

Epoxy Resin Composition

FIELD OF THE INVENTION

5 The present invention relates to an epoxy resin compound for use as encapsulant of semiconductor devices, in particular, an epoxy resin compound free from flame retardant which exhibits flame retardancy and stress resistivity performance.

BACKGROUND OF THE INVENTION

 Thermal shock and moisture are serious threats to delicate electronic devices and its components. Encapsulants are utilized as packaging materials to protect electronic devices and its components from harmful
15 effects of moisture and other contaminants and also from thermal and mechanical stresses. One of the most widely used encapsulants is epoxy resin compound.

 In the recent years, with higher integration of integrated circuits, chips
20 have become larger and surface-mounted have been gradually switched from Dual Inline Package (DIP) to small thin flat packages such as SOP (Small Outline Package), SOJ (Small Outline J-leads), PLCC (Plastic Leaded Chip Carrier) and the like. This is followed by industry trend towards more

condensed packages such as BGA (Ball Grid Array), CSP (Chip Size Package), FC (Flip Chip), non-lead packages and the like.

Apart from miniaturization of the packages and the chips, the electronic
5 industry is moving towards the use of environmentally friendly materials, eliminating the use of toxic materials from its production and packaging processes. The use of halogen-containing and/or antimony-containing encapsulants for sealing electronic devices is slowly becoming obsolete.

10 Similarly, the use of lead-tin (Pb-Sn) solder paste during the surface mounting process will be replaced by other lead-free system. Elimination of lead from solder paste exhibits higher eutectic point or reflow temperature. The typical reflow temperature for a lead-free solder is approximately 260°C. The use of lead-free solder paste in production of electronic devices requires
15 higher soldering temperature. Therefore, the encapsulants used for sealing the electronic devices must be able to protect the electronic devices from exposures to higher level of thermal-mechanical stress during the soldering process.

20 Encapsulants often rely on the use of halogen-based flame retardant and antimony trioxide in its composition for its performance in flame retardancy. Since elimination of the use of halogen-containing and/or antimony-containing encapsulants for sealing electronic devices is also the aim of the electronic industry, encapsulants have to be formulated as such

that they are free from halogen and/or antimony while still able to maintain their performance in protecting electronic devices.

Phosphorus-containing compounds, metal oxides and metal
5 hydroxides have been proposed as flame retardants. Although they are less hazardous, encapsulants containing these compounds generally possess undesirable properties such as high moisture absorption. Another approach to obtain encapsulants which show high performance in flame retardancy is to formulate the encapsulants by using multi aromatic epoxy resin and/or multi
10 aromatic curing agent.

One such approach is disclosed in Japan patent no. 3627736 wherein the epoxy resin compound comprises (A) a phenolic resin containing 30 – 100 wt % of a phenolic resin having novolac structure and containing a biphenyl
15 derivative and/or a naphthalene derivative in its molecule; (B) an epoxy resin containing 30 – 100 wt % of an epoxy resin having novolac structure and containing a biphenyl derivative and/or a naphthalene derivative in its molecule; (C) an inorganic filler and (D) a curing accelerator; as essential components. However, the epoxy resin compound has low curability and is
20 not able to meet product cycle time of integrated circuit (IC) packages, which requires high output.

In view of the above, there is a need for an epoxy resin compound free from flame retardant which exhibits flame retardancy, stress resistivity

performance and exhibits high curability so that it is able meet product cycle time of integrated circuit (IC) packages, which requires high output.

Any discussion of documents, devices, acts or knowledge in this
5 specification is included to explain the context of the invention. It should not be taken as an admission that any of the material forms a part of the prior art base or the common general knowledge in the relevant art in Singapore or elsewhere on or before the priority date of the disclosure and claims herein. All statements as to the date or representation as to the contents of these
10 documents is based on the information available to the applicant and does not constitute any admission as to the correctness of the dates or contents of these documents.

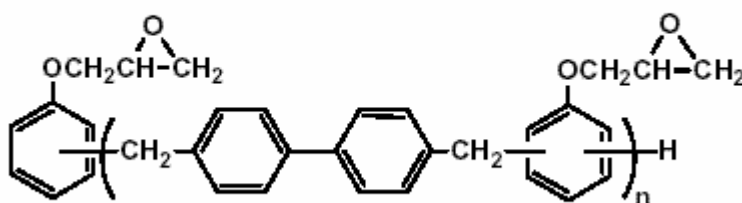
The present invention provides an epoxy resin compound free from
15 flame retardant which exhibits flame retardancy and stress resistivity performance. Further, the present invention provides an epoxy resin compound that is able to meet the reliability requirements of smaller integrated circuit (IC) packages up to 28L SOWB after 30⁰C/60% RH for 192 hours. In addition, the present invention provides an epoxy resin compound
20 with better curability and moldability compared to the prior art.

