

NOVEL EPOXY RESIN COMPOSITIONS

FIELD OF INVENTION

The present invention relates to a novel epoxy resin composition suitable for encapsulating electronic devices. More particularly but not exclusively, it relates to an epoxy resin composition that possesses improved strength, decreased flexural modulus and improved soldering stress resistance. A resin composition with these properties may be suitable for application in, *inter alia*, the semiconductor industry.

BACKGROUND

Electronic parts such as diodes, transistors, integrated circuits and the like are commonly sealed with a thermosetting resin. In integrated circuits in particular, a thermosetting resin such as an epoxy resin is often used, which has excellent heat resistance and moisture resistance.

With higher integration of integrated circuits, chips have become larger and surface-mounted packages have been gradually switched from DIP (Dual Inline Package) to thin flat packages such as SOP (Small Outline Package), SOJ (Small Outline J-leads), PLCC (Plastic leaded Chip Carrier), QFP (Quad Flat Package) among others. This is followed by the industrial trend towards more condensed packages such as the BGAs, Chip Size Packages (CSP), Flip Chip (FC), non-lead packages and the like.

Apart from the miniaturization of the packages as well as the chip, the industry is going towards a more environmental concerned direction. The toxic materials within the epoxy-molding compound such as bromine and antimony are regarded as hazardous materials towards human body. Besides, the lead used in the solder paste which serve as a electrical conducting path for the IC chip within the package to the outside environment also possess a negative effect to the human health.

In order to eliminate the toxicity in the compound and during the back end packaging process, a compound without toxic materials and a process without lead are critical in achieving the ultimate goal.

Within the compound, the use of brominated epoxy and antimony as a flame retardant is optional. It can be replaced by another flame retardant system or even totally removed. During the surface mount process, the Pb-Sn solder paste will be replaced by other system without the use of lead. The elimination of the lead in the solder paste brings up the eutectic point in the phase diagram. The solder (without lead) will only processable at a higher temperature.

In the semiconductor industry, the system used needs a reflow temperature up to 260°C. The increase in the reflow temperature posts a challenge in the compound supplier to supply a compound that is able to reflow at this elevated temperature without a failure.

In the soldering step, in particular, the package is suddenly exposed to high temperatures of 260°C or above, which invites cracking of the package or separation of sealing resin from chips, which causes reduction in moisture resistance.

OBJECT OF THE INVENTION

It is an object of the invention to provide an epoxy resin composition which may be suitable for encapsulating semiconductor devices, which additionally or alternatively has a higher solder cracking resistance at lead free solder reflow temperature, which additionally or alternatively behaves as a potential environmental friendly thermosetting material, and which additionally or alternatively provides the public with a useful alternative.

SUMMARY OF THE INVENTION

According to a first aspect of the invention there is provided an epoxy resin composition comprising or including:

- I. an epoxy resin component (A) comprising or including a paraxylene-modified phenol type epoxy resin of formula (I), and
- II. a phenolic curing agent component (B) comprising or including a paraxylene-modified phenolic curing agent of formula (II).

Preferably the epoxy resin (A) is in an amount substantially between 0.8 to 1.2 epoxy equivalents per hydroxyl group equivalent (mole ratio) of the phenolic resin curing agent (B).

Preferably in Formula (I) n is an integer between 0-20, and each of R_1 - R_5 is independently an atom or group selected from hydrogen, a halogen and/or an alkyl group of 1-20 carbon atoms.

Preferably in Formula (II) n is an integer between 0-20, and each of R_1 - R_5 is independently an atom or group selected from hydrogen atom, a halogen and an alkyl group

Preferably the epoxy resin component (A) comprises 50-100% by weight of the total quantity by weight of the paraxylene-modified phenol type epoxy resin of formula (I), and when this is less than 100% the epoxy resin component (A) includes one or more other secondary epoxy resins.

Preferably the phenolic curing agent component (B) comprises 50-100% by weight of the paraxylene-modified phenolic curing agent of formula (II) and wherein this is less than 100% the phenolic curing agent component (B) includes or more other secondary phenolic resin curing agents.

Preferably the epoxy resin composition further includes one or both of:

- (C) an inorganic filler, and/or
- (D) a curing accelerator.

Preferably both (C) and (D) are present and,

- the inorganic filler is silicon dioxide constituting between 70-92% by weight of the total epoxy resin composition, and
- the curing accelerator is in an amount substantially between 0.05-1wt% based on the total epoxy resin composition.

Preferably the inorganic filler constitutes between 80 and 90% by weight.

Preferably the curing accelerator is one or more of diazabicycloundecene (DBU), triphenylphosphine (TPP), benzyldimethylamine (BDMA), 2-methylimidazole (2-MZ).

Preferably wherein the secondary epoxy resin is a polymer which possesses epoxy groups, more preferably the secondary epoxy resin is selected from one or more of dicyclopentadiene type epoxy resins of formula (IV), bisphenol - type epoxy resins of formula (III), cresol novolac- type epoxy resins, phenol novolac type epoxy resins.

Preferably in Formula (III) all of R_1 to R_4 is a methyl group and all of R_5 to R_8 is hydrogen atom.

Preferably the secondary phenolic resin curing agent is one or more phenolic curing agents of formula (VIII).

Preferably the epoxy resin composition may further include one or more of:

- a silane coupling agent,
- a releasing agent (e.g., natural wax or synthetic wax),
- a stress-reducing additive (e.g., silicone oil or rubber);
- a flame retardant system.

Preferably the flame retardant system is selected from a bromine/antimony system or the aluminium and/or magnesium hydroxide system.

