

LIQUID RESIN COMPOSITION, SEMICONDUCTOR CHIP WITH AN ADHESIVE
LAYER, METHOD OF PRODUCING SUCH MATERIALS, AND
SEMICONDUCTOR DEVICES

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BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a liquid resin composition, a semiconductor chip with an adhesive layer, a method of producing such materials, and semiconductor devices.

10 Description of Related Art

In recent years, electronic devices such as mobile phones, personal digital assistant (PDA), digital video cameras (DVCs), have been remarkably enhanced in functions and reduced in both weight and size. As a result, there are strong driving force towards miniaturization and function enhancement on semiconductor devices.

15 Semiconductor devices functions could be enhanced, by making either multiple applications of different functions or multiple applications of same functions in a single semiconductor chip. The weight and the size of semiconductor devices, on the other hand, could be reduced by targeting at semiconductor devices that with semiconductor chips of almost equal in size. This, therefore, will normally leads to reduction in
20 semiconductor chips thickness, as well as the distance between the semiconductor chips and wire-bond pads on carrier such as metal or organic substrate.

With continuous reduction in semiconductor chip thickness and the distance between semiconductor chip and wire bond pads on substrate, process involves dispensing of liquid resin component at room temperature followed by curing at
25 elevated temperature may worsen contamination issues which include overflow of liquid resin component during die attach process onto the top of semiconductor chips or wire-bond pads, as well as kerf creep phenomenon (creeping of resin component of die

attach adhesive by capillary effect to the semiconductor chips top surfaces)

To tackle those issues, a method in which a die attach film is pre-applied on carrier, instead of through liquid dispensing, where a semiconductor chip is then bonded with heat; a method in which a die attach film is pre-applied on the backside of a semiconductor wafer, which is then attached to a dicing sheet and diced into individual semiconductor chips, where the semiconductor chip is then bonded with heat onto carrier; and a method in which a semiconductor wafer is attached to a die attach film having dicing sheet function and is diced into individual semiconductor chips, where the semiconductor chip is then bonded with heat onto carrier (see JP-A-2002-294177 and JP-A-2003-347321, for example) have been proposed.

To increase the number of semiconductor chips stacked layers and to reduce thickness of semiconductor devices, both the semiconductor chip and the carrier thickness have to be reduced. When using thin carrier, semiconductor devices may suffer warpage due to the difference in coefficient of thermal expansion of the components in it. As low dielectric constant insulating film with low mechanical strength is used as interlayer dielectric material, to increase device operation speed by reducing the transmission delay due to decrease in signal transmission rate that caused by an inter-wire parasitic capacitance, large semiconductor device warpage may lead to damage of the insulating film.

Since warpage of semiconductor device is due to the difference in coefficient of thermal expansion of various components in it, a die attach film with low bond temperature is therefore desirable. To achieve that, either thermoplastic components with low glass transition temperature or high amount of low-molecular-weight components are required in the liquid resin composition. This may, however, lead to the adhesive layer to exhibit tackiness at room temperature.

Die attach film that is tacky at room temperature may lead to pick-up failure of semiconductor chip from dicing sheet. Tacky die attach film may also lead to pick-up

failure of semiconductor chip from the stage, where the semiconductor chip is temporarily placed after being picked up from dicing sheet. (see JP-A-6-132327, JP-A-7-201897, and JP-A-2000-252303, for example).

Materials, which are tack free at room temperature, have been proposed as encapsulating materials for wafer-level chip-size packages (see JP-A-2000-174044, JP-A-2001-93940, and JP-A-2003-212964, for example).

In these inventions, a liquid resin composition is applied onto a semiconductor wafer with bumps (e.g., solder bumps) and is then heated so that the liquid resin composition is tack free at room temperature, and the semiconductor wafer is then diced into individual semiconductor chips. Since the semiconductor chip is encapsulated and soldered at the same time in the subsequent process, it is necessary to bond the semiconductor chip at a temperature of equal to or higher than the melting point of the solder.

As described above, an adhesive layer that enables a semiconductor chip to be bonded to carrier at low temperature and is tack free at room temperature has not been proposed.

SUMMARY OF THE INVENTION

The present invention is to provide a liquid resin composition capable of producing an adhesive layer, which is tack free at room temperature, that enables a semiconductor chip to be bonded to carrier at low temperature; a semiconductor chip with an adhesive layer formed using the liquid resin composition; a method of producing such a material; and a highly reliable semiconductor device formed using the semiconductor chip with the adhesive layer.

The above objectives are achieved as below.

