"Semiconductor device and process for producing the same".

This invention relates to a semiconductor device including a semiconductor element fixed to a supporting member by an organic adhesive and to a process of manufacturing the same.

There is known a semiconductor device in which a semiconductor element prepared from a semiconductor pellet is fixed to a supporting member of a metallic material with a paste containing an organic material. As the paste, there is known a system such as, for example, Able Bond 826-1 (a trademark of a product supplied by Able Stick Laboratories). In the final stage of manufacture, most semiconductor devices are embedded in a resin and supplied in the form of a resin-packaged device.

The present inventors, however, found that the resin-packaged semiconductor device assembled using a conventional paste presents problems associated with the moisture resistance such as that the aluminium wiring, electrodes or the bonded area of a semiconductor element deteriorates due to corrosion, or the leakage current between the electrodes increases for the following reasons:

(i) During the hardening (curing)of the paste by heating, those vapors of low molecular weight organic compounds containing such elements as C, H, and O which

are liberated from the paste materials are adsorbed on the surface of semiconductor element and interfere with the adhesion between the packaging resin and the semiconductor element. Under such conditions, if the moisture of the exterior environment penetrates into the package, the semiconductor element and the packaging resin easily become separated at the interface to give voids, and resulting in accelerated corrosion of the aluminium wiring and the bonded area.

(ii) The paste material contains as impurities such corrosive halogen ions as hydrolytic chloroions, bromide ions, etc. which, on being eluted, corrode the wiring or the electrode on the surface of element.

(iii) The hardened resin in the paste material is readily subject to hydrolysis and tends to cause the formation of voids containing moisture, as in the case of (ii), resulting in corrosion of the wiring.

An object of this invention, therefore, is to provide a semiconductor device which can have excellent moisture resistance or corrosion resistance as well as to provide a method of its manufacture.

This invention is characterized in that, when binding together a supporting member and a semiconductor element, in due consideration of the moisture problem, use is made of an adhesive composition (mixture) of materials, preferably in paste

form, comprising (1), (2), (3) and (5) selected from the following substances (1) to (6), preferably an adhesive composition in paste form comprising the substances (1) to (5), more preferably an adhesive composition in paste form comprising all of the substances from (1) to (6):

(1) An epoxy resin (preferably having two or more epoxy radicals in one molecule).

(2) A novolak type phenolic resin.

(3) A solvent capable of dissolving both the above-noted epoxy resin and novolak type phenolic resin.

(4) A accelerator.

(5) A conductive powdered filler.

(6) A coupling agent.

In the accompanying drawings, Fig. 1 is an oblique view of a lead frame used in one semiconductor device of this invention; Figs. 2 and 3 are sectional views of respective examples of the semiconductor devices according to this invention.

The ingredients which compose the adhesive composition are described below in detail.

(1) The epoxy resin has in the same molecule two or more epoxy groups and usually plays the role of main material:

Examples of such epoxy resins include bi-functional epoxy compounds such as diglycidyl ether of bisphenol A-type,diglycidyl ether of bisphenol F,

vinylcyclohexane diepoxide, and the like, and tri-functional or higher functional epoxy compounds such as triglycidyl ether of p-aminophenol, polyglycidyl ether of novolak type phenolic resin, and the like.

(2) The novolak type phenolic resin which acts as hardener:

Novolak type phenolic resins which are used include those formed by the reaction of a phenol or a phenol derivative with formaldehyde or p-formaldehyde, such as a novolak type phenolic resin using phenol as a starting material, a novolak type cresol resin using cresol as a starting material, a novolak type xylene resin using xylenol as a starting material, etc.