SUMMARY OF THE INVENTION

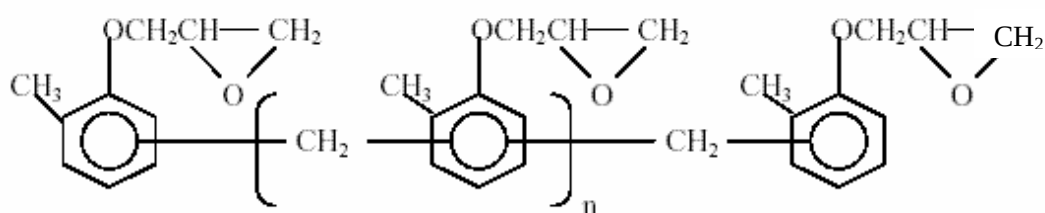
The present invention relates to an epoxy resin compound useful for encapsulating electronic devices comprising the following components:

- 5 (A) an epoxy resin whereby 25 – 75 wt % of the epoxy resin is of multi aromatic type and the balance of the epoxy resin is made up by one or more epoxy resin selected from the group comprising ortho-cresol novolac epoxy resin, epoxy resin of dicyclo-pentadiene type, epoxy resin of biphenyl type, epoxy resin of bisphenol type and a combination
10 thereof;
- (B) a phenolic resin curing agent whereby 25 – 75 wt % of the phenolic resin curing agent is made up by paraxylene-modified phenolic resin and the balance of the phenolic resin curing agent is of multi aromatic type;
- 15 (C) an inorganic filler; and
- (D) a curing accelerator.

The epoxy resin of multi aromatic type is particularly novolac epoxy resin of biphenyl type as represented by the following formula:

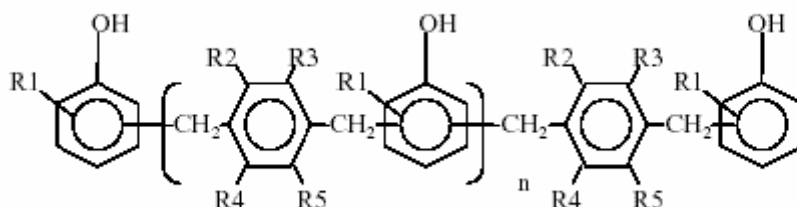


wherein n is an integer of 0 – 20 whereas the balance of the epoxy resin is made up by other types of epoxy resin, particularly ortho-cresol novolac epoxy resin as represented by the following formula:

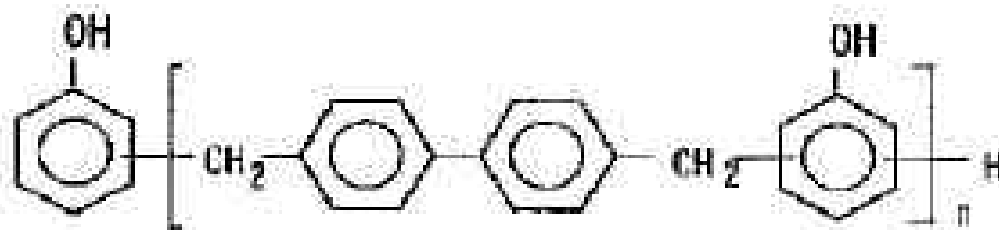


5 wherein n is an integer of 0 – 10.

The paraxylylene-modified phenolic resin is represented by the following formula:



10 wherein n is an integer of 0 – 20 and R1 – R5 are individually alike or different and are atoms or groups selected from hydrogen atom, halogen atom and C₁ to C₄ alkyl groups whereas the phenolic resin curing agent of multi aromatic type is particularly novolac phenolic resin of biphenyl type as represented by the following formula:



5

wherein n is an integer of 0 – 20.

The ratio of the epoxy resin (A) to the phenolic resin curing agent (B) is such that there is 0.8 – 1.2 epoxy group equivalent per hydroxyl group
10 equivalent. The amount of inorganic filler (C) used is 71 to 92 %, preferably 80 to 88 %, by weight of the epoxy resin compound. The amount of curing accelerator (D) used is 0.05 to 1.0 % by weight of the epoxy resin compound.

Other aspects and preferred aspects are disclosed in the specification
15 and / or defined in the appended claims, forming a part of the description of the invention.

Further scope of applicability of the present invention will become apparent from the detailed description given hereinafter. However, it should
20 be understood that the detailed description and specific examples, while indicating preferred embodiments of the invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become apparent to those skilled in the art from this detailed description.

DETAILED DESCRIPTION OF THE INVENTION

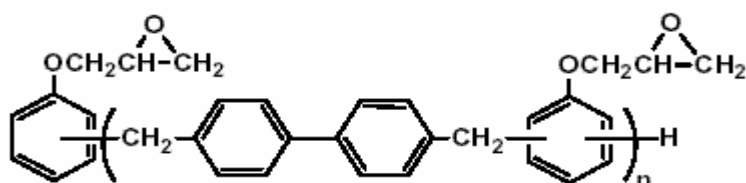
The present invention relates to an epoxy resin compound useful for
5 encapsulating electronic devices comprising the following components:

- (A) an epoxy resin whereby 25 – 75 wt % of the epoxy resin is of multi aromatic type;
- (B) a phenolic resin curing agent whereby 25 – 75 wt % of the phenolic
10 resin curing agent is made up by paraxylene-modified phenolic resin and the balance of the phenolic resin curing agent is of multi aromatic type;
- (C) an inorganic filler; and
- (D) a curing accelerator.

15

The epoxy resin (A) is a mixture of a multi aromatic epoxy resin, particularly novolac epoxy resin of biphenyl type as represented by Formula 1, and other types of epoxy resin. 25 -75 wt % of the mixture is made up by the multi aromatic epoxy resin while other types of epoxy resin made up the
20 balance of the mixture. If the multi aromatic epoxy resin is used at less than 25 wt %, the resultant epoxy resin compound would not show high performance in flame retardancy.

