

## DESCRIPTION

TITLE OF THE INVENTION: METHOD FOR MANUFACTURING ELECTRONIC  
DEVICE APPARATUS

### TECHNICAL FIELD

[0001]

The present invention relates to a resin sheet for sealing.

### BACKGROUND ART

[0002]

In recent years, as the speed of data processing of an electronic device apparatus (for example, a semiconductor device) is increased, the amount of heat generation from an electronic device (for example, a semiconductor chip) is increased, which causes an increase in the importance of design of an electronic device apparatus having heat releasing properties. Heat has various adverse influences not only on the electronic device apparatus itself but also on an electronic device body including the electronic device apparatus.

[0003]

Then, a thermosetting resin composition containing a thermally conductive secondary aggregate formed by aggregating scale-like boron nitride is conventionally proposed (for example, see Patent Document 1). The secondary aggregate of boron nitride has high thermal conductivity and electrical insulating

properties. Therefore, when the secondary aggregate of boron nitride is used for the electronic device apparatus, the electronic device apparatus is expected to have high heat releasing properties. Herein, the boron nitride generally has a scale-like crystal structure, and has thermal anisotropy such that coefficient of thermal conductivity in the direction of an axis a (plane direction) of a crystal is several times to several tens of times that in the direction of an axis c (thickness direction) of the crystal. Thus, in Patent Document 1, the boron nitride is used as a secondary aggregate of crystals that are aggregated so as to be isotropic.

PRIOR ART DOCUMENT

PATENT DOCUMENT

[0004]

Patent Document 1: JP-A-2014-40533

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0005]

However, there has been room for an improvement because the thermal conductivity of the electronic device apparatus manufactured using a resin sheet could not be remarkably improved by merely adding the secondary aggregate of boron nitride to the resin sheet.

[0006]

The present invention has been made in view of the aforementioned problem, and it is an object of the present invention to provide a method for manufacturing an electronic device apparatus with which more suitable thermal conductivity of a resin sheet for sealing can be exhibited.

#### MEANS FOR SOLVING THE PROBLEM

[0007]

The present inventors have made wholehearted research for a method for manufacturing an electronic device apparatus including a resin sheet for sealing containing a secondary aggregate of boron nitride. As a result, surprisingly, the inventors have found that, after embedding an electronic device into a resin sheet for sealing containing a secondary aggregate of boron nitride, the thermal conductivity of the obtained electronic device apparatus is improved in the case where the resin sheet for sealing is thermally cured in a pressurized state, as compared with the case where the resin sheet for sealing is thermally cured in a non-pressurized state. This finding has led to the completion of the present invention.

[0008]

That is, a method for manufacturing an electronic device apparatus according to the present invention includes:

a step A of preparing a laminated product including a

support and an electronic device fixed on the support;

a step B of preparing a resin sheet for sealing containing a secondary aggregate formed by aggregating thermally anisotropic boron nitride crystals, in which thermal conductivity differs depending on a direction, so as to be isotropic;

a step C of disposing the resin sheet for sealing on the electronic device of the laminated product;

a step D of embedding the electronic device apparatus into the resin sheet for sealing; and

a step E of, after the step D, heating the resin sheet for sealing while maintaining the laminated product and the resin sheet for sealing in a pressurized state in a direction in which the laminated product and the resin sheet for sealing are moved closer to each other, to subject the resin sheet for sealing to primary thermal curing.

[0009]

According to the constitution, the resin sheet for sealing contains the secondary aggregate formed by aggregating thermally anisotropic boron nitride crystals, in which thermal conductivity differs depending on a direction, so as to be isotropic. Therefore, the thermal conductivity of the resin sheet for sealing can be improved.

The electronic device is embedded into the resin sheet for sealing (step D), and the resin sheet for sealing is then

heated while the laminated product and the resin sheet for sealing are maintained in a pressurized state in a direction in which the laminated product and the resin sheet for sealing are moved closer to each other, to subject the resin sheet for sealing to primary thermal curing (step E).

