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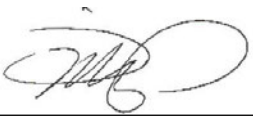
I, Alex Jo, declare:

I am a professional reviewer and coordinator specializing in translating Chinese, Japanese and Korean to English.

I have over 25 years of experience reviewing and coordinating translations of thousands of technical, legal, and business documents from Chinese to English submitted to, among others, various U.S. federal courts, the U.S. International Trade Commission (ITC), and the Patent Trial and Appeal Board (PTAB).

I certify that the following Japanese to English translation of the corresponding source text is a true, correct, and complete translation to the best of my knowledge and ability.

I hereby certify under penalty of perjury that the foregoing is true and correct. Executed this 5th day of August 2022 in the Contra Costa County of the State of California.

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(56) Reference documents:
Japanese Unexamined Patent Application H10-154874 (JP, A)
Japanese Unexamined Patent Application H10-275966 (JP, A)
Japanese Unexamined Patent Application H10-51150 (JP, A)

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(54) TITLE OF THE INVENTION:

ELECTRICAL ELEMENT MOUNTED WIRING BOARD AND MANUFACTURING METHOD OF SAME

(57) *What is claimed is:*

[Claim 1] An electrical element mounted wiring board, comprising:
an insulating substrate obtained by laminating a plurality of insulating layers containing at least a thermoset resin;
a wiring circuit layer formed on a surface of and inside the insulating substrate;
a via hole conductor filled with a metal powder;
an electrical element being mounted in a hermetically sealed gap inside the wiring board; and
an electrode of the electrical element and the via hole being electrically connected; wherein
the via hole conductor connected to the electrode containing a mixture of a low melting point metal having a melting point that is 10°C or more lower than the curing temperature of the thermoset resin and a high melting point metal with a melting point that is higher than the curing temperature of the thermoset resin, the low melting point metal and the high melting point metal being at a volume ratio of 10:90 to 90:10, and the via hole conductor and the electrode of the electrical element being electrically connected and secured by heating and melting the low melting point metal in the via hole conductor.

[Claim 2] A method of manufacturing an electrical element mounted wiring board, comprising:

a step A of forming a via hole in an uncured insulating sheet containing at least a thermoset resin and then filling a conductive paste containing a mixture of a low melting point metal having a melting point that is 10°C or more lower than the curing temperature of the thermoset resin and a high melting point metal with a melting point that is higher than the curing temperature of the thermoset resin, the low melting point metal and the high melting point metal being at a volume ratio of 10:90 to 90:10, into the via hole to form a via hole conductor;
a step B of mounting a prescribed electrical element on a surface of the insulating sheet and bringing an electrode of the electrical element into contact with an exposed portion of an end part of the via hole conductor;
a step C of laminating another insulating sheet on a surface of the insulating sheet provided with the electrical element such that the electrical element is stowed and mounted in a hermetically sealed gap; and
a step D of heating the laminate to the thermosetting temperature of the thermoset resin to cure the insulating sheet while simultaneously melting the low melting point metal in the via hole conductor and electrically connecting the electrode of the electrical element and the via hole conductor by the melted low melting point metal.

DETAILED DESCRIPTION OF THE INVENTION

[0001]

TECHNOLOGICAL FIELD OF THE PRESENT INVENTION

The present invention is suitable, for example, for a multilayer wiring board and a package for stowing a semiconductor element, and particularly relates to an electrical element mounted wiring board in which an electrical element is internally provided inside an insulating substrate and a manufacturing method thereof.

[0002]

CONVENTIONAL TECHNOLOGY

Electronic devices are decreasing in size, but the recent development of mobile information terminals and the spread of mobile computing, in which computers are operated while being carried around, are creating a trend toward even smaller, thinner, and higher-definition multilayer wiring boards. Furthermore, examples of adopted methods when mounting an electrical element such as a semiconductor element, capacitor element, resistor element, or the like on a conventional multilayer wiring board include methods of adhering the element to a surface of a pre-made printed wiring board and connecting to a wiring circuit layer of the wiring board by wire bonding, or directly mounting the electrical element to the surface of the wiring board by solder or the like, and then molding the mounted element with a resin, methods of forming a recessed part on a surface of an insulating substrate, stowing the element in the recessed part and molding with a resin, or hermetically sealing the recessed part with a lid, and the like.