Formula 1



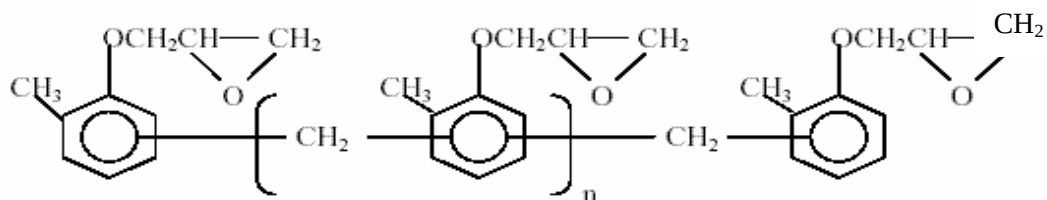
wherein n is an integer of 0 – 20. If n is larger than 20, the resultant epoxy resin compound would show lower fluidity and poorer moldability.

5

Other types of epoxy resin suitable to be used in the mixture are ortho-cresol novolac epoxy resin as represented by Formula 2; epoxy resin of dicyclo-pentadiene type as represented by Formula 3; epoxy resin of biphenyl type as represented by Formula 4 and epoxy resin of bisphenol type as represented by Formula 5.

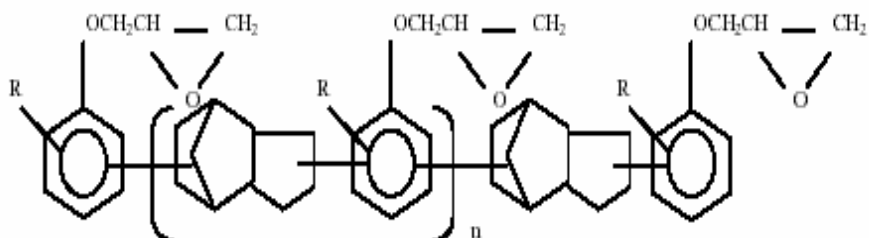
10

Formula 2



wherein n is an integer of 0 – 10.

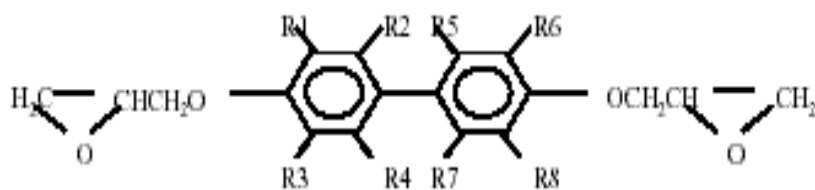
Formula 3



wherein n is an integer of 0 – 20 and R is an atom or a group selected from hydrogen atom, halogen atom and C₁ to C₄ alkyl groups.

5

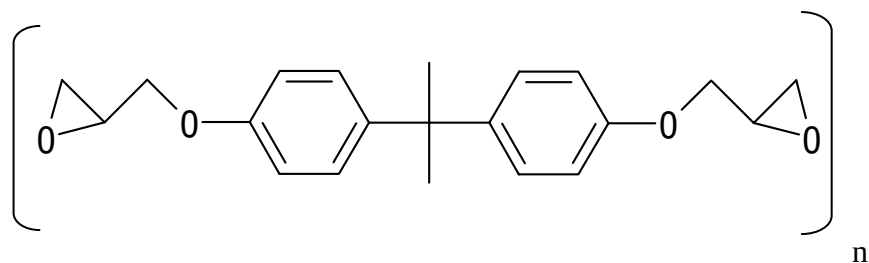
Formula 4



wherein R1 – R8 are individually alike or different and are atoms or groups selected from hydrogen atom, halogen atom and C₁ to C₄ alkyl groups.

10

Formula 5



15

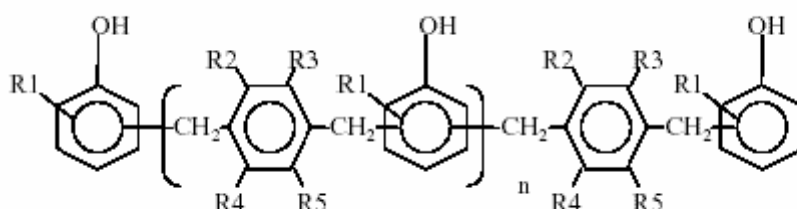
wherein n is an integer of 1 – 20.

Basically, any type of epoxy resin which is able to provide the resultant epoxy resin compound with matching flow properties as provided by ortho-cresol novolac epoxy resin (Formula 2) is suitable to be used in combination with multi aromatic epoxy resin in the mixture.

5

The phenolic resin curing agent (B) is a mixture of a paraxylene-modified phenolic resin as represented by Formula 6 and a multi aromatic phenolic resin. 25 – 75 wt % of the mixture is made up by the paraxylene-modified phenolic resin while multi aromatic phenolic resin made up the balance of the mixture. The paraxylene-modified phenolic resin provides the resultant epoxy resin compound with low modulus at high soldering temperature, thus the resultant epoxy resin compound shows high performance in soldering stress resistance. If the paraxylene-modified phenolic resin is used at less than 25 wt %, the resultant epoxy resin compound would not show high performance in flame retardancy and stress resistivity.