(3) The solvent capable of dissolving both the epoxy resin and the novolak type phenolic resin:

Such solvents include aromatic solvents such as toluene, xylene, etc., ketonic solvents such as acetone, methyl ethyl ketone, etc.; and solvents of the ether glycol type such as ethyl Cellosolve, butyl Cellosolve, etc. If the boiling point of the solvent is too low, the paste coated on a supporting member will become dry (tack-free state) before a satisfactory bond with the semiconductor element is formed, resulting in insufficient adhesion, while a solvent having a too high boiling point presents a problem of residual solvent after hardening. In view of this, a solvent boiling between 120° and 180°C is

preferred. The Cellosolve-type solvents such as butyl Cellosolve are particularly preferred from the viewpoints of boiling point as well as wettability of the adherend. Further, it is possible to use several solvents in combination for the purpose of extending the tack free time or for other purposes.

(4) The accelerator:

Known products may be used for the hardening accelerator. Imidazole type compounds, quaternary phosphonium compounds and borates such as tetrasubstituted borates are particularly useful.

(5) Conducting powdered filler:

The filler retards the evaporation of solvents and facilitates the operation of coating the paste on a supporting member. A primary object of adding a filler is to improve workability of the paste. Further objects of the addition of a filler are to improve bond strength and to improve moisture resistance of the paste. Particularly when powdered silver is used as the filler, as well as imparting electric conductivity to the paste it is possible to improve thermal conductivity of the paste when it is intended to dissipate the heat generated from the semiconductor element to the supporting member. The fillers suitable for use include, in addition to the powdered silver, conductive carbon powders such as graphite as well as a mixture of carbon powder and silver powder. Further, for the purposes of improving the bonding strength and

of giving thixotropy (viscosity change of the paste on mixing) to the paste, it is also possible to use powders of silica, metal oxides and silica glass in combinations as required.

The silver powder for use as electroconductive powder should be preferably 5 μm or less in particle size. This is because if the agglomerates are formed in the paste from the silver powder of greater than 5 μm in particle size, the gap between the semiconductor element and the supporting electrode will become larger than the normal thickness of the adhesive layer (5 to 40 μm) so that the adhesion between the semiconductor element and the supporting electrode becomes nonuniform, resulting in insufficient bonding strength. The silver powder content of the paste is preferably 15 to 50% by volume based on a total volume of the epoxy resin, novolak type phenolic resin and silver powder. If it is less than 15% by volume, the volume resistivity becomes 10^{-2} Ω·cm or more and fluctuating leading to technical disadvantage, while if it is larger than 50% by volume, the tack range becomes as small as 5 minutes, giving rise to the technical disadvantage such that a slight disturbance in the manufacturing steps will result in insufficient bonding of the adherents.

(6) The coupling agent maybe of the silane type, aluminum type or titanium type to improve the bonding power of the paste:

For instance, a silane coupling agent is used to improve the adhesive strength between a silicon semiconductor element and the paste. Although not a necessary condition, the addition of a coupling agent is favourable for achieving a high adhesive strength.

Preferably in this invention, the above-mentioned adhesive composition , suitably in the form of a paste, is coated over the area of the surface of a supporting member (tab) at which the semiconductor element is to be fixed, and then heat treated, whereby the supporting member and the semiconductor element are bonded or bound together. The paste can be applied in excess to the supporting member surface so that it may cover the side faces of semiconductor element to improve the moisture resistance of the finished semiconductor device.

Further, within this invention, the aforementioned adhesive composition e.g. as a paste, can be used not only for the bonding of a semiconductor element and a supporting member, but also as a surface protective film to cover the electrodes and other elements provided on the surface. By such means, the finished resin-packaged semiconductor device can be improved in moisture resistance.

The invention is further illustrated below with reference to the drawings and Examples.