(1) A liquid resin composition comprising (A) an epoxy resin component and (B) a curing agent component, where the epoxy resin component (A) being liquid at room

- temperature, and the curing agent component (B) including (B1) a compound which has phenolic hydroxyl group(s) and is dissolvable in the epoxy resin component (A), and (B2) a compound which has phenolic hydroxyl group(s) and is not dissolvable in the epoxy resin component (A).
- 5 (2) The liquid resin composition according to (1), which is tack free at room temperature, but tacky at temperature of equal to or higher than the first temperature, after being heated at a first temperature.
- (3) The liquid resin composition according to (1) or (2), wherein both the compound (B1) and the compound (B2) have two or more phenolic hydroxyl groups in the
10 molecule.
- (4) A semiconductor wafer or a semiconductor chip with an adhesive layer, where the adhesive layer is pre-applied and formed onto the semiconductor wafer or the semiconductor chip by using the liquid resin composition according to any one of (1) to (3), followed by heating the semiconductor wafer or the semiconductor chip at the first
15 temperature.
- (5) A semiconductor chip with an adhesive layer produced by dicing the semiconductor wafer with an adhesive layer according to (4).
- (6) A semiconductor device comprising the semiconductor chip with an adhesive layer according to (4) or (5) and a carrier, where the semiconductor chip is bonded.
- 20 (7) A method of producing a semiconductor wafer with an adhesive layer, by applying the liquid resin composition, according to any one of (1) to (3), to one side of a semiconductor wafer; a method of forming an adhesive layer, by heating at a first temperature, which is tack free at room temperature but tacky at temperature of equal to or higher than the first temperature; a method of laminating the semiconductor wafer
25 with the adhesive layer to a dicing sheet; a method of producing the semiconductor chip with the adhesive layer, by dicing the semiconductor wafer with the adhesive layer into individual semiconductor chips with the adhesive layer.

(8) A method of producing a semiconductor device, by bonding the semiconductor chip with the adhesive layer, according to (7), to carrier with heat & pressure.

According to the present invention, a liquid resin composition capable of producing an adhesive layer, which is tack free at room temperature, that enables a semiconductor chip to be bonded to a carrier at low temperature; a semiconductor chip with an adhesive layer formed using the liquid resin composition; a method of producing such a material; and highly reliable semiconductor device formed using the semiconductor chip with the adhesive layer can be provided.

10 DETAILED DESCRIPTION OF THE INVENTION AND PREFERRED EMBODIMENTS

The present invention provides a liquid resin composition comprising (A) an epoxy resin component and (B) a curing agent component, where the epoxy resin component (A) being liquid at room temperature, and the curing agent component (B), which includes (B1), a compound which contains phenolic hydroxyl group(s) and is dissolvable in the epoxy resin component (A); and (B2), a compound which contains phenolic hydroxyl group(s) and is not dissolvable in the epoxy resin component (A); the liquid resin composition capable of producing an adhesive layer, which is tack free at room temperature, that enables a semiconductor chip to be bonded to carrier at low temperature; a semiconductor chip with an adhesive layer formed using the liquid resin composition; a method of producing such a material; and a highly reliable semiconductor device formed using the semiconductor chip with the adhesive layer.

The epoxy resin component (A) according to the present invention refers to epoxy resins used in the liquid resin composition. When only single type of epoxy resin is used in the liquid resin composition, the epoxy resin component (A) refers to the single type of epoxy resin. When two or more types of epoxy resins are used in the liquid resin composition, the epoxy resin component (A) refers to a mixture of the two

or more types of epoxy resins. The epoxy resin component (A) is liquid at room temperature. Specifically, when only single type of epoxy resin is used as the epoxy resin component (A), the single type of epoxy resin is liquid at room temperature, and when two or more types of epoxy resins are used as the epoxy resin component (A), the mixture of the two or more types of epoxy resins is liquid at room temperature. Therefore, when two or more types of epoxy resins are used as the epoxy resin component (A), the epoxy resin component (A) may be either a combination of epoxy resins which are liquid at room temperature, or a combination of liquid and solid epoxy resins at room temperature, which gives liquid mixture at room temperature. When two or more epoxy resins types of are used in the epoxy resin component (A), the liquid resin composition need not be produced by having all the epoxy resins to be pre-mixed before mixing the resulting mixture with other components. The expression of "the epoxy resin component (A) is liquid at room temperature" used in the present invention means the mixture of all of the epoxy resins used in the epoxy resin component (A) is liquid at room temperature.

The epoxy resin used in the epoxy resin component (A) is a compound having glycidyl group(s). It is preferable that the epoxy resin used in the epoxy resin component (A) has two or more glycidyl groups in the molecule for high reactivity. Since the liquid resin composition according to the present invention is used for semiconductor applications, it is preferable that the epoxy resin contains small amount of ionic impurities. It is preferable that an epoxy resin with aromatic glycidyl ether group(s) is used to achieve high reactivity when a compound with phenolic hydroxyl group(s) is used as hardener.

Examples of the epoxy resins which are used in the epoxy resin component (A) and are liquid at room temperature include, but are not limited to, epoxidized bisphenol compounds such as bisphenol A or bisphenol F, which is liquid at room temperature, epoxidized aminophenol compounds, which is liquid at room temperature, an aromatic

glycidyl ether compound with alkylene oxide in the molecule, which is liquid at room temperature, and the like. Examples of the epoxy resins which are used in the epoxy resin component (A) and are solid at room temperature include, but are not limited to, a phenol novolac epoxy resin, a cresol novolac epoxy resin, a phenol aralkyl epoxy resin, a biphenyl aralkyl epoxy resin, a dicyclopentadiene epoxy resin, an epoxy resin with a triphenylmethine, an epoxy resin with a naphthalene, an epoxy resin with an anthracene, and the like.