Formula 6

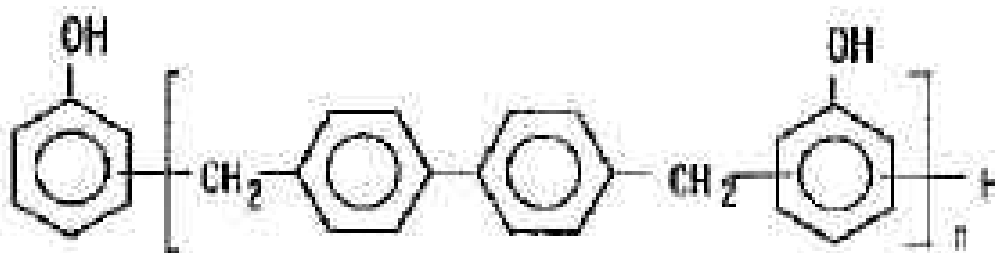


wherein n is an integer of 0 – 20 and R1 – R5 are individually alike or different and are atoms or groups selected from hydrogen atom, halogen atom and C₁ to C₄ alkyl groups.

- 5 The multi aromatic phenolic resin suitable to be used in the mixture is particularly novolac phenolic resin of biphenyl type as represented by Formula 7.

Formula 7

10



15

wherein n is an integer of 0 – 20.

- The blending ratio of the epoxy resin (A) to the phenolic resin curing agent (B), is preferably 0.8 – 1.2 epoxy group equivalent per hydroxyl group equivalent.
- 20

The inorganic filler (C) used in the present composition may be of silica type such as fused silica, spherical silica, crystalline silica, secondary agglomerated silica / grinded secondary agglomerated silica, porous silica /

grinded porous silica; alumina type; clay type; or calcium carbonate. Any of these inorganic fillers may be used alone or in combination of two or more types and may be used in the form of powder or beads.

- 5 Preferably, the inorganic filler used is selected from fused silica powder, spherical silica powder or a mixture thereof. More preferably, the inorganic filler is silica oxide.

10 The amount of inorganic filler used ranges from 71 to 92% by weight of the epoxy resin compound and preferably 80 to 88 % by weight of the epoxy resin compound. If less than 71% by weight of inorganic filler is used, the resultant epoxy resin compound would not show high performance in flame retardancy and/or solder crack resistance. On the other hand, if more than 92% by weight of inorganic filler is used, suitable flow properties for the
15 resultant epoxy resin compound might not be achieved.

 There are no particular limitations on the curing accelerator (D) used as long as it can accelerate reaction between epoxy groups from epoxy resin and hydroxyl groups from phenolic resin. General curing accelerator such as
20 diazabicycloundecene (DBU), triphenylphosphine (TPP), benzyl dimethylamine (BDMA), 2-methylimidazole (2-MZ), latent catalyst having a structure of phosphonium borate and the like can be used either alone or in combination of two or more.

The curing accelerator is preferably used in an amount of 0.05 to 1.0% by weight of the epoxy resin compound. When the amount of curing accelerator used is less than 0.05% by weight, hardness of the resultant epoxy resin compound decreases and its mold release characteristic tends to deteriorate. When the amount of curing accelerator used is more than 1.0% by weight, the reaction between epoxy groups and hydroxyl groups proceeds undesirably fast and fluidity of the resultant epoxy resin compound tends to decrease.

Other components that can be added to the epoxy resin compound, if necessary, are coupling agent such as silane; releasing agent such as natural or synthetic wax; stress relief agent such as silicone oil or rubber; ion catcher and the like.

The epoxy resin compound having the composition of present invention is produced in a known manner by first mixing various components of the epoxy resin composition to form a mixture; then melt-kneading the mixture to form a kneaded product; finally cooling and grounding the kneaded product to form the epoxy resin compound.

20

Various embodiments of the epoxy resin compound having the composition of present invention are shown in examples 1 to 10. Comparative examples 1 to 8 are meant for comparing performance of epoxy resin compounds having the composition of present invention with those having

different composition. The examples are presented in a non-limiting sense to illustrate the present invention while the comparative examples are meant for comparing performance of epoxy resin compound having the composition of present invention with those having different composition.

5

Unless defined otherwise all technical and scientific terms used herein have the same meaning as commonly understood to one of ordinary skill in the art to which this invention belongs.

10

The following examples are put forth so as to provide those of ordinary skill in the art with a complete disclosure and description of how to make and use the present invention, and are not intended to limit the scope of what the inventors regard as their invention nor are they intended to represent that the experiments below are all and only experiments performed. Efforts have been made to ensure accuracy with respect to numbers used (e.g. amounts, temperature, etc.) but some experimental errors and deviations should be accounted for. Unless indicated otherwise, parts are parts by weight, temperature is in degrees Celsius, and pressure is in kgf/cm².

15

20

EXAMPLES

Example 1

An epoxy resin compound was produced by first mixing various components as shown below together to form a mixture; kneading the mixture

at 70 – 100°C by using a biaxial roll to form a kneaded product; finally cooling and grounding the kneaded product to obtain the epoxy resin compound in powder form.