Preferably the specific composition is:

The Paraxylene-modified phenol type epoxy resin (I) is of formula (V)	softening point : 60°C., epoxy equivalent : 238g/eq	6-10 parts by weight
The Paraxylene-modified phenol resin curing agent (II) is of formula (VI)	softening point : 62°C., hydroxyl group equivalent : 172g/eq	4-8 parts by-weight
Fused silica filler	Average size: 13 micron m	80-88 parts by weight
Triphenylphosphine (TPP)		0.05-0.4 parts by weight
Epoxy function including silane coupling agent		0.1-0.5 parts by weight
Di-methyl silicone oil additive		0.1-0.4 parts by weight
Carbon black		0.2-0.4 parts by weight
Carnauba Wax		0.3-0.8 parts by weight

According to a second aspect of the invention there is provided a method of preparing an epoxy resin composition including or comprising the steps of:

- I. preparing an epoxy resin component (A) including or comprising a paraxylene-modified phenol type epoxy resin of formula (I);
- II. preparing a phenolic curing agent component (B) including or comprising a paraxylene-modified phenolic curing agent of formula (II);
- III. mixing or otherwise combining at least the epoxy resin and curing agents to provide a mixture;
- IV. obtaining the composition therefrom.

Preferably:

- in Formula (I) n is an integer between 0-20 and each of R_1 - R_5 is independently an atom or group selected from hydrogen, a halogen and/or an alkyl group of 1-20 carbon atoms, and
- in Formula (II) n is an integer between 0-20, and each of R_1 - R_5 is independently an atom or group selected from hydrogen atom, a halogen and an alkyl group.

Preferably wherein

- the total quantity by weight of modified phenol type epoxy resin of formula (I) in the epoxy resin component (A) is the range of 50-100% by weight, and when less than 100% the epoxy resin component includes one or more other secondary epoxy resins, and
- the total quantity by weight of the paraxylene-modified phenolic curing agent of formula (II) in the phenolic curing agent component (B) is the range of 50-100% by weight, and when less than 100% the phenolic curing agent component includes one or more other secondary phenolic curing agents.

Preferably the method further includes:

- combining the epoxy resin and curing agent with an inorganic filler, the inorganic filler being mixed with the other components as part of step 3), and/or
- combining the epoxy resin and curing agent with a curing accelerator, the curing accelerator being mixed with the other components as part of step 3).

Preferably:

- the inorganic filler is silicon dioxide, and constitutes substantially between 70-92% by weight of the total epoxy resin composition, and
- the curing accelerator is added to provide between 0.05-1 wt% based on the total epoxy resin composition.

Preferably the secondary epoxy resin is an polymer possessing epoxy groups, preferably selected from one or more of dicyclo-pentadiene type epoxy resins of formula (IV), bisphenol - type epoxy resins of formula (III), cresol novolac- type epoxy resins, phenol novolac type epoxy resins.

Preferably the secondary phenolic resin curing agent is one or more phenolic curing agents of formula (VIII).

Preferably the epoxy resin composition may further include one or both of:

- one or more additives, added as part of step 3), selected from more of a silane coupling agent, releasing agent (e.g., natural wax or synthetic wax), stress-reducing additive (e.g., silicone oil or rubber), and the like;
- a flame retardant system added as part of step 3).

Preferably step IV includes the steps of:

- melt kneading of the mixture using hot rolls, a kneader or the like;
- cooling and grinding or pulverizing of the product of the kneading step.

According to a third aspect of the invention there is provided a method of encapsulating an electronic device or component comprising or including the steps of:

- preparing an epoxy resin composition as above,
- encapsulating or otherwise treating the electronic device to produced an encapsulated electronic device.

According to a fourth aspect of the invention there is provided an encapsulated electronic device or component wherein the electronic device or component is encapsulated within or by an epoxy resin composition as above.

Other aspects of the invention may become apparent from the following description which is given by way of example only and with reference to the accompanying Examples and or Figures.

DEFINITIONS

By "Electronic Device or Component" as used herein we refer to, *inter alia* IC devices, Discrete (Transistor, Diode, Capacitor, etc) devices.

By "Curing Accelerator" as used herein we mean a substance capable of accelerating the reaction between the epoxy group of the component (A) and the hydroxyl group of the component (B). This includes, but is not limited to those curing accelerators widely used in sealing materials, such as diazabicycloundecene (DBU), triphenylphosphine (TPP), benzyldimethylamine (BDMA), 2-methylimidazole (2-MZ) and the like. These compounds can be used alone or in combination of two or more.

BRIEF DESCRIPTION OF THE FIGURES

The invention will now be described with reference to the Figures in which:

- Figure 1: illustrates the structure of the paraxylene-modified phenol type epoxy resin of formula (I);
- Figure 2: illustrates the structure of the paraxylene-modified phenolic curing agent of formula (II);
- Figure 3: illustrates the structure of the secondary epoxy resin component - biphenyl type epoxy resin of formula (III);
- Figure 4: illustrates the structure of the secondary epoxy resin component of formula (IV);
- Figure 5: illustrates the structure of a paraxylene-modified phenol type epoxy resin (V) the preferred paraxylene-modified phenol type epoxy resin of general formula (I);
- Figure 6: illustrates the structure of a paraxylene-modified phenolic curing agent (VI) , the preferred paraxylene-modified phenolic curing agent of general formula (II);
- Figure 7: illustrates the structure of an ortho-cresol novalac epoxy resin of formula (VII);

- Figure 8: illustrates the structure of a phenolic curing agent of formula (VIII);
Figure 9: A spiral flow mold;
Figure 10: illustrates a biphenyl type epoxy resin of formula (IX);
Figure 11: illustrates a dicyclo-pentadiene modified epoxy resin of formula (X)

DETAILED DESCRIPTION OF THE INVENTION

The present invention provides an epoxy resin composition having the principal components of an epoxy resin (A) and a phenolic curing agent (B) wherein (A) includes or is exclusively a paraxylene-modified phenol type epoxy resin represented by formula (I) and (B) includes or is exclusively a paraxylene-modified phenolic curing agent of formula (II).