[0003] In addition, recently, a method called TAB (tape automated bonding) has been used for substrates used in mobile information terminals and the like that require reduced size, weight, and thickness. The TAB connection method is a method of connecting a semiconductor element bump and an inner lead to a so-called TAB tape. Herein, a metal foil is adhered to an entire surface of polyimide resin film or the like provided with a hole at a prescribed location for stowing a semiconductor element. Also, a lead wiring layer is formed, which includes the inner lead and an outer leader for connecting the metal foil to the semiconductor element by photoetching.

[0004]

PROBLEM TO BE SOLVED BY THE INVENTION

However, in the conventional method of mounting an electrical element, a step of mounting an electrical element on a surface of a pre-made wiring board and then electrically connecting the element to a wiring circuit layer is required, resulting in many manufacturing processes until an electrical device including an electrical element is completed, which leads to high costs. Moreover, the only mounting portion for the electrical element is on the surface of the wiring board, which is an obstacle to thinner and smaller substrates and high-density mounting of a plurality of electrical elements.

[0005] In addition, 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, thereby making support of miniaturization impossible. In addition, a connection between individual terminals is required, in which there is a problem of increasing the time required for connection, thereby reducing productivity.

Moreover, wiring such that a wire draws a loop is required for connection by wire bonding, and therefore, a clearance of approximately 0.5 mm in a thickness direction of a silicon chip is inevitably created, which is an obstacle for reducing the thickness of a semiconductor device.

[0006] In contrast, the TAB connection method enables connecting a semiconductor device and a lead in a single connection process, and thus connection can be performed in a short period of time, which has an advantage of excellent mass productivity. On the other hand, this connection method can only be achieved by using a polyimide resin film with a copper foil adhered to one surface, referred to as a TAB tape. Therefore, there is a problem that handling an increase in the number of terminals on a silicon chip is not possible, such as the need for a wiring width of 20 μm or less when the number of connection terminals exceeds 500, and the like.

[0007] Therefore, an object of the present invention is to provide an electrical element mounted wiring board on which an electrical element such as a semiconductor element and electronic component (capacitor element, resistor element, filter element, oscillator element, or the like), can be mounted, the substrate size can be reduced, and the mounting density of the elements can be increased. Furthermore, an object of the present invention is to provide a method for manufacturing an electrical element mounted wiring board, which makes it easy to fabricate a wiring board capable of internally providing an electrical element inside the wiring board.

[0008]

MEANS FOR SOLVING THE PROBLEM

As a result of extensive studies for miniaturization and simplification of manufacturing of a wiring board in which an electric element is mounted in a hermetically sealed gap, the present inventor discovered that by including a mixture of a low melting point metal having a melting point lower than that of a thermoset resin included in an insulating substrate and a high melting point metal having a melting point higher than that of the thermoset resin in the insulating substrate at a prescribed ratio, and by connecting an electrode of the electrical element to a via hole conductor by heating and melting the low melting point metal, an electrical element can be easily internally provided in the wiring board, resulting in the present invention.

[0009] In other words, an electrical element mounted wiring board of the present invention includes:

an insulating substrate obtained by laminating a plurality of insulating layers containing at least a thermoset resin;
a wiring circuit layer formed on a surface of and inside the insulating substrate;

a via hole conductor filled with a metal powder;

an electrical element being mounted in a hermetically sealed gap inside the wiring board; and

an electrode of the electrical element and the via hole being electrically connected; wherein

the via hole conductor connected to the electrode containing a mixture of a low melting point metal having a melting point that is 10°C or more lower than the curing temperature of the thermoset resin and a high melting point metal with a melting point that is higher than the curing temperature of the thermoset resin, the low melting point metal and the high melting point metal being at a volume ratio of 10:90 to 90:10,

and the via hole conductor and the electrode of the electrical element being electrically connected and secured by heating and melting the low melting point metal in the via hole conductor.

[0010] In addition, a method of manufacturing an electrical element mounted wiring board of the present invention includes:

a step A of forming a via hole in an uncured insulating sheet containing at least a thermoset resin and then filling a conductive paste containing a mixture of a low melting point metal having a melting point that is 10°C or more lower than the curing temperature of the thermoset resin and a high melting point metal with a melting point that is higher than the curing temperature of the thermoset resin, the low melting point metal and the high melting point metal being at a volume ratio of 10:90 to 90:10, into the via hole to form a via hole conductor;

a step B of mounting a prescribed electrical element on a surface of the insulating sheet and bringing an electrode of the electrical element into contact with an exposed portion of an end part of the via hole conductor;

a step C of laminating another insulating sheet on a surface of the insulating sheet provided with the electrical element such that the electrical element is stowed and mounted in a hermetically sealed gap; and

a step D of heating the laminate to the thermosetting temperature of the thermoset resin to cure the insulating sheet while simultaneously melting the low melting point metal in the via hole conductor and electrically connecting the electrode of the electrical element and the via hole conductor by the melted low melting point metal.