	Parts by weight (%)
Novolac epoxy resin of biphenyl type (Formula 1) Softening point: approximately 60°C, epoxy equivalent: 272 g/eq	3.40
Ortho-cresol novolac epoxy resin (Formula 2) Softening point: approximately 55°C, epoxy equivalent: 196 g/eq	3.38
Novolac phenolic resin of biphenyl type (Formula 7) Softening point: approximately 107°C, epoxy equivalent: 199 g/eq	3.08
Paraxylene-modified phenolic resin (Formula 6) Softening point: approximately 62°C, epoxy equivalent: 174 g/eq	3.10
Fused silica filler (Average size: 20 µm)	85.69
Curing accelerator	0.30
Coupling agent	0.40
Stress relief agent	0.10
Colouring agent	0.30
Releasing agent	0.15
Ion catcher	0.10

- 5 The epoxy resin compound was then subjected to the following evaluation tests:

(1) Spiral Flow Measurement

A certain amount of the epoxy resin compound sufficient to give a cull

thickness of 3 ± 0.3 mm is weighted. A spiral flow mold die as shown in Figure 1 is placed in a molding machine and heated up to 175°C . When the temperature reached $175 \pm 2^{\circ}\text{C}$, a measured amount of the epoxy resin compound is poured into the mold's cavity and its plunger is lowered. The epoxy resin compound is molded for 120 seconds, then the mold's plunger is released, spiral flow length of the molded epoxy resin compound (up to its lustrous tip) is measured after the mold die is taken out from the molding machine.

10 (2) UL-94 Test Method.

UL-94 Test, developed by Underwriters Laboratories, is one of the most widely used flammability test for plastic materials. The test is conducted on a $\frac{1}{2}$ " x 5" test specimen with a range of thickness from $\frac{1}{8}$ " – $\frac{1}{2}$ ". The test specimen is mounted with its long axis vertical and a small blue $\frac{3}{4}$ " high flame is applied to the bottom of the test specimen for 10 seconds. If flaming ceases within 30 seconds, the flame is reapplied for additional 10 seconds. Duration of flaming and glowing is noted as soon as the flaming has ceased. If the test specimen drips particles, these shall be allowed to fall onto a layer of cotton placed beneath the test specimen to determine whether they will ignite the cotton. The test specimen is classified as V-2, V-1 or V-0 standard according to criteria as summarized in Table 1.

Table 1: Summary of criteria for achieving V-2, V-1 or V-0 classification of
UL-94 Test

Criteria	Classification		
	V-2	V-1	V-0
Number of specimens	5	5	5
Number of Ignitions	2	2	2
Maximum flaming time per specimen per flame application (seconds)	30	30	10
Total flaming time, five specimens, 2 ignitions (seconds)	250	250	50
Flaming drips ignite cotton	Yes	No	No
Maximum afterglow time, per specimen (seconds)	60	60	30
Burn to holding clamp	No	No	No

(3) Solder Crack Resistance Test

5 For performance testing at semiconductor packaging level, pelletized epoxy resin compound is molded into various packaging structures, depending on test purposes, before further testing is done on it. For solder crack resistance test, the epoxy resin compound is molded into 28L-SOWB packages and 80L-QFP packages.

10

28L-SOWB packages, encapsulating Silicon Nitride (SiN) coated chips of size 5.0 x 5.0 mm, are molded from the epoxy resin compound at the temperature of 175°C and pressure of 80 – 120 kgf/cm² for 90 seconds. Subsequently, the packages are sent for post mold cure (PMC) at 175°C for 4
15 hours before Moisture Sensitivity Level (MSL) evaluation. These packages are

allowed to stand in an atmosphere of 30°C/60% relative humidity (RH) for 192 hours prior to MSL 3 testing according to Joint Electron Devices Engineering Council (JEDEC) standard.

5 80L-QFP packages, encapsulating Polyimide or Silicon Nitride (SiN) coated chips of size 7.5 x 7.5 mm, are molded from the epoxy resin compound at a temperature of 175°C and pressure of 100 kgf/cm² for 120 seconds. Subsequently, the packages are sent for post mold cure (PMC) at 175°C for 4 hours before Moisture Sensitivity Level (MSL) evaluation. The
10 packages are allowed to stand in an atmosphere of 60°C/60% relative humidity (RH) for 168 hours prior to MSL 2 testing according to JEDEC standard.

 Thereafter, any cracks present at the surfaces of all the
15 abovementioned packages are observed using a microscope. In addition, the packages are also scanned, by using C-mode Scanning Acoustic Microscope (CSAM), for delaminated interfaces with focus on the chip top and the bottom die pad.

20 (4) Autoclave or Pressure Cooker Test

 Pelletized epoxy resin compound is molded into wire bonded and die bonded 16-pin Dual-Inline Packages (16p DIP) under the following condition: preheat temperature of 85°C, molding temperature of 175°C, cure time of 120 seconds, transfer pressure of 100 kgf/cm², clamp pressure of 150 kgf/cm² and

transfer time of 15 seconds. These packages are then subjected to post mold cure (PMC) at 175°C for 4 hours. Thereafter, they are subjected to pressure cooker test at temperature of 175°C. Checks are done at every 20 hours to test for electrical failure.

5

Pressure cooker test is an environmental test that measures device resistance to moisture penetration and effect of galvanic corrosion. During prolong exposure to high temperature and pressure, free ions present within the epoxy resin compound, especially bromide and antimony can corrode a gold ball bond to form, for example, Kirkendall void which in turn leads to higher electrical resistance ($> 1.0 \Omega$). Results are expressed by hours to first electrical failure.

Results of the above-mentioned evaluation tests are shown in Table 3.