We have found that resulting epoxy resin composition has high strength, low flexural modulus, high cure-ability and higher soldering stress resistance, for example at 260°C as compared with conventional cresol novolac type epoxy resin and phenol novolac curing agent compositions used for the same purpose. Other favourable properties include environmental friendliness, low thermal expansion and low moisture absorption, among others. Such a combination has not been attained with prior art.

1. Use as a Semiconductor Sealant

The present epoxy resin composition used for sealing comprises as described previously, as essential components, an epoxy resin, a curing agent, an inorganic filler and a curing accelerator. The resin composition may further comprise, if necessary, various additives such as silane coupling agent, releasing agent (e.g., natural wax or synthetic wax), stress-reducing additive (e.g., silicone oil or rubber), and the like.

2. Epoxy Resin

The epoxy resin component (A) used in the present invention includes or is exclusively an environmental friendly epoxy resin represented by formula (I) (see Figure 1) that possesses a group of para-xylene glycol dimethyl ether (glycidyl ether) as compared with conventional poly-functional epoxy resins. It is comprised of benzene rings that are very stable at elevated temperatures.

This enables the flame retardancy properties of the ultimate resin composition to be enhanced with the presence of the stable para-xylene group. Thus the soldering stress resistance of the product composition is enhanced by the use of this paraxylene-modified phenol type epoxy of formula (I). The aromatic ring attached to the main ring gives rigidity to the structure. It will result in high strength and modulus even at elevated temperature.

In formula (I), R_2 to R_5 can be any group, and n is preferably an integer from 0 to 20. When n is larger than 20, lower fluidity during transfer molding and lower moldability tends to appear.

The resin of formula (I) may make up the entire epoxy resin component (A) of the composition. If not it is at least desirable that the total quantity by weight of this paraxylene-modified phenol type epoxy resin of formula (I) in relation to other types of epoxy resin (secondary resins) in the epoxy resin component is in the range of 50-100% (See Examples 1 & 2). The invention includes within its scope quantities by weight of less than 50% (Comparative Example 2, 4, 5 & 6) however the resultant composition does not exhibit the preferred high performance of solder crack resistance and the resistance for flammability.

The other epoxy resins (secondary resins) may be used in combination with the paraxylene-modified phenol type epoxy resin of formula (I) to make up the entire epoxy resin component (A). These are generally ordinary polymers having epoxy groups. These include, for example dicyclo-pentadiene (Examples 8 & 9) type epoxy resins of formula (IV) (see Figure 4), bisphenol (Examples 8 & 9) type epoxy resins of formula (III) (see Figure 3), cresol novolac (Examples 2 & 4, Comparative Example 2, 4, 5 & 6) type epoxy resins, phenol novolac type epoxy resins and so on.

In order to obtain high soldering stress resistance, it is desirable to use the biphenyl type epoxy resin of formula (III) in combination with (I). Such epoxy resin composition will result in reduction of water absorption, and excellent soldering stress resistance. In formula (III), it is preferable that R_1 to R_4 be each methyl group and R_5 to R_8 be each hydrogen atom.

One preferred distribution of chain length of paraxylene-modified phenol type epoxy resin is that of formula (V) (See Figure 5).

3. Phenolic resin curing agent

The phenolic resin curing agent component (B) of the invention includes or is exclusively the paraxylene-modified phenol type phenolic resin curing agent represented by formula (II) (see Figure 2). It has an additional aromatic ring attached to its original molecular structure, a relatively rigid structure. This curing agent, as compared with a phenol novolac resin curing agent, etc., can provide the resulting resin composition with lower modulus at high modulus as soldering temperatures. Thus, the curing agent of formula (II) is effective in (a) providing high strength during solder reflow and (b) preventing the deterioration of package integrity during solder reflow, etc.

The soldering stress resistance of the present epoxy resin composition can be maximised by controlling the amount of phenolic resin curing agent of formula (II) in the phenolic resin curing agent component (B). The resulting resin composition is capable of providing strength during soldering and preventing the deterioration of package integrity during solder reflow, leading to higher soldering stress resistance.

It is preferred that the total quantity by weight of this paraxylene-modified phenol type phenolic resin curing agent of formula (II) in relation to other type of phenolic resin curing agent in the phenolic resin curing agent component (B) is in the range of 50-100% (Examples 3 & 4).

In case of less than 50% of this paraxylene-modified phenol type phenolic resin curing agent (Comparative Examples 1, 3, 5 & 6) based on the amount of total phenolic resin curing agent component (B), the resulting epoxy resin composition appears not to achieve as high a performance of solder crack resistance and the resistance for flammability.

In comparison to the combination of the use of ortho-cresol novolac epoxy resin of formula (VII) (see Figure 7) and phenolic curing agent of formula (VIII) (see Figure 8) in comparative example 6 (Table 2), the resulting composition will not be able to withstand the solder crack requirement as well as the reliability requirement of IC industry.