Fig. 2 illustrates a finished semiconductor device assembled according to this invention. Numeral 1 indicates a plurality of outgoing lead wires provided in correspondence to the aluminium

electrodes of a semiconductor element. Numeral 2 indicates a supporting member (tab) to mount and fix the semiconductor element and is made of Fe-Ni-Co alloy similarly to the lead wire 1. Numeral 3 indicates a semiconductor element comprising, for example, an integrated circuit (IC) element provided on a silicon semiconductor substrate (pellet) by the planar technique. On the front main face, are provided aluminum wiring or the like (not shown in the drawing) and output electrodes (not shown in the drawing). Numeral 4 indicates a paste to bond or fix the back-side of semiconductor element 3 to the supporting member 2. This paste has a specific composition according to this invention. Examples of the paste compositions are described later. Numeral 5 indicates fine lead wire electrically connecting the output electrode provided on the front main face of the semiconductor element to the corresponding outgoing lead wire 1. This fine lead wire is made of, for example, gold (Au) and bonded by a known wire bonding technique to the electrode on the main face of semiconductor element 3 and to lead wire 1. Numeral 6 indicates the resin packaging material formed by a known transfer molding technique.

A method of making the device of Fig. 2 is as described below.

The binder paste is prepared in the following manner: Prescribed amounts of an epoxy resin,

a phenol novolak resin and a solvent are charged into a reactor with stirrer provided with a heating device and heated at a temperature of 80°C or above, preferably 90° to 110°C to form a uniform solution. If the phenol novolak resin contained unreacted phenol or a dimer in amounts exceeding a certain limit, the hardened resin tends to become inferior in heat resistance. Therefore, if the existence of the said impurities is confirmed by gel-permeation chromatography (GPC) or other means, it is necessary to remove then by vacuum distillation or the like. The amount of the novolak type phenolic resin is preferably in such a range that the ratio of the number of phenolic hydroxyl groups to the number of epoxy groups be from 0.5 to 1.5/1 in order to obtain a desirable glass transition temperature and a desirable hardenability. The said solution is admixed with one or more accelerators and fillers and uniformly milled and mixed in a stirring and mixing machine to obtain the desired paste.

The paste is then coated on a supporting member (tab) 2 for the lead frame 7. The lead frame should be thoroughly washed previously. The paste is, then, applied in the shape shown by 8 in Fig. 1 by means of a dispenser or printing.

Subsequently, the semiconductor element 3 is placed on the supporting member 2 and slightly pressed so as to bind the semiconductor and the

supporting member well. Then, the paste is cured by heating at a temperature of 120°C or higher, preferably 150° to 220°C, for 1 to 10 hours. After this fine lead wires 5 as shown in Fig. 2 are bonded according to a conventional technique, and a resin packaging material 6 is formed by a conventional transfer molding technique. After molding the resin packaging material 6, the frame portion of the lead frame 7 shown in Fig. 1 is cut so as to give a semiconductor device having a plurality of outgoing lead wires 1.

In the above-mentioned procedure, the amount of paste to be coated on the tab 2 can be controlled so that when semiconductor element 3 is bonded to the tab 2, the hardened paste 4 will just cover the area of back main face of the semiconductor element as shown in Fig. 2, or the hardened paste will cover also the side faces 9 as shown in Fig. 3. When the paste is applied in excess so that the excess paste 4 will be squeezed out to cover the side faces 9 as shown in Fig. 3, adhesion deterioration between the semiconductor element and the tab can be reduced and, at the same time, delamination between the tab 2 or the semiconductor element 3 and the resin packaging material 6 can also be prevented. In such a way, the penetration of moisture from the supporting member 2 to the front main face of semiconductor element 3 through side faces can be prevented, resulting in a decrease in the occurrence of corrosion

of the aluminum electrode.

The composition of the paste used in the above example and its preparative procedure are described below in particular examples.

Paste preparation, Example 1.

The ingredients a), b) and c), which are an epoxy resin, a novolak type phenolic resin and a solvent, respectively, in the following formulation were stirred for one hour with heating at 100°C in a 300-ml flask provided with a reflux to form a uniform solution. The resulting solution was charged into a mortar. To the mortar, were added prescribed amounts of the ingredients d), e) and f), which are a hardening accelerator, a filler and a silane coupling agent, respectively. The mixture was ground for 2 hours to prepare a resin composition containing powdered silver.