15

Examples 2 to 10 and Comparative Examples 1 to 8

According to the components of the epoxy resin compound as shown in Table 2, the procedures in Example 1 were repeated for composition of Examples 2 to 10 and Comparative Examples 1 to 8. Performance evaluation of the epoxy resin compounds for Examples 2 to 10 and Comparative Examples 1 to 8 are conducted according to the test methods as disclosed above and the results of the test are shown in Table 3.

The results clearly showed that epoxy resin compound comprising (A)

a combination of epoxy resin comprising of multi aromatic type epoxy resin and ortho-cresol novolac epoxy resin and (B) a combination of curing agent comprising of multi aromatic type and paraxylene modified phenolic resin curing agent is able to achieve better flame retardancy, reliability, moldability
5 and curability.

The flammability test show that Examples 1 to 10 meet the UL 94 test requirement, V-0 standard compared to Comparative Examples 1 to 8. Further, the results in Examples 1 to 10 show that there is no internal crack
10 and delamination in the packages after JEDEC Moisture Sensitivity Level 3 or 2 solder crack resistance check compared to Comparative Examples 1 to 8.

In addition, it is observed that higher flowability can be achieved by substituting ortho-cresol novolac epoxy resin with epoxy resin of dicyclo-
15 pentadiene type, epoxy resin of biphenyl type or epoxy resin of bisphenol type as illustrated in Examples 2 to 4 respectively. From the result, it shows that besides having better performance in flame retardancy and stress resistivity, Examples 2 to 4 show better flowability as compared to Example 1.

20 In summary, epoxy resin compound produced by using the composition of the present invention shows flame retardancy and no internal crack after solder crack resistance check at JEDEC Moisture Sensitivity Level 3 or 2 as compared to epoxy resin compound of comparative examples 1 to 8.

All references cited herein are hereby incorporated by reference in their entireties, whether previously specifically incorporated or not. As used herein, the terms “a”, “an”, and “any” are each intended to include both the singular and plural forms.

5

Having now fully described this invention, it will be appreciated by those skilled in the art that the same can be performed within a wide range of equivalent parameters, concentrations, and conditions without departing from the spirit and scope of the invention and without undue experimentation.

10

While this invention has been described in connection with specific embodiments thereof, it will be understood that it is capable of further modification(s). This application is intended to cover any variations uses or adaptations of the invention following in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice within the art to which the invention pertains and as may be applied to the essential features hereinbefore set forth.

15

20

Table 2: Epoxy resin compositions

Components	Unit	Examples										Comparative Example							
		1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8
Novolac epoxy resin of biphenyl type (Formula 1) Softening point : 60°C, epoxy group equivalent : 278g/eq	%	3.40	3.64	3.40	3.26	5.31	1.66	4.89	2.79	3.44	3.34	3.95	3.95		4.27		3.54		7.51
Ortho-cresol novolac epoxy resin (Formula 2) Softening point : 55°C, epoxy group equivalent : 200g/eq)	%	3.38				1.77	4.98	4.89	2.79	3.44	3.34	3.95	3.95	6.30	4.27	8.09	3.54	6.59	7.51
Epoxy resin of dicyclopentadiene type (Formula 3) Softening point : 60°C, epoxy group equivalent : 260g/eq)	%		3.64																
Epoxy resin of biphenyl type (Formula 4) Softening/melting point : 102°C, epoxy group equivalent : 198g/eq)	%			3.38															
Epoxy resin of bisphenol type (Formula 5) Softening/melting point : 45°C, epoxy group equivalent : 171g/eq)	%				3.26														
Novolac phenolic resin of biphenyl type (Formula 7) Softening point : 107°C,	%	3.08	2.84	3.08	3.22	2.94	3.16	4.44	2.53	1.52	4.72		2.63	3.33					6.82

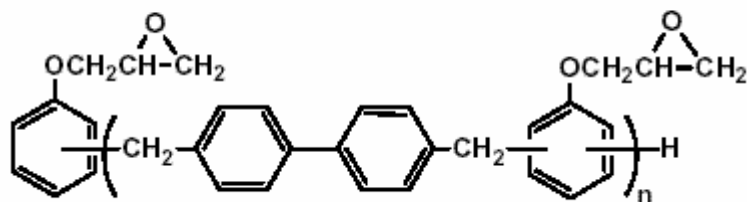
Components	Unit	Examples										Comparative Example							
		1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8
epoxy group equivalent : 199g/eq)																			
Paraxylene-modified phenolic resin (Formula 6) Softening/melting point : 62°C, hydroxyl group equivalent : 174g/eq.)	%	3.10	2.84	3.10	3.22	2.94	3.16	4.44	2.53	4.56	1.57	2.53		3.33			5.88	6.37	6.82
Novolac phenolic resin (Formula 8) Softening/melting point: 81°C, hydroxyl group equivalent: 104g/eq)	%											2.53	2.63		4.42	4.87			
Fused silica filler (Average size: 20 µm)	%	85.69	85.69	85.69	85.69	85.69	85.69	79.99	88.01	85.69	85.68	85.69	85.69	85.69	85.69	85.69	85.69	85.69	69.99
Curing accelerator	%	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Coupling agent	%	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Stress relief agent	%	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Colouring agent	%	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Releasing agent	%	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Ion catcher	%	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Total	%	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Table 3: Results of the evaluation tests