In formula (II), n must be an integer from 0 to 20. When n is larger than 20, lower fluidity during transfer molding and lower moldability tends to be apparent.

One preferred distribution of chain length of paraxylene-modified phenol type phenolic resin curing agent is that of formula (VI) (Figure 6).

4. Combination of Epoxy Resin Component and Phenolic Resin Curing Agent Component

With regard to the blending ratio of the epoxy resin component (A) to the phenolic resin curing agent (B), preferably the epoxy resin (A) is used in an amount of 0.8 to 1.2 epoxy equivalent per hydroxyl group equivalent of the phenolic resin curing agent (B). Properties such as humidity resistance tend to deteriorate the composition outside of said range.

5. Inorganic Filler

The inorganic filler is preferably silica oxide and ideally in the range of 70% to 92% by weight based on total epoxy resin composition, preferably between 80% and 90% (Example 7).

Small amounts of carefully selected fine fused or crystalline silica can facilitate the flow of the molten resin composition during transfer molding and also help cut down air-vent flashes.

We have found that in the case of less than 70% by weight of amount of silica oxide inorganic filler (Comparative Example 7), the resulting epoxy resin composition does not exhibit as high performance of solder crack resistance and resistance for flammability.

In the cases of use of silica oxide at greater than 92% by weight (Comparative Example 8), the resulting epoxy resin composition does not exhibit suitable flowability during transfer molding of semiconductor packages. Hence, its corresponding reliability performance (HTSL) is poor due to the pre-test occurrence of delamination.

A typical filler distribution that can provide a better flowability even in a narrow flow channel should preferably exhibit bimodal distribution in the regions of (i) 0.5-10.0 μ m, (ii) 20.0-100.0 μ m. The smallest peak (i) is fine silica filler. These fine fillers serve as lubricating "bearings" that promote flowability as well as minimising air-vent flashes during transfer

molding. Too much or too little of such filler can render these functions ineffective. In addition, spherical fillers as well as wide filler distribution are necessary to maintain good flowability and processibility. Spherical fillers also help in reducing abrasiveness and the modulus of the resin composition.

6. Curing Accelerator

The curing accelerator used in the present composition can be any material capable of accelerating the reaction between the epoxy group of the component (A) and the hydroxyl group of the component (B). This includes, but is not limited to those curing accelerators widely used in sealing materials, such as diazabicycloundecene (DBU), triphenylphosphine (TPP), benzyldimethylamine (BDMA), 2-methylimidazole (2-MZ) and the like. These compounds can be used 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 in the total epoxy resin composition. In an amount less than 0.05 wt %, the hardness of the resulting molded product decreases and mold release characteristics tend to deteriorate. In an amount more than 0.5 wt %, the reaction proceeds undesirably fast and fluidity tends to decrease.

7. Production of the Composition

In producing the present epoxy resin composition for sealing as a molding material, an epoxy resin, a curing agent, a curing accelerator, a filler and other additives are mixed sufficiently and uniformly using a mixer or the like; then, the mixture is melt kneaded using hot rolls, a kneader or the like; and the kneaded product is cooled and ground. The molding material thus obtained can be used for sealing, coating, insulation, etc. of electronic parts or electric parts.

As a safety consideration, molding compound must achieve UL-94 flammability standard. The addition of a flame retardant to the recipe of molding compound is common to attain the said flammability standard. The conventional bromine/antimony combination can effectively prevent the flaming to occur when package reaches flame ignition point. Recent environmental considerations rule out the use of bromine/antimony based flame retardant system. It has been replaced by another flame retarding technology that has been developed in the molding compound industry. The removal of bromine/antimony flame-retardant system

greatly improve the HTSL performance of the package. This is due to the absence of antimony that is the root cause of the ball bond corrosion during the high temperature storage.

Other than Br/Sb system, aluminium and/or magnesium hydroxide is a good replacement for the flame retardant system in order to attain the UL-94 standard (Example 6). With a lower filler content (<75%), the resin content increases and it promotes flaming (Example 5). The addition of the flame retardant (aluminium hydroxide) enables the compound to exhibit sufficient flame retardancy. Besides, the uses of conventional flame retardant system (Br/SB, Example 10) to effectively achieve UL-94,V-0 standard for the low filler content system.

At package level, these are translated into (a) good solder cracking resistance, (b) high HTSL performance, (c) the possibility of recycling of excess molded material. The present epoxy resin composition can be used for sealing, coating, insulation, etc. of electronic or electric parts, in particular, lead free solder reflow temperature application on ICs for surface-mount purposes.

By using the epoxy resin compositions for encapsulating of semiconductors of the present invention, there are obtained semiconductor devices containing no bromine compounds and no antimony oxide and excellent in flame retardancy, moisture resistance, moldability, curability and electric characteristics.

8. EXPERIMENTAL

The present invention is hereinafter described specifically by way of Examples. In the Examples, the amount of each component used in compounding is given in parts by weight.

Example 1

The following components of the following proportions are mixed at room temperature using a mixer, then kneaded at 70-100°C. using a biaxial roll, cooled and ground to obtain a molding material.