In the present invention, mono-functional epoxy compound which is liquid at room temperature (e.g., phenyl glycidyl ether and cresyl glycidyl ether) may also be used in the epoxy resin component (A). The mono-functional epoxy compound which is liquid at room temperature is suitably used to dilute the epoxy resin which is solid at room temperature for a liquid mixture at room temperature.

The curing agent component (B) according to the present invention is a curing agent for the epoxy resin component (A). The curing agent component (B) includes the compound (B1) which has phenolic hydroxyl group(s) and is dissolvable in the epoxy resin component (A), and the compound (B2) which has phenolic hydroxyl group(s) and is not dissolvable in the epoxy resin component (A). Specifically, the curing agent component (B) comprises both the compound (B1) and the compound (B2).

The compound (B) is considered as dissolvable in the epoxy resin component (A), (the compound (B1)), if transparent mixture is observed with the following mixing process. The mixing process involves charging 90g of the epoxy resin component (A) and 10g of the compound (B) into 300cc separable flask, which is then heated in an oil bath. The mixture in the separable flask is stirred and heated at 145 to 155°C. After being stirred for 30 minutes at 145 to 155°C, the mixture is then cooled down and staged for 72 hours at room temperature. The compound (B) is, otherwise, considered as not dissolvable in the epoxy resin component (A), (the compound (B2)).

The softening point or the melting point of the compound (B1) is normally 200°C or below. Examples of the compound (B1) include bisphenols such as bisphenol A, bisphenol F, or derivatives thereof, a compound obtained by reacting a phenol (e.g., phenol novolac or cresol novolac) or its derivative with formaldehyde, a
5 compound obtained by reacting a phenol or its derivative with benzaldehyde, a phenol aralkyl phenol resin, a biphenyl aralkyl phenol resin, a compound having a naphthalene, a compound which has an anthracene and two or more phenolic hydroxyl groups (including a hydroxyl group directly bonded to an aromatic ring such as a naphthol hydroxyl group) in the molecule, and the like. The compound (B2) is normally a
10 highly crystalline compound having a melting point exceeding 200°C. Examples of the compound (B2) include biphenol, triphenylethane, and the like.

The compound (B1) which is dissolvable in the epoxy resin component (A) and the compound (B2) which is not dissolvable in the epoxy resin component (A) are used in combination as the curing agent component (B) so that the liquid resin composition,
15 according to the present invention, forms an adhesive layer that is tack free at room temperature, but is tacky at temperature of equal to or higher than the first temperature, after being heated at the first temperature.

When using only the compound (B1), the resulting adhesive layer is tack free at a temperature of equal to or higher than the first temperature after being heated at the
20 first temperature. When using only the compound (B2), the resulting adhesive layer is either tacky at room temperature or tack free at temperature of equal to or higher than the first temperature after being heated at the first temperature.

Specifically, when the liquid resin composition according to the present invention is heated at the first temperature, the epoxy resin component (A) and the
25 compound (B1) react entirely or partially so that the molecular weight of the liquid resin composition increases. Since the curing reaction is partially completed, the liquid resin composition after being heated at the first temperature is tack free at room

temperature, but tacky at temperature of equal to or higher than the first temperature. Subsequently, when heated at the second temperature, unreacted glycidyl groups, the compound (B2), and unreacted compound (B1) react so that the adhesive layer is completely cured, whereby the target products can be permanently bonded.

5 It is preferable that the content of a compound with two or more phenolic hydroxyl groups in the molecule is 80 wt% or more of the compound (B1). If the content of a compound with two or more phenolic hydroxyl groups in the molecule is less than 80 wt% of the compound (B1), a product obtained by heating the adhesive layer may not be tacky enough at the second temperature. The compound (B1) and the
10 compound (B2) are preferably used in a weight ratio of 1:5 to 5:1, and more preferably 1:4 to 4:1.

 The first temperature refers to a temperature at which the liquid resin composition in the form of adhesive layer is heated to become tack free at room temperature, but tacky at the temperature of equal to or higher than the first temperature.
15 The first temperature is preferably 60 to 200°C, more preferably 80 to 150°C, and more preferably 100 to 120°C. The second temperature refers to a temperature at which the adhesive layer is converted to almost a full cured material after being heated at the first temperature. The second temperature is higher than the first temperature. The second temperature is preferably 200°C or below.