Components	Unit	Examples										Comparative Example							
		1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8
Spiral flow	cm	70	83	95	91	76	80	89	61	65	74	71	63	58	64	50	68	42	96
UL-94 (thickness: 3.2 mm)	-	V-0	V-0	V-0	V-0	V-0	V-0	V-0	V-0	V-0	V-0	V-1	V-1	V-1	V-1	V-1	V-1	V-1	V-1
Soldering crack resistance test (28L-SOWB, after 30°C/60% RH for 192 hours)																			
No. of cracked devices /Total no. of tested devices	No.	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	1/12	0/12	5/12	6/12	9/12	3/12	7/12	12/12
Delamination Check - Die Top		0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	3/12	2/12	7/12	6/12	8/12	4/12	6/12	12/12
- Bottom Pad		0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	6/12	7/12	8/12	5/12	7/12	12/12
Soldering crack resistance test (80L-QFP, after 60°C/60% RH for 168 hours)																			
No. of cracked devices / Total no. of tested devices	No.	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	2/12	2/12	6/12	7/12	10/12	4/12	9/12	12/12
Delamination Check - Die Top		0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	4/12	2/12	5/12	7/12	10/12	5/12	8/12	12/12
- Bottom Pad		0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	3/12	4/12	9/12	2/12	6/12	12/12
Pressure cooker test at 175°C (hour to 1 st electrical failure)	Hrs	>1000																	

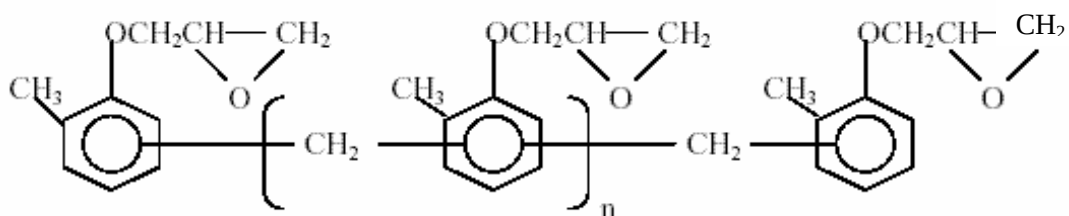
Claims

1. An epoxy resin compound useful for encapsulating electronic devices comprising the following components:
 - 5 A) an epoxy resin whereby 25 – 75 wt % of the epoxy resin is of multi aromatic type and the balance of the epoxy resin is made up by one or more epoxy resin selected from the group comprising ortho-cresol novolac epoxy resin, epoxy resin of dicyclo-pentadiene type, epoxy resin of biphenyl type, epoxy
10 resin of bisphenol type and a combination thereof;
 - B) a phenolic resin curing agent whereby 25 – 75 wt % of the phenolic resin curing agent is made up by paraxylene-modified phenolic resin and the balance of the phenolic resin curing agent is of multi aromatic type;
 - 15 C) an inorganic filler; and
 - D) a curing accelerator.
2. An epoxy resin compound according to claim 1 wherein the epoxy resin of multi aromatic type is novolac epoxy resin of biphenyl type as represented
20 by the following formula:



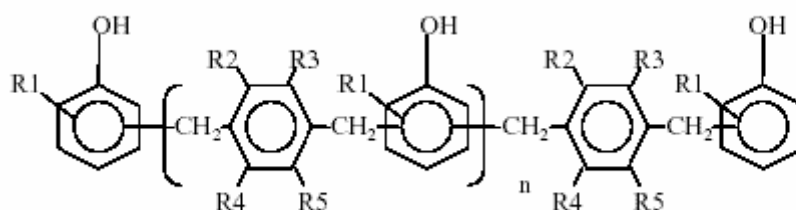
wherein n is an integer of 0 – 20.

3. An epoxy resin compound according to claim 1 or 2 wherein the
5 balance of the epoxy resin is made up by ortho-cresol novolac epoxy resin as represented by the following formula:



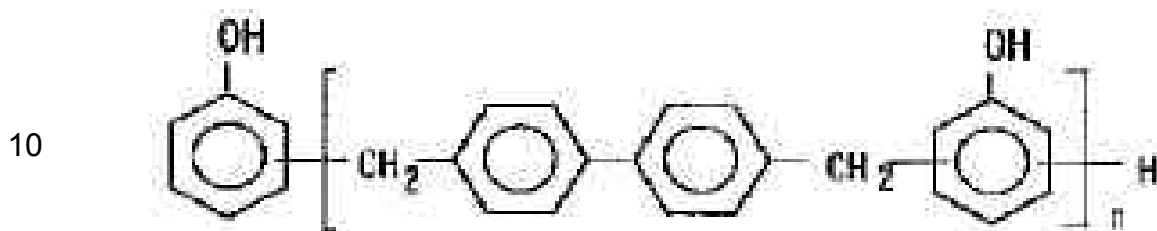
wherein n is an integer of 0 – 10.

- 10 4. An epoxy resin compound according to claim 1 wherein the paraxylene-modified phenolic resin is represented by the following formula:



wherein n is an integer of 0 – 20 and R1 – R5 are individually alike or different and are atoms or groups selected from hydrogen atom, halogen atom and C₁ to C₄ alkyl groups.

- 5 5. An epoxy resin compound according to claim 1 or 4 wherein the phenolic resin curing agent of multi aromatic type is novolac phenolic resin of biphenyl type as represented by the following formula:



wherein n is an integer of 0 – 20.

- 15 6. An epoxy resin compound according to any of claims 1 to 5 wherein the ratio of the epoxy resin (A) to the phenolic resin curing agent (B) is such that there is 0.8 – 1.2 epoxy group equivalent per hydroxyl group equivalent.