[0011]

EMBODIMENTS OF THE INVENTION

The present invention will be described below based on the drawings. FIG. 1 is an explanatory diagram of a manufacturing process for manufacturing an electrical element mounted wiring board of the present invention.

[0012] According to FIG. 1, first, as illustrated in FIG. 1(a), a soft (B-stage state) insulating sheet 1 containing a thermoset resin with a curing temperature T_1 is formed and via holes penetrating in a thickness direction are formed in the insulating sheet 1. Of the via holes, a via hole that is connected to an electrode of an electrical element is filled with a conductive paste containing a low melting point metal having a low melting point T_2 , which is equal to or lower than the curing temperature T_1 of the thermoset resin, and a high melting point metal having a melting point that is higher than the curing temperature of the thermoset resin while screen printing or a suctioning process to form a via hole conductor 2a for connecting an electrical element. Furthermore, according to FIG. 1(a), in addition to the via hole conductor 2a for connecting an electrical element, a general via hole conductor 2b is also formed.

[0013] The insulating sheet 1 used herein is prepared by sufficiently mixing a thermoset resin or a composition of a thermoset resin and a filler or the like by means such as a kneading machine, three rollers, or the like, which is then molded into a sheet by a rolling method, extruding method, injecting method, doctor blade method, or the like, or, if desired, semi-cured by heat treatment at a temperature slightly lower than the curing temperature.

[0014] Furthermore, a conventionally known method such as drilling, punching, sandblasting, or processing by irradiating a carbon dioxide gas laser, YAG laser, excimer laser, or the like is used to form the via holes and gap portion in the insulating sheet.

[0015] Note that the thermoset resin forming the insulating sheet is not particularly limited so long as the thermoset 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, allyl resin, and the like 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 board as a whole. Inorganic fillers such as SiO_2 , Al_2O_3 , ZrO_2 , TiO_2 , AlN , SiC , BaTiO_3 , SrTiO_3 , zeolite, CaTiO_3 , aluminum borate, and the like are preferably used as the filler compounded with the organic resin. Furthermore, a woven fabric, non-woven fabric composed of glass or aramid resin, or the like may also be used impregnated with the resin described above. Note that it is appropriate to compound the organic resin and filler at a volume ratio of 15:85 to 50:50.

[0017] Of these, a mixture of at least one type of thermoset resin selected from a group consisting of epoxy resins, imide resins, and phenylene ether resins and silica or an aramid nonwoven fabric as a filler component is most preferable from the perspective of ease of processing by punching, laser, or the like.

[0018] On the other hand, tin (Sn), zinc (Zn), bismuth (Bi), and alloys thereof with silver (Ag), copper (Cu), or the like are preferably used as the low melting point metal in the conductive paste filled into the via hole conductor 2a, which is connected to the electrode of the electrical element.

[0019] The melting point T_2 of the low melting point metal and the curing temperature T_1 of the thermoset resin must satisfy the relationship $T_1 - T_2 \geq 10^\circ\text{C}$. This allows the low melting point metal to heat and melt during curing of the thermoset resin to enable simple and firm bonding with the electrode of the electrical element.

[0020] Furthermore, if the low melting point metal constitutes all of the metal components in the conductive paste, shape retention within the via hole conductor will be inferior when melted during thermal curing as described below, and therefore, the low melting point metal is used mixed with the high melting point metal with a melting point that is higher than the curing temperature of the thermoset resin. Copper, silver, copper-silver alloys, or mixtures thereof are preferably used as the high melting point metal with a higher melting point than the curing temperature of the thermoset resin. The high melting point metal and the low melting point metal are mixed at a volume ratio of 90 to 10 : 10 to 90.

[0021] Furthermore, the via hole conductor 2b, which is not connected to the electrical element, is not necessarily required to include a low melting point metal, but can be filled with a conductive paste containing metal powder with a high melting point such as ordinary copper, silver, an alloy containing these, or the like.

[0022] When preparing the conductive paste, the low melting point metal or the high melting point metal and low 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 metal powders increases and the resistance of the via hole conductor tends to be high. Furthermore, if the average particle size exceeds 50 μm , low resistance of the via hole conductor tends to be difficult to achieve.