20 It is preferable that the liquid resin composition according to the present invention includes a reaction catalyst for a glycidyl group and a phenolic hydroxyl group. A compound known as a reaction catalyst for a glycidyl group and a phenolic hydroxyl group may be used without specific limitations. Examples of such a catalyst include phosphorous catalysts such as salts of triphenyl phosphine and tetraphenyl
25 phosphine, and nitrogen catalysts such as diazabicycloundecene, dicyandiamide, hydrazine derivatives, and imidazoles. It is preferable that a reaction catalyst with a low melting point such as phosphorus catalyst, tertiary amine catalyst, or imidazole catalyst,

and a reaction catalyst with a high melting point such as dicyandiamide or imidazole catalyst are responsible for reaction at both the first temperature and the second temperature respectively. The imidazole catalyst with a high melting point preferably has a melting point of 180°C or above. Examples of such imidazole catalysts include
5 an addition product of 2-methylimidazole and 2,4-diamino-6-vinyltriazine,
2-phenyl-4-methyl-hydroxymethylimidazole, and
2-phenyl-4,5-dihydroxymethylimidazole.

The liquid resin composition according to the present invention may include filler. Examples of the fillers include, metal powders such as silver powder, gold powder,
10 copper powder, aluminum powder, nickel powder, and palladium powder and ceramic
powders such as silica powder, alumina powder, titania powder, aluminum nitride
powder, and boron nitride powder, and polymer powders such as polyethylene powder,
polyacrylate powder, polytetrafluoroethylene powder, polyamide powder, polyurethane
powder, polysiloxane powder, and polysilsesquioxane powder. Either to prevent
15 clogging in a nozzle while applying the liquid resin composition using dispense nozzle,
or to ensure an even and smooth printed surface while printing the liquid resin
composition using squeegee or blade, the average filler size is preferably 15 μm or
below, and more preferably 10 μm or below. It is preferable to reduce the number of
large particles. Therefore, it is preferable to sieve the filler through a filter with
20 opening size of 30 μm . It is preferable that the filler contains only small amount of
ionic impurities (e.g., sodium and chlorine).

It is preferable that silver powder is used as filler when electrical conductivity
and/or thermal conductivity are required. As a silver powder commercially available
for electronic materials, a reduced silver powder, an atomized silver powder, and the
25 like can be given. The average filler size is preferably 1 to 15 μm . Average filler size
of less than 1 μm will lead to high viscosity and poor process-ability. Average filler
size of above 15 μm may lead to clogged nozzle while dispensing and uneven printed

surface in printing application. It is preferable that silver powder for semiconductor application is used, as silver powder for general application may contain a large amount of ionic impurities. Though flake type is preferred, spherical shaped filler could be also used together with flake filler, which are easily available for semiconductor application. The filler content in liquid resin composition is normally 70 to 95 wt%. Below 70 wt% of silver gives less than desired electrical conductivity, while above 95 wt% of silver will lead to high viscosity of the composition that makes process-ability poor.

The liquid resin composition according to the present invention may further include a coupling agent. Examples of the coupling agent include, but are not limited to, epoxysilane coupling agents such as 3-glycidoxypropyltrimethoxysilane and 3-glycidoxypropyltriethoxysilane, vinylsilane coupling agents such as vinyltrimethoxysilane and vinyltriethoxysilane, (meth)acryloxysilane coupling agents such as 3-methacryloxypropyltrimethoxysilane, 3-methacryloxypropyltriethoxysilane, and 3-acryloxypropyltriethoxysilane, aminosilane coupling agents such as N-phenyl-3-aminopropyltrimethoxysilane and 3-aminopropyltrimethoxysilane, and mercaptosilane coupling agents such as 3-mercaptopropyltrimethoxysilane and 3-mercaptopropyltriethoxysilane. It is preferable to use a sulfide silane coupling agent such as bis(3-(triethoxysilyl)propyl)disulfide or bis(3-(triethoxysilyl)propyl)tetrasulfide.

The liquid resin composition according to the present invention may optionally include additives such as low stress additives, defoaming agents, leveling agents, and surfactant.

The viscosity (25°C) of the liquid resin composition according to the present invention is 10 to 100 Pa·s, preferably 15 to 80 Pa·s, more preferably 20 to 60 Pa·s. The viscosity of the liquid resin composition is measured at 25°C, at 5.0 rpm, using a Brookfield viscometer (CP51 cone).

The liquid resin composition according to the present invention is produced by pre-mixing the components, kneading the mixture using a three-roller mill, and degassing the resulting product under vacuum, for example.

The semiconductor device according to the present invention may be produced using a known method. For example, the liquid resin composition is applied to a semiconductor chip or a semiconductor wafer and then heated to obtain a semiconductor chip (or semiconductor wafer) with the adhesive layer. The semiconductor chip with the adhesive layer is then bonded to carrier with heat and pressure and subjected to curing. After wire-bonding process, the semiconductor chip is then encapsulated using epoxy molding compound through transfer molding process to form a semiconductor device. The semiconductor device according to the present invention includes integrated circuits (IC) and large scale integration (LSI), diode, transistor, and the like.

A method of producing a semiconductor chip with an adhesive layer and a method of producing a semiconductor device using the liquid resin composition according to the present invention are described below.