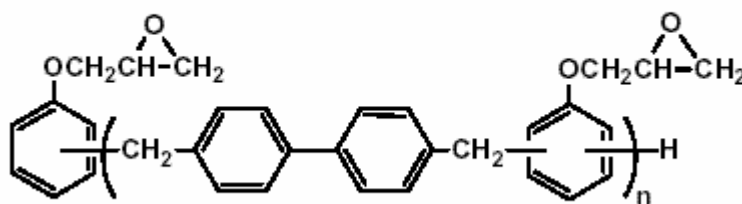
7. An epoxy resin compound according to claim 6 wherein the amount of
20 inorganic filler (C) used is 71 to 92 % by weight of the epoxy resin compound.

8. An epoxy resin compound according to claim 6 wherein the amount of inorganic filler (C) used is 80 to 88 % by weight of the epoxy resin compound.

9. An epoxy resin compound according to claim 7 or 8 wherein the amount of curing accelerator (D) used is 0.05 to 1.0 % by weight of the epoxy resin compound.

5 10. An epoxy resin compound useful for encapsulating electronic devices comprising the following components:

A) an epoxy resin whereby 25 – 75 wt % of the epoxy resin is made up by novolac epoxy resin of biphenyl type as represented by the following formula:

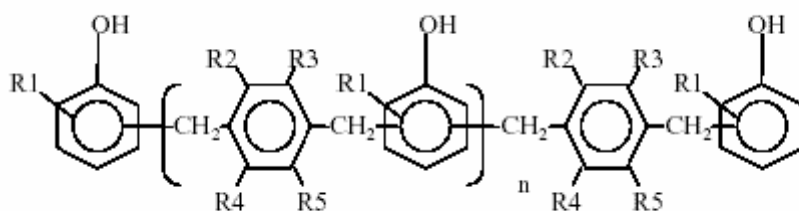


10

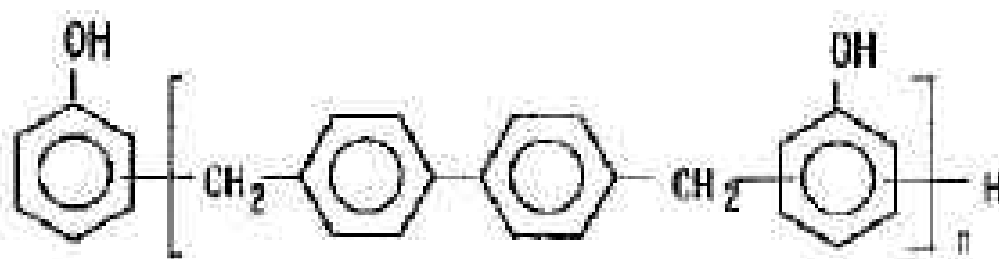
wherein n is an integer of 0 – 20 and the balance of the epoxy resin is made up by one or more epoxy resin selected from the group comprising ortho-cresol novolac epoxy resin, epoxy resin of dicyclo-pentadiene type, epoxy resin of biphenyl type, epoxy resin of bisphenol type and a combination thereof;

15

B) a phenolic resin curing agent whereby 25 – 75 wt % of the phenolic resin curing agent is made up by paraxylene-modified phenolic resin as represented by the following formula:



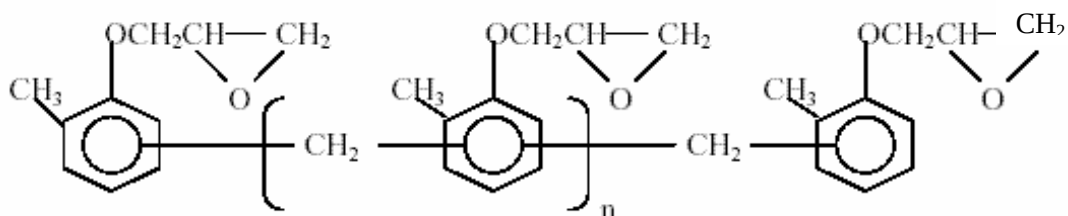
wherein n is an integer of 0 – 20 and R1 – R5 are individually alike or different and are atoms or groups selected from hydrogen atom, halogen atom and C₁ to C₄ alkyl groups and the balance of the phenolic resin curing agent is made up by novolac phenolic resin of biphenyl type as represented by the following formula:



wherein n is an integer of 0 – 20;

- C) an inorganic filler; and
- D) a curing accelerator.

11. An epoxy resin compound according to claim 10 wherein the balance of the epoxy resin is made up by ortho-cresol novolac epoxy resin as represented by the following formula:



wherein n is an integer of 0 – 10.

12. An epoxy resin compound according to claim 10 or 11 wherein the ratio
5 of the epoxy resin (A) to the phenolic resin curing agent (B) is such that there is 0.8 – 1.2 epoxy group equivalent per hydroxyl group equivalent.

13. An epoxy resin compound according to claim 12 wherein the amount of
inorganic filler (C) used is 71 to 92 % by weight of the epoxy resin compound.
10

14. An epoxy resin compound according to claim 12 wherein the amount of
inorganic filler (C) used is 80 to 88 % by weight of the epoxy resin compound.

15. An epoxy resin compound according to claim 13 or 14 wherein the
15 amount of curing accelerator (D) used is 0.05 to 1.0 % by weight of the epoxy resin compound.