	Parts by weight
a) Epoxy resin (Epikote 1001, manufactured by Shell Chemical Co.)	100
b) Novolak type phenol resin (average molecular weight 800)	29
c) Butyl Cellosolve	106
d) 2-Undecylimidazole (C11Z, manufactured by Shikoku Kasei Co.)	1
e) Powdered silver (average particle size 1.2 μm)	41

f) γ-Glycidoxy-propyl-trimethoxy-silane (KBM-403, made by Shin-etsu Chemical Industry Co.) 0.1

In the above recipe, the quantity of each ingredient was based on 100 parts by weight of the epoxy resin a) in the recipe. The silane coupling agent f) had been added in order to improve the strength of bond toward the back main face of the silicon semiconductor element.

Paste preparation, Example 2

In a manner similar to that described in above-mentioned Example 1, a resin composition of the following formulation was prepared.

	Parts by weight
a) Novolak type cresol resin (ECN1273 made by CIBA Co., Ltd.)	100
b) Novolak type phenolic resin (average molecular weight 800)	60
c) Ethyl Cellosolve	150
d) Triethyl ammonium tetraphenyl-borate	2
e) Powdered silver (average particle size 1.2 μm)	80
f) KBM 403 of Shin-etsu Chemical Industry Co.	0.5

In the above formulation, a) is an epoxy resin, b) a novolak type phenol resin, c) a solvent, d) hardening

accelerator, e) a filler, and f) a silane coupling agent.

The above pastes obtained in Examples 1 and 2 had excellent moisture resistance.

The present inventors compared the characteristics of the above two pastes with those of a paste prepared in a similar manner using an acid anhydride as the hardening accelerator b) according to the following formulation.

Comparative Example

		Parts by weight
a)	Epikote 1001	100
b)	Methyl-tetrahydrophthalic anhydride (HN-2200 made by Hitachi Chemical Co., Ltd.)	52
c)	Butyl Cellosolve	75
d)	2-Ethyl-4-methylimidazole (2E4MZ of Shikoku Kasei Co.)	2
e)	Powdered silver (average particle size 1.2 μm)	60
f)	KBM 403 (Shin-etsu Chemical Industry Co.)	0.1

The pastes of above-mentioned Preparative Examples 1 and 2 and Comparative Example were each cast into a metallic Petri disk to a depth of about 2 mm and heat-treated at 120°C for 24 hours, then at 180°C for 5 hours. The cast specimens thus formed were tested for the PCT moisture absorption ratio,

pH of the extract water, electric conductivity and chloride ion concentration. The results obtained were as shown in the table.

Table

	Preparative Example 1	Preparative Example 2	Comparative Example
PCT water absorption (% by weight)	1.1	0.6	8.6
Aqueous extract			
pH	4.2	4.7	3.9
Conductivity (μΩ/cm)	57	38	170
Chloride ion concentration (ppm)	1.2	0.8	3.0

The characteristic values shown in the table were obtained by the following methods:

PCT (pressure cooker test) water absorption: The weight increase (%) of a specimen, 10 x 10 x 1 mm, after having been left standing under a steam atmosphere at 121°C and 2.0 atmospheres for 20 hours.

Preparation of aqueous extract: 10 g of a ground sample which had passed through a 100-mesh screen was put in 50 g of purified water, left standing for 20 hours at 100°C, and filtered through a No. 5 C filter paper.

pH: Determined by means of a pH meter.

Electric conductivity: The electric conductivity of the sample was measured by means of a conductivity meter.

Chloride ion concentration: The chloride ion concentration of a sample was determined by means of an ion meter provided with electrodes for the chloride ion concentration determination.

It is found from the results that the samples of Preparative Examples 1 and 2 are excellent in moisture resistance, because they are less hydrolyzable and contain less impurities.