Paraxylene-modified phenol type epoxy resin of formula (V) (softening point : 60°C., epoxy equivalent : 238g/eq)	8.23 parts by weight
Paraxylene-modified phenol resin curing agent of formula (VI) (softening point : 62°C., hydroxyl group equivalent : 172g/eq.)	5.94 parts by-weight
Fused silica filler (Average size: 13 micron m)	84.23parts by weight
Triphenylphosphine (TPP)	0.20 parts by weight
Epoxy function including silane coupling agent	0.30 parts by weight
Di-methyl silicone oil additive	0.25 parts by weight
Carbon black	0.30parts by weight
Carnauba Wax	0.55 parts by weight

For performance testing at the semiconductor package level, it also began with similar pellet preparation into various sizes. Depending on test purposes, it can then be molded into (i) 28L-SOIC Wide Body encapsulating SiN (Silicon Nitride) coated chips of size 5x5mm at a temperature of 175°C, 80-120kgf/cm² and 90sec. Subsequently the packages are sent for post mold cure (PMC) at 175°C for 4hrs before MSL (Moisture Sensitivity Level) evaluation. (ii) Similarly the pellets are also molded into 80pin QFPs (14x20mm) encapsulating PI (Polyimide) and SiN (Silicon Nitride) coated chips of size 7.5x7.5mm at a temperature of 175°C, 100kgf/cm² and 120sec. Subsequently the packages are sent for PMC at 175°C for 4hrs.

Thereafter the packages are sent through a varying temperature profile according to the JEDEC standard with peak temperature 260°C in an infrared (IR) oven. Thereafter, any cracks present at the surfaces of the devices are observed using a microscope. In addition, the packages are also scanned using CSAM (C-mode Scanning Acoustic Microscope) for delaminated interfaces with focus on the chip top and the bottom die pad with these chips to obtain devices for solder cracking test. The tablets are also made into 16p DIPs (16-pin Dual-Inline Packages) for HTSL test at 175°C, after which circuit resistance are examined for values exceeding 1.0 Ω (value of electrical resistance after mold is typically <0.8 Ω). During prolong exposure to high temperature, free ions present within the encapsulant material, especially bromide and antimony can corrode the gold ball bond to form for example Kirkendall void which in turn leads to higher electrical resistance). The results are expressed by average life.

Spiral Flow Measurement

A certain amount of molding material which shall give a cull thickness of $3 \pm 0.3\text{mm}$ was weighted. A spiral flow mold die as shown in Figure 9 below was placed in the molding machine and was heated up to 175°C . When the temperature reaches $175 \pm 2^\circ\text{C}$, the certain amount of molding material was poured into the transfer pot and plunger was lower. The material was molded for 120sec then the mold press was opened, the spiral flow length (up to the lustrous tip) was measured after the mold die was taken out from the molding machine.

UL test method.

UL-94, developed by Underwriters Laboratories, is one of the most widely used flammability test for plastic materials. In the test, the specimens are clamped vertically. The materials are classified V-2, the least stringent classification, or V-1 or V-0, which are the most stringent classification for the test. Table 1 below summarizes the requirements for each classification.

Table 1 : Summary of UL 94 Vertical Burning Test for Classification Materials V-0, V-1, V-2

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 (sec)	30	30	10
Total flaming time, five specimens, 2 ignitions (sec)	250	250	50
Flaming drips ignite cotton	Yes	No	No
Maximum afterglow time, per specimen (sec)	60	60	30
Burn to holding clamp	No	No	No

The test is conducted on a $1/2 \times 5$ in. specimen with a range of thickness from 0.12-0.50 in. A small $3/4$ in. high blue flame is applied to the bottom of the specimen for 10sec. Withdrawn, and reapplied for an additional 10 sec; the duration of flaming and glowing is noted as soon as the specimen has extinguished. A layer of cotton is placed beneath the specimen to determine whether dripping materials will ignite it during the test period.

Examples 2-8

Epoxy resin compositions are compounded in the respective recipes shown in Table 2, and subjected to the same procedures as in Example 1 to obtain molding materials. Devices for test purposes are prepared using these molding materials and subjected to the reliability test (solder cracking test and high temperature storage test: HTSL). The results are shown in Table 2.

Table 2 : Results

	Unit	Examples										Comparative examples							
		1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8
Paraxylene-modified phenol type epoxy resin of formula (V) (softening point : 60°C., epoxy equivalent : 238g/eq.)	%	8.23	4.37	9.11	4.85	14.75	14.75	5.46	4.50	4.98	12.8	9.55		9.86	2.34	2.72		17.7	2.55
Ortho-cresol novolac epoxy resin of formula (VII) (softening point : 65°C., epoxy equivalent : 200g/eq.)	%		3.57		3.97								7.62		5.45	6.36	9.32		
Biphenyl type epoxy resin of formula (IX) (Figure 10) (melting point : 102°C., epoxy equivalent : 198g/eq.)	%								1.5	1.5									
Dicyclo-pentadiene modified epoxy resin of formula (X) (Figure 11) (softening point : 60°C., epoxy equivalent : 260g/eq.)	%								2.19	2.58									
Paraxylene-modified phenol resin curing agent of formula (VI) (melting point : 62°C., hydroxyl group equivalent : 172g/eq.)	%	5.94	6.23	2.78	2.95	10.65	10.65	3.94	5.98	2.81	10.6	1.16	6.55		6.38	1.53		12.8	1.85
Phenol novolac of formula (VIII) (melting point : 90°C., hydroxyl group equivalent : 104g/eq.)	%			2.28	2.40					2.30		3.46		4.31		3.56	4.85		
Brominated Epoxy	%										2.0								
Fused silica filler (Average size: 13 micron m)	%	84.23	84.23	84.23	84.23	73.00	69.00	89.00	84.23	84.23	70.00	84.23	84.23	84.23	84.23	84.23	84.23	68	94
Aluminium Hydroxide	%					4.0													
antimony Trioxide	%										3.0								
Triphenylphosphine (TPP)	%	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Epoxy function including silane coupling agent	%	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Di-methyl silicone oil additive	%	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Carbon black	%	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Carnauba Wax	%	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Total	%	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Spiral flow	cm	90	83	74	70	102	96	65	88	75	75	78	80	73	77	65	58	120	30
UL-94/3.2mm thickness (V-0/V-1)	-	V-0	V-0	V-0	V-0	V-1	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-0
Soldering crack test (28L-SOWB, after 85C/85% RH for 168hrs soaking)																			
No. of cracked devices /Total no.	No.	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	2/12	12/12	4/12	7/12
Delamination Check	Die Top	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	2/12	2/12	0/12	5/12	10/12	8/12	8/12
	Bottom Pad	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	3/12	7/12	6/12	5/12	10/12	10/12	8/12	
Soldering crack test (80L-QFP, after 60C/60% RH for 168hrs soaking)																			
No. of cracked devices /Total no.	No.	0/12	0/12	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	12/12	12/12	9/12
Delamination Check	Die Top	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	2/12	3/12	0/12	8/12	8/12	9/12	10/12

