

PATENT SPECIFICATION

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(54) METHOD OF MANUFACTURING A SEMICONDUCTOR/DEVICE

(71) We, PHILIPS ELECTRONIC AND ASSOCIATED INDUSTRIES LIMITED, of Abacus House, 33, Gutter Lane, London, E.C.2., a British Company, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

10 This invention relates to a method of manufacturing a semiconductor device in which a surface of a semiconductor body and a surface of a substrate are mechanically connected together by an electrically insulating adhering layer and in which an electrically conductive connection is produced between parts of a conductive pattern on said surface of the semiconductor body and parts of a conductive pattern on the said surface of the substrate. This invention also relates to a semiconductor device, for example, a transistor, a diode or an integrated circuit, manufactured by this method.

25 It is known to connect a semiconductor body having part of a conductive pattern, reinforced, for example, electrolytically, to parts of a conductive pattern on a substrate by soldering. Such an electrically conductive connection is not always sufficiently rigid which becomes apparent particularly when the substrate is flexible, for example, when it consists of a synthetic resin foil. When a flexible substrate is handled or manipulated, it often changes in shape as a result of which inadmissibly high stresses can occur in the electric connection so that the electric connection breaks. When a flexible substrate changes its shape the conductive patterns on the semiconductor body and the substrate may contact each other in undesirable places.

40 It is known from Dutch Patent Application 6,915,992 to provide a semiconductor body having a conductive pattern with an insulating layer of adhesive which bonds the semiconductor body to a foil of a synthetic resin. Corresponding parts of conductive patterns on

the semiconductor body and the foil of synthetic resin are then connected together after which the layer of the adhesive is hardened. The method described in the abovementioned Patent Application has the drawback that adhesive also lodges on the parts of the conductive pattern still to be connected, which adhesive has to be removed from said parts by pressing the semiconductor body and the substrate against each other. Such a removal may be incomplete. Residues of adhesives often cause the subsequently made electric connections to have inferior electric and mechanical properties, particularly when corresponding parts of the conductive patterns are connected thermally during which decomposition of the adhesive residues may occur.

It is also highly desirable that the insulating adhering layer should have a passivating action on the surface of the semiconductor body.

The invention is based on the recognition of the fact that methods of adhering can be found for appropriate adhesives in which the exposed surfaces of the conductive patterns to be connected, which parts must always be as clean as possible, are not covered with adhesive or adhesive material.

The present invention provides a method of manufacturing a semiconductor device in which a surface of a semiconductor body and a surface of a substrate are mechanically connected together by an electrically insulating adhering layer and in which an electrically conductive connection is formed between parts of a conductive pattern on the said surface of the semiconductor body and parts of a conductive pattern on the said surface of the substrate, comprising the steps of forming the electrically conductive connection between the semiconductor body and the substrate, then drawing a liquid adhesive into the free space between the semiconductor body and the substrate by capillary action, and then hardening the liquid adhesive so as to form the electrically insulating adhering layer.

In the method according to the invention

[Price 25p]

Price 75p

the parts of the conductive patterns to be connected can thus be kept clean.

5 The drawing-in of the liquid through an aperture between the semiconductor body and the substrate occurs by capillary action due to the small dimension of the aperture. The dimension of the aperture is preferably chosen to be between 1μ and 100μ .

10 An additional advantage of the capillary drawing-in of the liquid as compared with the squeezing-out of the excess adhesive according to the prior art is that in the method according to the present invention the quantity of excess material which is not used for adhering purposes can be minimized since the liquid is preferably contacted locally with the aperture between the semiconductor body and the substrate and can nevertheless substantially fill the whole free space between the body and the substrate.

20 In choosing the liquid adhesive, it is important that during hardening no important changes in volume of the adhesive occur, for example, by solvent evaporation, as a result of which the filling of the free space between the semiconductor body and the substrate and hence the mechanical bonding would be incomplete and electric short-circuit might occur between the conductive patterns.

30 The liquid adhesive preferably contains an organic epoxy compound and a silane of which at least one hydrogen atom is replaced by an amino-alkyl group and at least one hydrogen atom is replaced by an OR-group, wherein R is a hydrocarbon radical, and is drawn into the free space between the semiconductor body and the substrate. The favourable effect of such a liquid adhesive is probably due on the one hand to the adhesion of such a silane to oxidic surfaces by reaction of the —OR-group with hydroxyl groups present on said surfaces, and on the other hand to the adhesive effect of organic epoxy compounds on substrates of, for example, high-molecular weight organic material, and to the reaction of the amino compound with the epoxy compound during the hardening. At any rate, an adhering layer with the said amino compound shows a significantly passivating effect which is of particular importance for that side of the semiconductor body where the conductive pattern is present and which faces the substrate.