< Process of applying liquid resin component >

The liquid resin composition according to the present invention is applied to the backside of a semiconductor wafer (i.e., opposite to the circuit-formation side, which has wire-bond pads). A semiconductor wafer on which circuits are not formed may also be used. The backside of the semiconductor wafer is normally grinded before dicing to control the thickness of the semiconductor wafer. The liquid resin composition is then applied onto the backside surface of the semiconductor wafer. The liquid resin composition may be applied using a known method such as screen printing, stencil printing, spin coating, and the like. For example, a semiconductor wafer with back grind tape (i.e., a tape attached to the circuit-formation side of semiconductor wafer to protect it during back grind process) is placed in a printer such that the backside of the semiconductor wafer facing upward, and the liquid resin composition is

then applied onto the surface via a screen mask or a stencil mask using a metal or polymer blade, so that the thickness of the liquid resin composition is uniform.

Alternatively, a semiconductor wafer is placed onto a spin coater, with the backside of semiconductor wafer facing upward, and the liquid resin composition is applied at the center of the semiconductor wafer. A thin and uniform layer of the liquid resin composition is then formed by centrifugal force of high speed spinning. The liquid resin composition may also be applied to a stationary wafer through one or more moving nozzles, or to a rotating wafer through a moving nozzle.

It is preferable to use a back grind tape, which exhibits excellent heat resistance sufficient to withstand heating process in the later processes. It is also preferable to use a back grind tape that has support function (i.e., a function of suppressing warpage and deformation of back grinded semiconductor wafer with reduced thickness) for semiconductor wafer.

<Adhesive layer formation process>

The semiconductor wafer with the liquid resin composition is heated at the first temperature so that the liquid resin composition turns into the adhesive layer which is tack free at room temperature, but tacky at temperature of equal to or higher than the first temperature. The heating process of semiconductor wafer at the first temperature may be carried out on hot plates, in a convention oven, in a re-flow oven, and the like. The heating temperature (first temperature) is preferable 60 to 200°C, more preferably 80 to 150°C, and more preferably 100 to 120°C. Warpage of the semiconductor wafer reduces, when heated at lower temperature (first temperature). The heating time is preferably one hour or below, above which productivity may be affected and warpage of semiconductor wafer may increase. The heating conditions are preferably 150°C or below for 30 minutes or below, and more preferably 120°C or below for 30 minutes or below.

The thickness of the adhesive layer, after heating at the first temperature, is

preferably 200 μm or below, more preferably 5 to 50 μm . The thickness of the adhesive layer may be controlled by adjusting the process parameters and the viscosity of the liquid resin composition. For example, a relatively thin adhesive layer could be achieved by using a liquid resin composition having a low viscosity. This is in contrast to die attach film, which is necessary to provide a film in a desired thickness prior to die attach process.

When the adhesive layer formed after heating at first temperature contains a large amount of volatile components, the adhesive layer may be tacky at room temperature, the pick-up capability may be poor, and voids may be formed when the semiconductor chip with is bonded to carrier. Therefore, it is preferable that the adhesive layer, obtained by applying the liquid resin composition onto the backside of semiconductor wafer, at thickness of 50 μm , is to have volatile content of 1 wt% or less after being heated at first temperature of 110°C for 30 minutes. The thickness of the liquid resin composition formed is measured using a non-contact thickness meter. The volatile content is defined as follows. Specifically, a semiconductor wafer on which the liquid resin composition is formed at thickness of 50 $\pm$ 5 μm , is heated in a oven controlled at 110 $\pm$ 5°C for 30 $\pm$ 5 minutes. After retrieving the semiconductor wafer from the oven, 5 to 30 mg of the adhesive layer is sampled using a spatula before the semiconductor wafer is cooled down and solidified. A weight loss curve is determined by thermogravimetric analysis (TGA) by heating the sample from room temperature to 300°C at a rate of 10°C/min. The volatile content refers to the weight loss rate at 200°C in the weight loss curve. The weight loss rate is preferably 0.5 wt% or less, and more preferably 0.1 wt% or less.

The adhesive layer formed should be tack free at room temperature. The tackiness may lead to handling issue during laminating semiconductor wafer with the adhesive layer on dicing sheet in <laminating process>, as well as pick-up failure of semiconductor chip from dicing sheet in <dicing process>.

The adhesive layer formed on semiconductor wafer is preferably to have thickness accuracy of $\pm 5 \mu\text{m}$ or less, more preferably $\pm 3 \mu\text{m}$ or less. The thickness accuracy, which is measured by a laser roughness meter, means the difference between the mean height and the highest/lowest point. Beyond $\pm 5 \mu\text{m}$, a stable bond line
5 thickness cannot be achieved.

<Laminating process and dicing process>

The semiconductor wafer with adhesive layer formed is then attached to a dicing sheet <laminating process>, and is diced into individual semiconductor chips with adhesive layer attached <dicing process>. A commercially available dicing sheet may be
10 used. The dicing sheet is attached and fixed to a wafer ring. The semiconductor wafer is diced into individual semiconductor chips with the adhesive layer using dicing saw machine. When the flatness and smoothness of the adhesive layer is poor, air may be trapped in between the adhesive layer and the dicing sheet. In this case, a chipping phenomenon (i.e., the edge of the semiconductor chip chipped-off), a chip crack
15 phenomenon (i.e., cracks found at the edge of the semiconductor chip), a chip fly phenomenon (i.e., the semiconductor chip dropped-off from the dicing sheet during dicing), and the like may occur, which affect the production yield of the semiconductor chips with adhesive layer attached.