The present inventors have found the following. If the resin sheet for sealing is heated with no pressure applied after the step D, that is, after the electronic device is embedded into the resin sheet for sealing, to subject the resin sheet for sealing to primary thermal curing, the resin sheet for sealing is hardly thermally cured, and therefore, the resin sheet for sealing is cured in a state where the thickness of the resin sheet for sealing deformed so as to be decreased with pressure during embedding is returned to be slightly increased (spring back state). It is inferred that the distance between the secondary aggregates is increased by the spring back as compared with the distance during embedding, and this causes inhibition of an improvement in thermal conductivity.

Further according to the constitution, after the electronic device is embedded into the resin sheet for sealing, the resin sheet for sealing is heated to subject the resin sheet for sealing to primary thermal curing, while maintaining the laminated product and the resin sheet for sealing in a pressurized state in a direction in which the laminated product and the resin sheet for sealing are moved closer to each other so as to suppress

the spring back. Therefore, the distance between the secondary aggregates is suppressed from being increased as compared with the distance during embedding, and this can provide an improvement in thermal conductivity.

The primary thermal curing refers to thermal curing causing no spring back even when the pressurization is released after the primary thermal curing, or thermal curing having little influence of the spring back. The primary thermal curing may not be perfect thermal curing.

[0010]

In the constitution, the step E includes a condition in which the thermal conductivity is 0.8 or more when the thermal conductivity of the resin sheet for sealing after being thermally cured at a temperature of 150°C under pressure of 3 MPa for 1 hour is defined as 1.

[0011]

The condition of thermal curing at a temperature of 150°C under pressure of 3 MPa for 1 hour is a condition supposing the case where the resin sheet for sealing is completely thermally cured in a pressurizing condition in which the spring back does not occur.

If the condition of the step E is a condition in which the thermal conductivity is 0.8 or more when the thermal conductivity of the resin sheet for sealing after being thermally cured at a temperature of 150°C under pressure of 3 MPa for 1

hour is defined as 1, the thermal conductivity can be set to 0.8 or more as compared with the case where the spring back does not occur, even when the spring back is caused. Therefore, the thermal conductivity can be more suitably improved.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

Fig. 1 is a sectional view schematically showing a resin sheet for sealing according to one embodiment of the present invention.

Fig. 2A schematically shows one step of a method for manufacturing an electronic device apparatus according to one embodiment of the present invention.

Fig. 2B schematically shows one step of a method for manufacturing an electronic device apparatus according to one embodiment of the present invention.

Fig. 2C schematically shows one step of a method for manufacturing an electronic device apparatus according to one embodiment of the present invention.

Fig. 2D schematically shows one step of a method for manufacturing an electronic device apparatus according to one embodiment of the present invention.

Fig. 2E schematically shows one step of a method for manufacturing an electronic device apparatus according to one embodiment of the present invention.

## MODE FOR CARRYING OUT THE INVENTION

[0013]

Hereinafter, the present invention will be described in detail with reference to embodiments, but the present invention is not limited only to these embodiments.

[0014]

Hereinafter, first, a resin sheet for sealing will be described, and a method for manufacturing an electronic device apparatus including the resin sheet for sealing will be then described.

[0015]

[Resin Sheet for Sealing]

[0016]

Fig. 1 is a sectional view schematically showing a resin sheet for sealing according to one embodiment of the present invention (hereinafter, sometimes simply referred to as a "resin sheet"). A resin sheet 11 is typically provided in a state of being laminated on a separator 11a such as a polyethylene terephthalate (PET) film. The separator 11a may be subjected to a mold release treatment for easily peeling off the resin sheet 11.

[0017]

The resin sheet 11 preferably has a coefficient of thermal conductivity after thermal curing of 3 W/m·K or more, more

preferably 4 W/m·K or more, and still more preferably 5 W/m·K or more. When the resin sheet 11 has a coefficient of thermal conductivity after thermal curing of 3 W/m·K or more, the resin sheet 11 has excellent thermal conductivity. As described below, a method for setting the coefficient of thermal conductivity after thermal curing at 3 W/m·K or more can be achieved by adding a first filler.

In the present invention, the "coefficient of thermal conductivity after thermal curing" means a coefficient of thermal conductivity after heating the resin sheet at 90°C under a pressure of 3 MPa for 5 minutes, and further heating the resin sheet at 150°C for 30 minutes.

[0018]

The resin sheet 11 contains a secondary aggregate formed by aggregating thermally anisotropic boron nitride crystals, in which thermal conductivity differs depending on a direction, so as to be isotropic (hereinafter, such a secondary aggregate is referred to as "a first filler").