45 An amino-alkyl silane in which at least three hydrogen atoms bound to silicon are replaced by —OR-groups before it is combined with the organic epoxy compound is preferably reacted, in the presence of water, with a silane in which at least one hydrogen atom is replaced by a hydrocarbon radical and at least three hydrogen atoms bound to silicon are replaced by —OR-groups.

60 A liquid adhesive for use in the method according to the present invention may be prepared as follows:

An amino-alkylsilane in which at least three hydrogen atoms bound to silicon are replaced by —OR-groups, for example, γ -aminopropyltriethoxy-monosilane, is reacted prior to combination with an organic epoxy compound, in the presence of water with a silane in which at least one hydrogen atom is replaced by a hydrocarbon radical and at least three hydrogen atoms bound to silicon are replaced by —OR-groups, for example phenyltriethoxy-monosilane. The molar ratio of the amino-propylsilane to the phenylsilane is preferably 1:3.

70 Polymeric siloxanes are formed in this reaction. The polymeric siloxane compounds together with the epoxy compound give a particularly readily insulating adhering layer in the free space between the semiconductor body and the substrate, while the passivation of the semiconductor body was found to be excellent.

75 The ratio of the number of molecules of amino-alkylsilane to the number of molecules of hydrocarbonsilane is preferably 1:3. With this value optimum properties of the adhering layer are obtained. With such composition, approximately 50% by weight of the liquid consists of the polymerized siloxane.

80 Readily available compounds such as the diglycidyl ether of 2:2-bis-(4-hydroxyphenyl)propane may be used as the epoxy compound. Preferably the substrate is a flexible foil.

85 In order that the invention may be readily carried into effect, one embodiment thereof will now be described in greater detail, by way of example, with reference to the accompanying drawings, the single Figure of which is a diagrammatic sectional view of a semiconductor device in a stage of manufacture by means of the method according to the present invention.

90 The semiconductor device is manufactured using conventional planar methods in which regions of opposite conductivity types adjoining a semiconductor surface 9 are formed in a semiconductor body 1 by using photo-etching and diffusion processes. The surface 9 of the semiconductor body 1 and the opposed surface 10 of a substrate 2 are also provided with conductive patterns 3 and 4 by means of photo-etching methods. The surface 9 of the semiconductor body 1 and the surface 10 of the substrate 2 are mechanically connected together by an insulating adhering layer 7, and an electrically conductive connection is produced, for example by soldering or an ultrasonic treatment, between projecting parts 5 of the conductive pattern 3 on the said surface 9 of the semiconductor body 1 and parts of the conductive pattern 4 on the said surface 10 of the substrate 2.

110 The electrically conductive connection between the semiconductor body 1 and the substrate 2 is first produced after which a liquid adhesive is drawn by capillary action into the 125 130

free space between the semiconductor body and the substrate, said liquid being converted into the insulating adhering layer 7 by hardening. The distance between the surfaces 9 and 10 is 20 μ .

Projecting parts may also occur in the semiconductor device or may occur exclusively on the substrate and may project beyond the side faces 8 of the semiconductor body.

The substrate 2 consists of a Kapton (Trade Mark) polyimide foil. Substrates may be used which consist of a ceramic material, for example aluminium oxide.

In the method described the upper surface 11 of the semiconductor body 1 remains exposed and may be provided with a current conductor or be connected to a suitable heat sink.

If desired, the conductive pattern 4 may be provided with current conductors as a result of which it becomes suitable for assembly in an envelope or on a printed circuit board.

If desired, the method may be carried out so that several semiconductor bodies are connected to a long foil ribbon, after which the foil ribbon is divided into parts having one or more semiconductor bodies.