	Bottom Pad	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	0/12	5/12	5/12	7/12	5/12	10/12	12/12	12/12	10/12
HTSL at 175C (hr to 1st failure)	Hrs		>1000	>1000	>1000	>1000	>1000	>1000	>1000	>1000	>1000	600	400	350	700	500	200	800	700

Table 3 provides details of the preferred composition of the invention. The paraxylene-modified phenol type epoxy resin of general formula (I) is preferred to be the paraxylene-modified phenol type epoxy resin of formula (V), and the paraxylene-modified phenol resin curing agent of general formula (II) is preferred to be the paraxylene-modified phenol resin curing agent of formula (VI).

Table 3 :

Paraxylene-modified phenol type epoxy resin of formula (V)	softening point : 60°C., epoxy equivalent : 238g/eq	6-10 parts by weight
Paraxylene-modified phenol resin curing agent of formula (VI)	softening point : 62°C., hydroxyl group equivalent : 172g/eq	4-8 parts by-weight
Fused silica filler	Average size: 13 micron m	80-88 parts by weight
Triphenylphosphine (TPP)		0.05-0.4 parts by weight
Epoxy function including silane coupling agent		0.1-0.5 parts by weight
Di-methyl silicone oil additive		0.1-0.4 parts by weight
Carbon black		0.2-0.4 parts by weight
Carnauba Wax		0.3-0.8 parts by weight

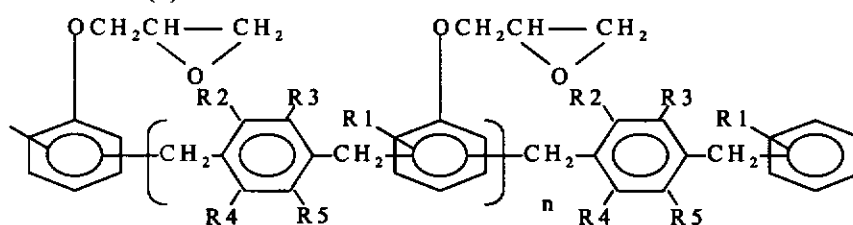
With the filler content in the range of 80 to 88wt%, the compound demonstrates good mechanical performance with excellent solder crack resistance. The corresponding paraxylene-modified phenol type epoxy resin of formula (V) falls in the range of 6-10wt% whereas the paraxylene-modified phenol resin curing agent of formula (VI) is in the range of 4-8wt%.

Although the invention has been described by way of example and with reference to particular embodiments, it is to be understood that modifications and/or improvements may be made without departing from the scope or spirit of the invention.

THE CLAIMS

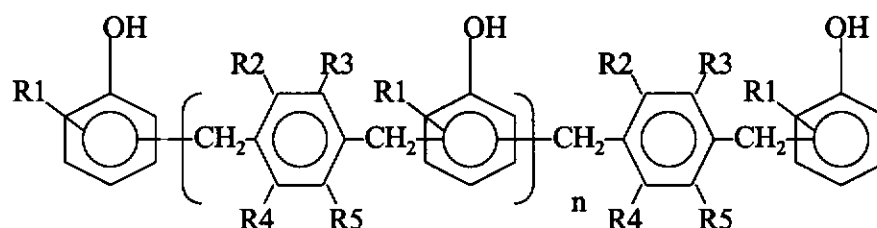
1. An epoxy resin composition comprising or including:
 - I. an epoxy resin component (A) comprising or including a paraxylene-modified phenol type epoxy resin of formula (I), and
 - II. a phenolic curing agent component (B) comprising or including a paraxylene-modified phenolic curing agent of formula (II);
 wherein :

Formula (I)



Wherein n is an integer of 0-20 and each R1-R5 is independently an atom or group selected from hydrogen atom, a halogen and an alkyl group.

Formula (II)



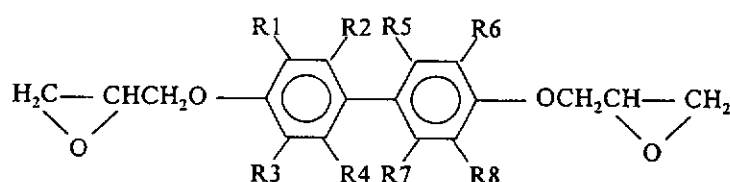
Wherein n is an integer of 0-20 and each R1-R5 is independently an atom or group selected from hydrogen atom, a halogen and an alkyl group

2. An epoxy resin composition as claimed in claim 1 wherein the epoxy resin (A) is in an amount substantially between 0.8 to 1.2 epoxy equivalents per hydroxyl group equivalent (mole ratio) of the phenolic resin curing agent (B).
3. An epoxy resin composition as claimed in claim 2 wherein, in Formula (I) n is an integer between 0-20, and each of R₁-R₅ is independently an atom or group selected from hydrogen, a halogen and/or an alkyl group of 1-20 carbon atoms.