<Method of producing semiconductor devices>

20 The diced semiconductor chips with adhesive layer, which attached to dicing sheet, are then placed onto a die bonder to perform pick and place process. The semiconductor chips are then picked up from the dicing sheet <pick-up process> and bonded onto carrier with heat and pressure <bonding process>. The semiconductor chip with the adhesive layer attached must be removed from the dicing sheet at the interface
25 between the adhesive layer of semiconductor chip and the dicing sheet during pickup. If the adhesive layer is tacky at room temperature, the semiconductor chip may fail to be picked up, or the semiconductor chip may be displaced during pickup and may not

subsequently be correctly positioned, or the adhesive layer may partially remain on the dicing sheet, for example. The dicing sheet is attached and fixed on the wafer ring during pickup.

The carrier, on which the semiconductor chip with adhesive layer according to the present invention is bonded, refers to a lead frame, an organic substrate, and the like. When stacking the semiconductor chips, the carrier refers to a mother semiconductor chip bonded on a lead frame, an organic substrate, and the like. The semiconductor chip is bonded at a temperature of equal to or higher than the first temperature. The bond temperature of the semiconductor chip is preferably 200°C or below, more preferably 175°C or below. If the semiconductor chip is bonded at a higher temperature, severe warpage may occur. The load applied when bonding the semiconductor chip differs depending on the type of the die bonder, e.g. a lead-on-chip (LOC) bonder allows bond force of up to 20 N per semiconductor chip. The bond force applied when bonding the semiconductor chip is normally about 3 to 5 N. The bond force is preferably 5N or below, more preferably 1 to 4 N, particularly when a thin semiconductor chip or a semiconductor chip with low mechanical strength is used. The bond time (i.e., the duration in which the semiconductor chip is being bonded onto the carrier) is preferably 10 seconds or less, more preferably 3 seconds or less, more preferably 1 second or less, from the viewpoint of productivity.

The adhesion strength (25°C) of the adhesive layer after bonding but before curing at second temperature, is preferably 1 N or above. The adhesion strength (25°C) of the adhesive layer after bonding but before curing at second temperature is measured as follows. Specifically, semiconductor chips (6×6 mm²) with adhesive layer are picked up using die bonder. The semiconductor chips are bonded on QFP lead frame (package size: 14×20 mm, die pad size: 7.5×7.5 mm, copper frame with silver plated die pad, thickness: 0.15 mm), at bond temperature of 165°C, bond force of 1.0 N and bond time of 8 seconds (including ramp up time of 7 seconds to 165°C).

The adhesion strength of the adhesive layer after bonding, before curing at second temperature is then measured using die shear tester (Dage 4000 series). If the adhesion strength (25°C) of the adhesive layer after bonding, before curing at second temperature, is below 1 N, the semiconductor chip may drop-off from the carrier during transportation. The adhesion strength of the adhesive layer is more preferably 10 N and above, more preferably 20 N and above.

The carrier with bonded semiconductor chips is then heated at the second temperature to cure the adhesive layer. The subsequent wire bonding process is without particular limitation on the wire bonding conditions. Considering low carrier warpage, the wire bond temperature is preferably 200°C or below. If the adhesion strength of the adhesive layer is too low at wire bond temperature, either the semiconductor chip may drop-off from carrier, or the ball shear strength or wire-pull strength will be low. The adhesion strength (175°C) of the adhesive layer after second temperature curing is preferably 30 N or above, more preferably 50 N or above, and still more preferably 100 N or above. The adhesion strength (175°C) of the adhesive layer after second temperature curing is measured as follows. Specifically, semiconductor chips (6×6 mm²) with the adhesive layer are picked up from dicing sheet using die bonder. The semiconductor chips are bonded on QFP lead frame (package size: 14×20 mm, die pad size: 7.5×7.5 mm, copper frame with silver plated die pad, thickness: 0.15mm), at bond temperature of 165°C, bond force of 1.0 N, and bond time of 8 seconds (including ramp up time of 7 seconds to 165°C). The adhesive layer is then cured at 175°C for 60 minutes. The adhesion strength of the adhesive layer after curing is then measured using die shear tester (Dage 4000 series).

The wire bonded semiconductor chips are then encapsulated with molding compound using transfer molding process. Molding compounds that prepared by dispersing filler in epoxy resins are normally used. The molding compound, which may be used, is not particularly limited. It is preferable to use molding compound,

which does not contain any antimony compound and brominated compound that are harmful to environment. It is preferable to use molding compound, which contains a biphenyl aralkyl epoxy resin and/or a biphenyl aralkyl phenol resin and does not contain any antimony compound and brominated compound. This is because molding
5 compound, which contains a biphenyl aralkyl epoxy resin and/or a biphenyl aralkyl phenol resin, shows excellent burning resistance (UL test) and excellent reflow crack resistance, even without using any antimony compound and brominated compound.