The resin sheet 11 preferably contains a second filler different from the first filler, in addition to the first filler.

[0019]

The average particle size of the first filler is preferably 1  $\mu\text{m}$  or more and 80  $\mu\text{m}$  or less, and more preferably 3  $\mu\text{m}$  or more and 70  $\mu\text{m}$  or less. By setting the average particle size of the first filler at 1  $\mu\text{m}$  or more, suitable thermal conductivity can

be given to the resin sheet. On the other hand, by setting the average particle size of the first filler at 80  $\mu\text{m}$  or less, the thickness of the electronic device apparatus manufactured using the resin sheet 11 is easily decreased.

[0020]

The maximum particle size of the first filler is preferably 200  $\mu\text{m}$  or less, and more preferably 180  $\mu\text{m}$  or less. By setting the maximum particle size of the first filler at 200  $\mu\text{m}$  or less, the thickness of the electronic device apparatus is more easily decreased.

In the present description, the average particle size and maximum particle size of the filler mean values measured with a laser diffraction particle size distribution measuring device.

[0021]

The shape of the first filler, that is, the shape of the secondary aggregate is not limited to a spherical shape as long as thermal isotropy is secured. The secondary aggregate may have other shapes such as a scale shape. However, considering that the blending amount of the secondary aggregate can be increased while the flowability of a thermosetting resin is secured at the time of manufacture of the resin sheet 11, the secondary aggregate preferably has a spherical shape. When the first filler has a shape other than the spherical shape, the average particle size means the length of a long side in the shape.

[0022]

The secondary aggregate can be manufactured in accordance with a known method using the predetermined crystals of boron nitride. Specifically, the predetermined crystals of boron nitride are fired to produce a fired product, and the fired product is crushed. Alternatively, the predetermined crystals of boron nitride are aggregated according to a known method such as spray drying to produce an aggregated product, and the aggregated product is then fired for sintering (grain growth). Herein, the firing temperature is not particularly limited, but is generally 2,000°C.

[0023]

Known products can be used as the secondary aggregate. Specific examples of the products include "PT" series (for example, "PTX60") manufactured by Momentive Performance Materials Japan Inc., "HP series" (for example, "HP-40") manufactured by Mizushima Ferroalloy Co., Ltd., and "SHOBN UHP" series (for example, "SHOBN UHP-EX") manufactured by Showa Denko K.K.

[0024]

The second filler is not particularly limited as long as it is different from the first filler. However, it is preferable that the second filler has some degree of thermal conductivity or can give functions other than thermal conductivity to the resin sheet 11. Examples of the second filler include metal

nitrides such as aluminum nitride, silicon nitride, and gallium nitride; metal oxides such as silica dioxide, aluminum oxide, magnesium oxide, titanium oxide, zinc oxide, tin oxide, copper oxide, and nickel oxide; hydroxides such as aluminum hydroxide, boehmite, magnesium hydroxide, calcium hydroxide, zinc hydroxide, silicic acid, iron hydroxide, copper hydroxide, and barium hydroxide; hydrated metal oxides such as zirconium oxide hydrate, tin oxide hydrate, basic magnesium carbonate, hydrotalcite, dawsonite, borax, and zinc borate; and silicon carbide, calcium carbonate, barium titanate, and potassium titanate. Among these, at least one of alumina and molten silica is preferable.

Alumina (aluminum oxide,  $\text{Al}_2\text{O}_3$ ) has a relatively high coefficient of thermal conductivity (36 W/m·K) which is lower than that of boron nitride. The resin does not enter alumina particles which are not an aggregate. Thus, alumina is less likely to cause the high viscosity and high elastic modulus of the sheet than the case where the secondary aggregate is used. That is, when the resin sheet contains the secondary aggregate of boron nitride, for example, resin enters into voids in the secondary aggregate, which causes problems in that the sheet is hard and brittle, and has poor followability. However, the use of alumina as the second filler makes it possible to maintain high thermal conductivity while reducing the high viscosity and high elastic modulus of the sheet.

The molten silica has a low linear expansion coefficient ( $0.5 \times 10^{-6}/K$ ), which is similar to that of a semiconducting material. Therefore, the use of the molten silica as the second filler can further suppress the warpage of the electronic device apparatus.