4. An epoxy resin composition as claimed in claim 2 wherein in Formula (II) n is an integer between 0-20, and each of R_1 - R_5 is independently an atom or group selected from hydrogen atom, a halogen and an alkyl group
5. An epoxy resin composition as claimed in claim 3 wherein the epoxy resin component (A) comprises 50-100% by weight of the total quantity by weight of the paraxylene-modified phenol type epoxy resin of formula (I), and when this is less than 100% the epoxy resin component (A) includes one or more other secondary epoxy resins.
6. An epoxy resin composition as claimed in claim 4 wherein the phenolic curing agent component (B) comprises 50-100% by weight of the paraxylene-modified phenolic curing agent of formula (II) and wherein this is less than 100% the phenolic curing agent component (B) includes or more other secondary phenolic resin curing agents.
7. An epoxy resin composition as claimed in claim 5 or 6 wherein the epoxy resin composition further includes one or both of:
 - (C) an inorganic filler, and/or
 - (D) a curing accelerator.
8. An epoxy resin composition as claimed in claim 7 wherein both (C) and (D) are present and,
 - the inorganic filler is silicon dioxide constituting between 70-92% by weight of the total epoxy resin composition, and
 - the curing accelerator is in an amount substantially between 0.05-1wt% based on the total epoxy resin composition.
9. An epoxy resin composition as claimed in claim 8 wherein the inorganic filler constitutes between 80 and 90% by weight.
10. An epoxy resin composition as claimed in claim 8 wherein the curing accelerator is one or more of diazabicycloundecene (DBU), triphenylphosphine (TPP), benzyldimethylamine (BDMA), 2-methylimidazole (2-MZ).

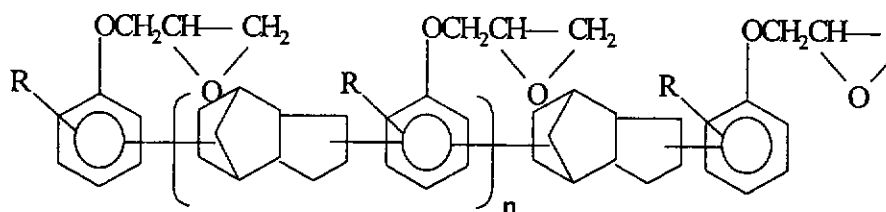
11. An epoxy resin composition as claimed in any one of the preceding claims wherein the secondary epoxy resin is a polymer which possesses epoxy groups.
12. An epoxy resin composition as claimed in claim 11 wherein the secondary epoxy resin is selected from one or more of dicyclo-pentadiene type epoxy resins of formula (IV), bisphenol - type epoxy resins of formula (III), cresol novolac- type epoxy resins, phenol novolac type epoxy resins, wherein

Formula (III)



Wherein R1-R8 are the same or different atoms or groups selected from hydrogen, halogens and alkyl groups

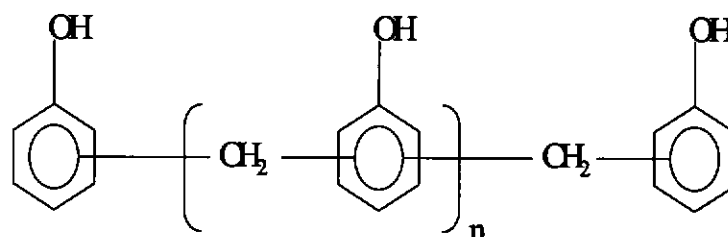
Formula (IV)



Wherein n is an integer of 0-20 and each R is independently an atom or group selected from hydrogen atom, a halogen and an alkyl group

13. An epoxy resin composition as claimed in claim 12 wherein in Formula (III) all of R₁ to R₄ is a methyl group and all of R₅ to R₈ is hydrogen atom.
14. An epoxy resin composition as claimed in claim 11 wherein the secondary phenolic resin curing agent is one or more phenolic curing agents of formula (VIII), wherein

Formula (VIII)



Wherein n is an integer of 0-5 and ratio of molecular amount of each n is $n=0$: 0.21, $n=1$: 0.34, $n=2$: 0.45, $n=3$: 0.21, $n=4$: 0.17, $n=5$: 0.04

15. An epoxy resin composition as claimed in claim 13 or 14 wherein the epoxy resin composition may further include one or more of:

- a silane coupling agent,
- a releasing agent (e.g., natural wax or synthetic wax),
- a stress-reducing additive (e.g., silicone oil or rubber);
- a flame retardant system.

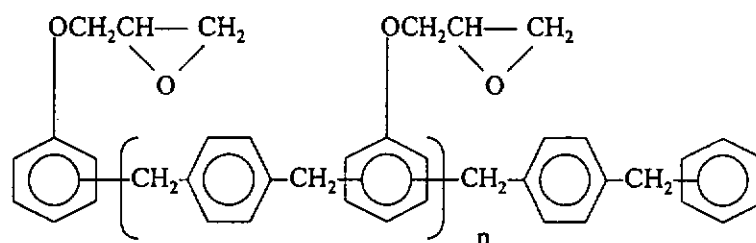
16. An epoxy resin composition as claimed in claim 15 wherein the flame retardant system is selected from a bromine/antimony system or the aluminium and/or magnesium hydroxide system.