After molding, post-mold curing is optionally performed. When lead frame is used as carrier, trim and form process, solder plating process, and the like are optionally
10 performed to produce the semiconductor device. When organic substrate is used as carrier, a solder ball attachment process, and the like are optionally performed to produce the semiconductor device.

EXAMPLES

15 Example 1

Diglycidyl bisphenol A synthesized by reaction between bisphenol A and epichlorohydrin (epoxy equivalent: 180, liquid at room temperature, hereinafter referred to as "bis A epoxy") (epoxy resin (A)), cresyl glycidyl ether (epoxy equivalent: 185 hereinafter referred to as "CGE") (epoxy resin (A)), a phenol novolac (hydroxyl
20 equivalent: 104, softening point: 80 to 90°C, hereinafter referred to as "phenol B1") (compound (B1)), 3,3',5,5'-tetramethylbiphenol (manufactured by Honshu Chemical Industry Co., Ltd., hereinafter referred to as "phenol B2") (compound (B2)), 2-phenyl-4,5-dihydroxymethylimidazole (manufactured by Shikoku Chemicals Corporation, hereinafter referred to as "2PHZ") (reaction catalyst),
25 diazabicycloundecene (reaction catalyst), dicyandiamide (reaction catalyst), and a flake silver powder (particle diameter: 1 to 30 μm, average particle diameter: 3 μm, hereinafter referred to as "silver powder") (filler) were mixed in a ratio shown in Table

1. The mixture was kneaded using a triple-roll mixer to obtain a liquid resin composition. The amount of each component is indicated in parts by weight.

The liquid resin composition was degassed at 2 mmHg for 30 minutes using a vacuum chamber. The performance of the liquid resin composition was then evaluated using the following methods.

Evaluation method

<Viscosity> The viscosity of the liquid resin composition was measured at 25°C and 5.0 rpm using a Brookfield viscometer (CP51 cone) after the preparation of the liquid resin composition.

10 <Thickness of adhesive layer> The thickness of an adhesive layer obtained by heating a semiconductor wafer, to which the liquid resin composition was applied, at a first temperature (110°C for 30 minutes) was measured. The thickness of the adhesive layer was calculated from the difference between the thickness of the semiconductor wafer before applying the liquid resin composition and the thickness of the semiconductor wafer plus the thickness of the liquid resin composition after heating the semiconductor wafer.

15 <Volatile content and appearance> The liquid resin composition was applied onto a semiconductor wafer. After heating the semiconductor wafer at 110°C for 30 minutes, part of the adhesive layer was immediately collected using a spatula to obtain a volatile content measurement sample. The volatile content refers to a weight loss ratio measured by thermogravimetric analysis (TGA) when heating the sample (weight: 10 mg) from room temperature to 200°C at a heating rate of 10°C/min. The sample was collected immediately after heating because the adhesive layer may solidify when cooled down to room temperature. The appearance of the adhesive layer was also observed visually. The appearance was evaluated by based on the number of pinholes, voids, and foreign objects. The appearance of the adhesive layer without pinholes, voids, and foreign objects was considered "Good".

<Tackiness> A thin layer of the liquid resin composition was applied onto a glass slide. After heating the glass slide with the liquid resin composition at 110°C for 30 minutes, a Teflon (registered trademark) tape ("NITOFロン" manufactured by Nitto Denko Co., Ltd.) was then used to adhere to the adhesive layer formed. The Teflon tape was then
5 peeled off from the adhesive layer. The results, with no residue of the liquid resin composition found on the Teflon tape was considered "Good".

<Adhesion strength> Semiconductor chips ($6 \times 6 \text{ mm}^2$) with an adhesive layer were picked up from dicing sheet using die bonder. The semiconductor chips were bonded on QFP lead frame (package size: $14 \times 20 \text{ mm}$, die pad size: $7.5 \times 7.5 \text{ mm}$, copper frame
10 with silver plated die pad, thickness: 0.15 mm), at bond temperature of 165°C, bond force of 1.0 N and bond time of 8 seconds (including ramp up time of 7 seconds to 165°C). The adhesion strength of the bonded sample prior to second temperature curing was measured at 25°C. The adhesive layer was then cured at 175°C for 60 minutes. The adhesion strength of the cured sample was then measured at 175°C using
15 die shear tester (Dage 4000 series). The adhesion strength, of the cured sample measured at 175°C, of 30 N or above was considered "Good".