A liquid adhesive is prepared by the following process:—

22.1 g (0.1 gmol) of γ - amino - propyltriethoxy - monosilane and 72.3 g (0.3 gmol) of phenyltriethoxy - monosilane are weighed into a glass vessel. 10 ml of a solution of water in absolute ethanol (totally 16.2 g of water in 100 ml) is then added, said 10 ml containing 0.09 g mol of H_2O . The glass vessel is closed by means of a ground glass stopper which has an open capillary and is heated for 4 hours in an oven at 100 to 110°C. The vessel is swirled once every fifteen minutes. Cooling is then carried out, another 0.09 g mol of H_2O in the alcoholic solution is added and heating is carried out at 100—110°C for a further 4 hours. This treatment is repeated twice more with the difference that the last time heating is carried out at 125—130°C for 8 hours. The added ethanol as well as the ethanol liberated during the reaction evaporates through the capillary so that substantially no air can penetrate into the capillary. The last traces of ethanol are driven out of the vessel after the reaction by heating the vessel at 130—150°C while dry nitrogen is passed over the residue in the container *via* a separate inlet. The residue in the vessel resembles a thin oil and weighs 67 to 67.5 g which corresponds substantially to the weight to be expected theoretically on the basis of the added quantity of water and the reaction. 339 g of the material of which the residue consists comprises 1 g at. of hydrogen bound to nitrogen and one nitrogen atom has two directly bound hydrogen atoms.

3.39 g of the residue is then carefully mixed with 2.2 g of the dried diglycidyl ether of

4,4' - diphenylolpropane - 2,2' the equivalent weight of which is approximately 185. The resulting liquid is heated at 50—60°C for 15 to 30 minutes in a closed polythene bottle so as to obtain a certain pre-polymerisation. During this pre-heating the viscosity increases in accordance with the temperature and time of heating. A very small drop of the liquid is then placed beside the semiconductor body on the substrate by means of a micro dropping pipette after the conductive connection between the body and the substrate has been effected. The semiconductor body and the substrate are preheated at 70 to 80°C while the drop is placed beside this assembly. As soon as the drop is contacted with the edge of the substrate and the semiconductor body interface, it is drawn into the free space between said body and the substrate by capillary action.

The liquid gels in 10 to 15 minutes at 125°C to a mass which is then no longer tacky so that the assembly of semiconductor body and the synthetic foil substrate may then be rinsed and further hardened at 125°C for 16—24 hours.

It has been found in testing that the current amplification and the leakage current of transistors vary only slightly when the semiconductor device is maintained for 500 hours at 67°C and 95% relative humidity.

It is possible, for example, to use, instead of the liquid with the aminoalkyl silane and the epoxy compound, a liquid with an acryl silane and a styrene compound with a peroxide accelerator.

In addition to the epoxy compound, a hardener, for example of the anhydride type, may also be used.

Good results were obtained in general when the ratio of the number of molecules γ - amino - propyltriethoxysilane to the number of molecules of phenyltriethoxysilane were between 2:1 and 1:5.

WHAT WE CLAIM IS:—

1. A method of manufacturing a semiconductor device in which a surface of a semiconductor body and a surface of a substrate are mechanically connected together by an electrically insulating adhering layer and in which an electrically conductive connection is produced between parts of a conductive pattern on the said surface of the semiconductor body and parts of a conductive pattern on the said surface of the substrate, comprising the steps of forming the electrically conductive connection between the semiconductor body and the substrate, then drawing a liquid adhesive into the free space between the semiconductor body and the substrate by capillary action, and then hardening the liquid adhesive so as to form the electrically insulating adhering layer.

2. A method as claimed in Claim 1, where-

free space between the semiconductor body and the substrate, said liquid being converted into the insulating adhering layer 7 by hardening. The distance between the surfaces 9 and 10 is 20 μ .

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2. A method as claimed in Claim 1, where-



in the dimension of the aperture between the semiconductor body and the substrate is chosen to be between 1μ and 100μ .

3. A method as claimed in Claim 1 or
5 Claim 2, wherein the liquid adhesive comprises an organic epoxy compound and a silane in which at least one hydrogen atom is replaced by an amino-alkyl group and at least one hydrogen atom is replaced by an —OR-
10 group, wherein R is a hydrocarbon radical.
4. A method as claimed in Claim 3, wherein an amino-alkyl silane in which at least three hydrogen atoms bound to silicon are replaced by —OR-groups, is reacted, prior to
15 being combined with the organic epoxy compound, in the presence of water with a silane in which at least one hydrogen atom is replaced by a hydrocarbon radical and at least three hydrogen atoms bound to silicon are
20 replaced by —OR-groups.

5. A method as claimed in Claim 4, wherein the ratio of the number of molecules of amino-alkylsilane derivative to the number of molecules of the hydrocarbonsilane derivative is 1:3.

6. A method as claimed in any preceding Claim, wherein the substrate is a flexible foil.

7. A method of manufacturing a semiconductor device, substantially as herein described with reference to the accompanying
30 drawing.

8. A semiconductor device manufactured by the method as claimed in any preceding Claim.

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