17. An epoxy resin composition as claimed in claim 15 wherein the specific composition is:

The Paraxylene-modified phenol type epoxy resin (I) is of formula (V)	softening point : 60°C., epoxy equivalent : 238g/eq	6-10 parts by weight
The Paraxylene-modified phenol resin curing agent (II) is of formula (VI)	softening point : 62°C., hydroxyl group equivalent : 172g/eq	4-8 parts by-weight
Fused silica filler	Average size: 13 micron m	80-88 parts by weight
Triphenylphosphine (TPP)		0.05-0.4 parts by weight
Epoxy function including silane coupling agent		0.1-0.5 parts by weight
Di-methyl silicone oil additive		0.1-0.4 parts by weight
Carbon black		0.2-0.4 parts by weight
Carnauba Wax		0.3-0.8 parts by weight

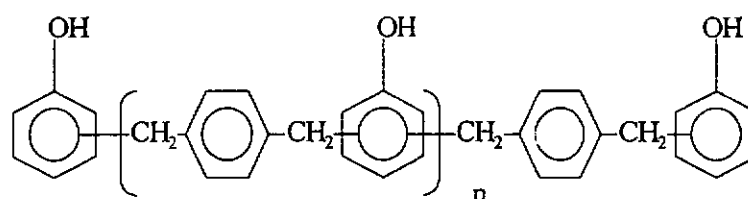
wherein

Formula (V)



Wherein n is an integer of 0-5 and ration of molecular amount of each n is n=0: 0.02, n=1: 0.12, n=2: 0.24, n=3: 0.35, n=4: 0.42 and n=5: 0.23

Formula (VI)



Wherein n is an integer of 0-5 and ration of molecular amount of each n is n=0: 0.08, n=1: 0.18, n=2: 0.30, n=3: 0.43, n=4: 0.28 and n=5: 0.17

18. A method of preparing an epoxy resin composition including or comprising the steps of:

- I. preparing an epoxy resin component (A) including or comprising a paraxylene-modified phenol type epoxy resin of formula (I);
- II. preparing a phenolic curing agent component (B) including or comprising a paraxylene-modified phenolic curing agent of formula (II);
- III. mixing or otherwise combining at least the epoxy resin and curing agents to provide a mixture;
- IV. obtaining the composition therefrom.

19. A method of preparing an epoxy resin composition as claimed in claim 18 wherein:

- in Formula (I) n is an integer between 0-20 and each of R₁-R₅ is independently an atom or group selected from hydrogen, a halogen and/or an alkyl group of 1-20 carbon atoms, and
- in Formula (II) n is an integer between 0-20, and each of R₁-R₅ is independently an atom or group selected from hydrogen atom, a halogen and an alkyl group.

20. A method of preparing an epoxy resin composition as claimed in claim 19 wherein

- the total quantity by weight of modified phenol type epoxy resin of formula (I) in the epoxy resin component (A) is the range of 50-100% by weight, and when less than 100% the epoxy resin component includes one or more other secondary epoxy resins, and
- the total quantity by weight of the paraxylene-modified phenolic curing agent of formula (II) in the phenolic curing agent component (B) is the range of 50-100% by weight, and when less than 100% the phenolic curing agent component includes one or more other secondary phenolic curing agents.

21. A method of preparing an epoxy resin composition as claimed in claim 20 wherein the method further includes:

- combining the epoxy resin and curing agent with an inorganic filler, the inorganic filler being mixed with the other components as part of step 3), and/or
- combining the epoxy resin and curing agent with a curing accelerator, the curing accelerator being mixed with the other components as part of step 3).

22. A method of preparing an epoxy resin composition as claimed in claim 21 wherein:

- the inorganic filler is silicon dioxide, and constitutes substantially between 70-92% by weight of the total epoxy resin composition, and
- the curing accelerator is added to provide between 0.05-1 wt% based on the total epoxy resin composition.

23. A method of preparing an epoxy resin composition as claimed in claim 22 wherein the secondary epoxy resin is an polymer possessing epoxy groups, preferably selected from one or more of dicyclo-pentadiene type epoxy resins of formula (IV), bisphenol - type epoxy resins of formula (III), cresol novolac- type epoxy resins, phenol novolac type epoxy resins.

24. A method of preparing an epoxy resin composition as claimed in claim 23 wherein the secondary phenolic resin curing agent is one ore more phenolic curing agents of formula (VIII).

25. A method of preparing an epoxy resin composition as claimed in claim 24 wherein the epoxy resin composition may further include one or both of:
- one or more additives, added as part of step 3), selected from more of a silane coupling agent, releasing agent (e.g., natural wax or synthetic wax), stress-reducing additive (e.g., silicone oil or rubber), and the like;
 - a flame retardant system added as part of step 3).
26. A method of preparing an epoxy resin composition as claimed in claim 25 wherein step IV includes the steps of:
- melt kneading of the mixture using hot rolls, a kneader or the like;
 - cooling and grinding or pulverizing of the product of the kneading step.
27. A method of encapsulating an electronic device or component comprising or including the steps of:
- preparing an epoxy resin composition as claimed in claim 18 to 26,
 - encapsulating or otherwise treating the electronic device to produced an encapsulated electronic device.
28. An encapsulated electronic device or component wherein the electronic device or component is encapsulated within or by an epoxy resin composition as claimed in any one of claims 1 to 17.
29. The use of an epoxy resin composition as claimed in any one of claims 1 to 17 in encapsulating an electronic device.