<Moisture sensitivity level test> The liquid resin composition was applied onto the backside of a dummy semiconductor wafer ("Phase 8" manufactured by Hitachi ULSI Systems, Co., Ltd.), where the circuit surface is protected with polyimide resin
20 ("CRC-8800" manufactured by Sumitomo Bakelite Co., Ltd.) with 50 μm thickness. After heating the wafer at 110°C for 30 minutes, the wafer was diced into semiconductor chips ($6 \times 6 \text{ mm}^2$) with adhesive layer. The semiconductor chips were bonded on QFP lead frame (package size: $14 \times 20 \text{ mm}$, die pad size: $7.5 \times 7.5 \text{ mm}$, copper frame with silver plated die pad, thickness: 0.15 mm), at bond temperature of 165°C,
25 bond force of 1.0 N and bond time of 8 seconds (including ramp up time of 7 seconds to 165°C). The adhesive layer was cured at 175°C for 60 minutes. The resulting product was molded with molding compound ("EME-G700" manufactured by

Sumitomo Bakelite Co., Ltd.) at molding condition of 175°C for 90 seconds. The molded packages were then post mold cured for 4 hours to form semiconductor devices. The semiconductor devices were then treated under condition of 60°C, 60% relative humidity for 120 hours, followed by an IR reflow process (260°C, 10 seconds, three times). Delamination of the packages was then checked using Scanning Acoustic Tomograph (through Scan). Delamination area of less than 10% was considered "Good".

Examples 2 to 5

The liquid resin compositions were produced in the same manner as in Example 1 using the components shown in Table 1, and evaluated in the same manner as in Example 1.

In Example 2, a phenol aralkyl resin ("PR-54869" manufactured by Sumitomo Bakelite Co., Ltd., hydroxyl equivalent: 180, hereinafter referred to as "phenol B12") was used as the compound (B1).

Comparative Examples 1 and 2

The liquid resin compositions were produced in the same manner as in Example 1 using the components shown in Table 1, and evaluated in the same manner as in Example 1.

TABLE I

		Example					Comparative Example	
		1	2	3	4	5	1	2
Bis A epoxy		19.7	19.7	14.0	19.7	19.7	19.7	19.7
CGE		2.2	2.2	3.5	2.2	2.2	2.2	2.2
Phenol B11		1.1		0.9	0.5	1.6	2.2	
Phenol B12			1.1					
Phenol B2		1.1	1.1	0.9	1.6	0.5		2.2
2PHZ		0.7	0.7	0.5	0.7	0.7	0.7	0.7
Diazabicycloundecene		0.1	0.1	0.1	0.1	0.1	0.1	0.1
Dicyandiamide		0.2	0.2	0.2	0.2	0.2	0.2	0.2
Silver powder		75.0	75.0	80.0	75.0	75.0	75.0	75.0
Viscosity	Pas	23.0	24.2	25.2	23.4	22.6	20.6	24.8
Thickness of adhesive layer	μm	52	48	53	49	47	51	50
Volatile content	w%	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.5
Appearance	-	Good	Good	Good	Good	Good	Good	Good
Tackiness	-	Good	Good	Good	Good	Good	Good	Bad
Adhesion	25°C	N	130	120	110	160	15	10
	175°C	N	>100	>100	>100	>100	20	>100
Moisture-proof solderability test (separation area)	%	<10	<10	<10	<10	<10	>50	>50
Overall evaluation		Good	Good	Good	Good	Good	Bad	Bad

Obviously, numerous modifications and variations of the present invention are possible in light of the above teachings. It is therefore to be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described herein.

5

What is claimed is:

- (1) A liquid resin composition comprising (A) an epoxy resin component and (B) a curing agent component, where the epoxy resin component (A) being liquid at room temperature, and the curing agent component (B) including (B1) a compound which has phenolic hydroxyl group(s) and is dissolvable in the epoxy resin component (A), and (B2) a compound which has phenolic hydroxyl group(s) and is not dissolvable in the epoxy resin component (A).
- (2) The liquid resin composition according to (1), which is tack free at room temperature, but tacky at temperature of equal to or higher than the first temperature, after being heated at a first temperature.
- (3) The liquid resin composition according to (1) or (2), wherein both the compound (B1) and the compound (B2) have two or more phenolic hydroxyl groups in the molecule.
- (4) A semiconductor wafer or a semiconductor chip with an adhesive layer, where the adhesive layer is pre-applied and formed onto the semiconductor wafer or the semiconductor chip by using the liquid resin composition according to any one of (1) to (3), followed by heating the semiconductor wafer or the semiconductor chip at the first temperature.
- (5) A semiconductor chip with an adhesive layer produced by dicing the semiconductor wafer with an adhesive layer according to (4).
- (6) A semiconductor device comprising the semiconductor chip with an adhesive layer according to (4) or (5) and a carrier, where the semiconductor chip is bonded.
- (7) A method of producing a semiconductor wafer with an adhesive layer, by applying the liquid resin composition, according to any one of (1) to (3), to one side of a semiconductor wafer; a method of forming an adhesive layer, by heating at a first temperature, which is tack free at room temperature but tacky at temperature of equal to

or higher than the first temperature; a method of laminating the semiconductor wafer with the adhesive layer to a dicing sheet; a method of producing the semiconductor chip with the adhesive layer, by dicing the semiconductor wafer with the adhesive layer into individual semiconductor chips with the adhesive layer.

- 5 (8) A method of producing a semiconductor device, by bonding the semiconductor chip with the adhesive layer, according to (7), to carrier with heat & pressure.