[0023] In addition, the conductive paste is prepared by adding and mixing the aforementioned binding organic resin or a solvent to the metal powder as described above. The solvent added to the paste can be any solvent that can dissolve the binding organic resin to be used, such as isopropyl alcohol, terpineol, 2-octanol, butylcarbitol acetate, and the like.

[0024] As the binding organic resin in the conductive paste, cellulose or the like is used in addition to the aforementioned organic resin included in the various insulating layers. The organic resin binds the metal powders in contact with each other and also acts to adhere the metal powders to the insulating sheet. The organic resin is preferably included in the metal paste at a ratio of 0.1 to 40 volume%, and particularly 0.3 to 30 volume%. This is because if the amount of resin is less than 0.1 volume%, it is difficult to bind the metal powders firmly together, making it difficult to firmly adhere a low resistance metal to the insulating layer. Conversely, if the amount exceeds 40 volume%, the resin intervenes between the metal powders, making it difficult for the powders to make sufficient contact with each other, thereby increasing the resistance of the via hole conductor. Next, as illustrated in FIG. 1(b), a wiring circuit layer 3 is formed on a front surface or back surface of the insulating sheet 1, as appropriate. Examples of methods of forming the wiring circuit layer 3 include: 1) a method of adhering a metal foil to the surface of the insulating sheet 1 to form a circuit pattern; 2) a method of depositing a resist on the insulating sheet 1 surface, which is formed by plating; 3) a method of adhering a metal foil to a transfer film surface, etching the metal foil to form a circuit pattern, and then transferring the circuit pattern composed of the metal foil onto the insulating sheet 1 surface; and the like. At this time, with regard to the via hole conductor 2a, which is connected to the electrode of the electrical element, a wiring circuit layer may not be formed or a connection pad containing the low melting point metal may be provided.

[0025] The wiring circuit layer 3 preferably contains at least one or more alloy selected from a group consisting of copper, aluminum, gold, and silver, with copper or alloys containing copper being most preferable. In addition, in some cases, a high resistance metal such as a Ni-Cr alloy or the like may be mixed or alloyed as a conductor composition to adjust circuit resistance. Furthermore, to lower the resistance of the wiring circuit layer, a metal with a lower melting point than the low resistance metal, such as solder, tin or other low melting point metal, may be included in a metal component in the conductor composition at a ratio of 2 to 20 weight%.

[0026] Thereafter, as illustrated in FIG. 1(c), an electrical element 4 is mounted on the surface of the insulating sheet 1, and an electrode 5 formed on a back surface of the electrical element 4 is brought into contact with an exposed portion of an end surface of the via hole conductor 2a.

[0027] Examples of the electrical element 4 at this time include a semiconductor element, capacitor element, resistance element, filter element, oscillator element, and the like. The heat resistance temperature is particularly preferably higher than the curing temperature T_1 .

[0028] Furthermore, the insulating sheet 1 provided with the electrical element 4 is laminated together with other insulating sheets 6, 7, 8 on which the via hole conductor 2b and the wiring circuit layer 3 are formed. At this time, as illustrated in FIG. 1(d), an opening 9 for stowing the electrical element 4 is formed in the insulating sheet 6 and laminated directly above the insulating sheet 1, such that electrical element 4 can be stored and mounted in a hermetically sealed gap formed by the insulating sheets 1, 6, 7.

[0029] Thereafter, the laminate prepared as described above is heated at or above the curing temperature T_1 of the thermoset 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 conductor 2a melts during the above thermal curing because the melting point T_2 thereof is lower than the curing temperature T_1 . As a result, the electrode 5 of the electrical element 4 and the via hole conductor 2a can be electrically connected.

[0031] As a result, as illustrated in FIG. 1(e), the electrical element 4 is stowed and mounted in a hermetically sealed gap 10 inside a multilayer wiring board A, and thus it is possible to prepare a multilayer electrical element mounted wiring board with an electrical element electrically connected to the via hole conductor 2a mounted in the gap 10.

[0032] Note that according to the present invention, the method described above can be developed to prepare a wiring board with various forms of electrical elements mounted. For example, a plurality of electrical elements can be provided by forming a plurality of gap portions in the same or different layers in a multilayer wiring board to stow and mount the electrical elements. In addition, it is preferable to make the thermoset resin flow before curing to minimize a gap with an insulating phase at the periphery of the electrical element 4 to improve reliability.

[0033] In addition, although the aforementioned method is described for a case where an electrical element is stowed inside a substrate, the method can also be applied to a case where an electrical element is connected to a via hole conductor on a surface of a substrate, and it is also possible to simultaneously mount on a substrate surface in conjunction with stowing and mounting inside the substrate as described above.