As described above, the semiconductor device has improved moisture resistance, because in bonding the semiconductor elements, use is made of a paste which is improved in moisture resistance by using a novolak type phenolic resin as hardening agent, and said resin has low hydrolyzable chloride ion concentration. Further, since a solvent such as butyl Cellosolve having no harmful effect on the surface of semiconductor element is used, the paste can protect the aluminum wiring from acceleration of the corrosion.

The results of tests performed similarly to the above-mentioned pressure cooker test on the illustrated semiconductor device of this invention revealed that as compared with a semiconductor device assembled by using a conventional paste, the device of this invention shown in Fig. 2 showed a five-fold increase in service life (the time elapsed before 50% of the

samples under test became defective in electric characteristics owing to the corrosion or disconnection of aluminium electrode or wiring on the surface of semiconductor element).

As is clear from the foregoing description, the present invention is very effective particularly in improving the moisture resistance of a resin-packaged semiconductor device. Moreover, the principle of this invention can be utilizable in other sealing systems such as the ceramic-packaged type.

CLAIMS

1. A process for manufacturing a semiconductor device including a step of bonding a semiconductor element to a supporting member, which comprises applying between said semiconductor element and said supporting member an adhesive composition comprising an epoxy resin, a novolak-type phenolic resin, a solvent capable of dissolving both of said resins, and an electro-conductive powdery filler.

2. A process according to claim 1 wherein the solvent is butyl cellosolve.

3. A process according to claim 1 or claim 2 wherein the powdery filler is powdered silver.

4. A process according to claim 3, wherein the powdered silver has a particle size of 5 μm or less and the powdered silver content in the adhesive composition is 15 to 50% by volume based on the total volume of the epoxy resin, the novolak-type phenolic resin, and the powdered silver.

5. A process according to any one of claims 1 to 4 wherein the adhesive composition further comprises a hardening accelerator and/or a coupling agent.

6. A process according to any one of claims 1 to 5, wherein the step of bonding the semiconductor element to the supporting member comprises coating the adhesive composition over a surface portion of the supporting member at which the semiconductor element is to be fixed, placing the semiconductor element over the surface portion of the supporting member so that the adhesive composition is interposed between the semiconductor element and the supporting member, and heat treating the interposed adhesive composition.

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7. A semiconductor device comprising a semiconductor element, the back main face of which is fixed to a supporting member with an adhesive layer formed by heat-curing an adhesive composition comprising an epoxy resin, a novolak-type phenolic resin, a solvent capable of dissolving both of said resins, and an electroconductive powdery filler, and, optionally, a hardening accelerator and/or a coupling agent, the front main face of said semiconductor element carrying an electrode connected electrically to an electroconductive member through a fine lead wire, and said semiconductor element, said supporting member, and said lead wire being encapsulated with a resin packaging material.

8. A semiconductor device according to Claim 7, wherein the powdery filler is powdered silver.

9. A semiconductor device comprising a semiconductor element, the back main face of which is fixed to a supporting member with an adhesive layer formed by heat-curing an adhesive composition comprising an epoxy resin, a novolak-type phenol resin, a solvent capable of dissolving both of said resins, and an electroconductive powdery filler, and, optionally, a hardening accelerator and/or a coupling agent, the front main face of said semiconductor element carrying an electrode connected electrically to an electroconductive member through a fine lead wire, the side faces of said semiconductor element being covered with the same material as that of said adhesive layer, and said semiconductor element, said supporting member,

and said lead wire being encapsulated with a resin packaging material.

10. A semiconductor device according to Claim 9, wherein the powdery filler is powdered silver.

11. A process according to claim 1 for manufacturing a semiconductor device substantially as herein described with reference to Fig. 2 or Fig. 3 of the accompanying drawings and/or in any one of the Examples.

12. A semiconductor device substantially as herein described with reference to and as shown in Fig. 2 or Fig. 3 of the accompanying drawings and/or in Examples 1 and 2.