 wt%.

[0026]

Afterward, as shown in FIG. 1 (c), an electrical element 4 is mounted on the surface of the insulating sheet 1, and the electrodes 5 formed on the back surface of the electrical element 4 are brought into contact with the exposed portions on the end surfaces of the via-hole conductors 2a.

[0027]

Examples of the electrical element 4 used at this time include a semiconductor element, capacitor element, resistance element, filter element, and oscillator element, etc. The heat resistance temperature is preferably higher than thermosetting temperature T_1.

[0028]

The insulating sheet 1 on which the electrical element 4 has been mounted is laminated with other insulating sheets 6, 7, 8 in which via-hole conductors 2b and wiring circuit layers 3 have been formed. At this time, as shown in FIG. 1 (d), an opening 9 for housing the electrical element 4 is formed in insulating sheet 6 and laminated directly above insulating sheet 1 so that electrical element 4 can be housed and mounted in a hermetically sealed void formed by insulating sheets 1, 6, 7.

[0029]

Afterward, the laminate prepared as described above is heated at or above the thermosetting temperature T_1 of the thermosetting resin in the insulating sheet 1 to fully cure the insulating sheets 1, 6, 7.

[0030]

At this time, the low melting point conductor material in the via-hole conductors 2a melts during thermosetting because the melting point T_2 of the material is lower than thermosetting temperature T_1. As a result, the electrodes 5 of the electrical element 4 and the via-hole conductors 2a can be electrically connected.

[0031]

As a result, as shown in FIG. 1 (e), the electrical element 4 is housed and mounted in a hermetically sealed void 10 inside a multilayer wiring substrate A, and a multilayer wiring substrate can be fabricated that has electrical elements inside voids 10 electrically connected to via-hole conductors 2a.

[0032]

Note that according to the present invention, the method described above can be developed to prepare a wiring substrate with various forms of electrical elements mounted. For example, a plurality of electrical elements can be provided by forming a plurality of void portions in the same or different layers in a multilayer wiring substrate to stow and mount the electrical elements. In addition, it is preferable to make the thermosetting resin flow before curing to minimize a void with an insulating phase at the periphery of the electrical element 4 to improve reliability.

[0033]

Although the method was described above using an electrical element housed inside the substrate, the method can be applied to electrical elements connected to via-hole conductors on the surface of the substrate, and to electrical elements housed inside the substrate and connected to via-hole conductors on the surface of the substrate.

[0034]

Thus, the present invention is able to provide a wiring substrate with mounted electrical elements, in which one or more electrical elements can be easily mounted inside the wiring substrate, thereby reducing the size of the wiring substrate and increasing the electrical element mounting density. The manufacturing method of the present invention allows for the connection of electrical elements to a wiring substrate at the same time a multilayer wiring substrate is being manufactured, resulting in a simplified manufacturing process, increased manufacturing yields, and reduced costs.

[0035]

[Example]

(1) An insulating sheet a having a thickness of 75 mm was prepared by mixing a resin varnish and a powder and using the doctor blade method to obtain a ratio of 50 vol% PPE (polyphenylene ether) resin (thermosetting temperature T_1 = 200°C) and 50 vol% silica powder. A plurality of via-holes with a diameter of 0.1 mm were formed in the insulating sheet a using the punching process. The via-holes to be connected to the electrodes of the electrical element were filled to the surface with a conductive paste to form via-hole conductors. This conductive paste consisted of a metal component composed of 50 vol% copper powder with an average particle size of 5 μm plated with silver and 50 vol% Sn-Pb eutectic solder powder with an average particle size of 3 μm (melting point T_2 = 183°C) serving as the low melting point metal, to which triallyl isocyanurate was added at a ratio of 5 vol%. The same conductive paste was also used to fill the via-holes that were not connected to an electrical element.

[0036]

(2) Meanwhile, an adhesive was applied to a surface of a transfer sheet containing a polyethylene terephthalate (PET) resin, and copper foil with a thickness of 12 μm and a surface roughness of 0.8 μm was affixed. A photoresist (dry film) was then applied, exposed to light and developed, and then immersed in a ferric chloride solution to etch away the non-patterned portion and form a wiring circuit layer. The resulting wiring circuit layer had a fine pattern with a line width of 20 μm and a spacing of 20 μm between wiring.

[0037]

(3) Then, the wiring circuit layer side of the transfer sheet was pressure bonded to a surface of the insulating sheet a prepared in (1) under 50 kg/cm^2 of pressure. Afterward, the transfer sheet was peeled off the insulating sheet a, leaving behind the wiring circuit layer transferred to the insulating sheet a.

[0038]

(4) Next, a silicon semiconductor memory chip (heat resistance temperature: 250°C) was placed on the surface of the insulating sheet a in which the via-hole conductors had been

formed and on which the wiring circuit layer had been formed, positioned so that the electrodes formed on a back surface of the chip and the exposed portions at the ends of the via-hole conductors were in contact, and then temporarily secured with an adhesive.

[0039]

(5) Afterward, an opening slightly larger than the size of the electrical element was formed by punching an insulating sheet b, in which the via-hole conductors had been formed and on which the wiring circuit layer had been formed in the same manner as described above, and the insulating sheets were laminated to the thickness of the electrical element. Finally, an insulating sheet c without an opening was laminated and pressure bonded under 20 kg/cm^2 of pressure.

[0040]

(6) The laminate was then heated at 200°C for one hour to complete the hardening process and produce a multilayer wiring substrate. The opening in the insulating sheet contracted due to the flow of resin caused by heating, and the insulating layer and the chip were bonded closely together, leaving almost no void between the chip and the insulating layer.

[0041]

After observing the area around the formation of the wiring circuit layers and via-hole conductors in the cross section for the resulting multilayer wiring board, it was found that the IC element and the via-hole conductors were in a proper connected state due to melting of the low melting point metal in the via-hole conductors. In conductivity testing of the wiring, no disconnected wiring was observed. In addition, there were no problems with the operation of the IC element. The resulting multilayer wiring substrate was left in a hot and humid environment at 85% humidity and 85°C for 100 hours and no visually discernible changes occurred.

[0042]

[Effect of the Invention]

As described in detail above, the present invention is able to provide a wiring substrate with mounted electrical elements, in which one or more electrical elements can be easily mounted inside the wiring substrate, thereby reducing the size of the wiring substrate and increasing the electrical element mounting density. The manufacturing method of the present invention allows for the connection of electrical elements to a wiring substrate at the same time a multilayer wiring substrate is being manufactured, resulting in a simplified manufacturing process, increased manufacturing yields, and reduced costs.

[Brief Description of the Drawings]

[FIG. 1]

FIG. 1 is a process diagram used to describe the method for manufacturing a wiring substrate with a mounted electrical element in the present invention.

[Reference Numbers]

1, 6, 7, 8 Insulating sheet

2	Via-hole conductor
3	Wiring circuit layer
4	Electrical element
5	Electrode
9	Opening
10	Void

[FIG. 1]