[0034] Thus, with the present invention, an electrical element mounted wiring board that can easily provide not only a single but also a plurality of electrical elements inside the wiring board, thereby reducing the size of the wiring board and increasing the mounting density of electrical elements can be provided. Moreover, the manufacturing method of the present invention allows for the connection of an electrical element to a wiring board and the manufacture of a multilayer wiring board at the same time, resulting in the simplification of the manufacturing process, which increases manufacturing yield and reduces costs.

[0035]

EMBODIMENTS

(1) An insulating sheet a with a thickness of 75 μm was prepared by mixing a varnished resin and powder and using a doctor blade method to achieve a ratio of 50 volume% for PPE (polyphenylene ether) resin (curing temperature $T_1 = 200^\circ\text{C}$) and 50 volume% of silica powder. A plurality of via holes with a diameter of 0.1 mm were formed in the insulating sheet a by punching, of which a via hole connected to an electrode of an electrical element was filled with a conductive paste in which triallyl isocyanurate was added at a rate of 5 volume% to a metal component that contains 50 volume% of a copper powder with an average particle size of 5 μm plated with silver on the surface and 50 volume% of a powder (melting point $T_2 = 183^\circ\text{C}$) with an average particle size of 3 μm containing Sn-Pb eutectic solder as a low melting point metal, to form a via hole conductor. Furthermore, the same conductive paste was also filled into a via hole that was not connected to an electrical element.

[0036] (2) On the other hand, an adhesive was coated on a surface of a transfer sheet containing a polyethylene terephthalate (PET) resin, and a copper foil with a thickness of 12 μm and a surface roughness of 0.8 μm was adhered to one surface. Furthermore, a photoresist (dry film) was coated, exposed, and developed, and then immersion in a ferric chloride solution was performed to etch away the non-patterned portion to form a wiring circuit layer. Note that the prepared wiring circuit layer has a fine pattern with a line width of 20 μm and an interval of 20 μm between wiring.

[0037] (3) Furthermore, on the surface of the insulating sheet a prepared in (1), the wiring circuit layer side of the transfer sheet was pressure bonded to the insulating sheet a at a pressure of 50 kg/cm^2 , after which the transfer sheet was peeled off and the wiring circuit layer was 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 on which the via hole conductor and wiring circuit layer were formed, positioned such that an electrode formed on a back surface of the chip and an exposed portion of an end part of the via hole conductor are in contact, and then temporarily secured with an adhesive.

[0039] (5) Thereafter, an opening slightly larger than the size of the electrical element was formed by punching an insulating sheet b, in which a via hole conductor or wiring circuit layer was formed in the same manner as described above, which was laminated for the thickness of the electrical element. Finally, an insulating sheet c without an opening was laminated and pressure bonded by applying a pressure of 20 kg/cm^2 .

[0040] (6) The laminate was then heated at 200°C for 1 hour for complete curing to prepare a multilayer wiring board. Note that an opening portion of the insulating sheet contracted due to the flow of resin caused by heating, and the insulating layer and the chip adhered closely together, leaving almost no gap between the chip and the insulating layer.

[0041] As a result of cross sectionally observing the formation area of the wiring circuit layer and via hole conductor of the obtained multilayer wiring board, the IC element and the via hole conductor were in a favorable connected state due to melting of the low melting point metal in the via hole conductor. As a result of a continuity test between each

wiring, no disconnection of wiring was observed.

Furthermore, there were no problems with the operation of the IC element. The obtained multilayer wiring board was left in a hot and humid atmosphere of 85% humidity and 85°C for 100 hours and no visually discernible changes occurred.

[0042]

EFFECT OF THE INVENTION

As described above, with the present invention, an electrical element mounted wiring board that can easily provide a single or a plurality of electrical elements inside the wiring board, thereby reducing the size of the wiring board and increasing the mounting density of electrical elements can be provided. Moreover, the manufacturing method of the present invention allows for the connection of an electrical element to a wiring board and the manufacture of a multilayer wiring board at the same time, resulting in the simplification of the manufacturing process, which increases manufacturing yield and reduces costs.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a process diagram for describing a method of manufacturing an electrical element mounted wiring board of the present invention.

DESCRIPTION OF REFERENTIAL NUMERALS

- 1, 6, 7, 8. Insulating sheet
2. Via hole conductor
3. Wiring circuit layer
4. Electrical element
5. Electrode
9. Opening
10. Gap