When both the alumina and the molten silica are used, effects of both the compounds can be exhibited.

[0025]

The average particle size of the second filler is not particularly limited, and is  $0.005 \mu\text{m}$  or more and  $80 \mu\text{m}$  or less, for example. The maximum particle size of the second filler can be set to  $200 \mu\text{m}$  or less, for example. The shape of the second filler is not also particularly limited, and may be a spherical shape, for example.

[0026]

The content of the first filler is preferably 20% by volume or more and 80% by volume or less, and more preferably 25% by volume or more and 75% by volume or less, based on the whole resin sheet 11. By setting the content at 20% by volume or more, suitable thermal conductivity can be given to the resin sheet. By setting the content at 80% by volume or less, the extremely high viscosity and extremely high elastic modulus of the sheet can be suppressed.

[0027]

The content of the second filler differs depending on the

materials to be selected, and is preferably 5% by volume or more and 65% by volume or less, and more preferably 10% by volume or more and 60% by volume or less, based on the whole resin sheet 11.

[0028]

The total content of the first filler and the second filler is preferably 25% by volume or more and 85% by volume or less, and more preferably 30% by volume or more and 80% by volume or less, based on the whole resin sheet 11.

[0029]

The resin sheet 11 preferably contains a thermosetting resin and a thermoplastic resin.

[0030]

The thermosetting resin is preferably an epoxy resin and a phenol resin. These resins give good thermosetting properties.

[0031]

The epoxy resin is not particularly limited. The resin may be an epoxy resin that may be of various types, examples thereof including triphenylmethane type epoxy resin, cresol novolak type epoxy resin, biphenyl type epoxy resin, modified bisphenol A type epoxy resin, bisphenol A type epoxy resin, bisphenol F type epoxy resin, modified bisphenol F type epoxy resin, dicyclopentadiene type epoxy resin, phenol novolak type epoxy resin, and phenoxy resin. These epoxy resins may be singly

or in any combination of two or more thereof.

[0032]

From the viewpoint of securing the reactivity of the epoxy resin, it is preferable that the epoxy resin has an epoxy equivalent of 150 to 250 and a softening point or melting point of 50 to 130°C, and is solid at normal temperature. Among such epoxy resins, a triphenylmethane type epoxy resin, a cresol novolac type epoxy resin, and a biphenyl type epoxy resin are more preferable from the viewpoint of reliability. A bisphenol F type epoxy resin is preferable because it can give flexibility to the thermosetting resin sheet 11.

[0033]

The phenol resin is not particularly limited as far as the resin is a phenol resin which is combined with the epoxy resin to cause a setting reaction between the two resins. Examples thereof include phenol novolac resin, phenol aralkyl resin, biphenyl aralkyl resin, dicyclopentadiene type phenol resin, cresol novolac resin and resol resin. These phenol resins may be used singly or in any combination of two or more thereof.

[0034]

From the viewpoint of reactivity with the epoxy resin, the phenol resin used preferably has a hydroxyl equivalent of 70 to 250 and a softening point of 50 to 110°C. From the viewpoint of high curing reactivity, a phenol novolac resin can be suitably used. From the viewpoint of reliability, phenol resins having

low hygroscopic properties such as a phenol aralkyl resin and a biphenyl aralkyl resin can also be suitably used.

[0035]

About the blend ratio between the epoxy resin and the phenol resin, the phenol resin is blended with the epoxy resin to set the total amount of hydroxyl groups in the phenol resin into the range of 0.9 to 1.2 equivalents per equivalent of epoxy groups in the epoxy resin.

[0036]

The content of the thermosetting resin in 100% by weight of all the ingredients other than the filler is preferably 70% by weight or more, more preferably 75% by weight or more, and still more preferably 80% by weight or more. When the content is 70% by weight or more, the CTE<sub>1</sub> of the cured product can be decreased. On the other hand, the content of the thermosetting resin is preferably 95% by weight or less, more preferably 92% by weight or less, still more preferably 90% by weight or less, and particularly preferably 88% by weight or less.

[0037]

The resin sheet 11 preferably contains a curing accelerator.

[0038]

The curing accelerator is not particularly limited as long as the curing accelerator advances the curing of the epoxy resin and the phenol resin. Examples of the curing accelerator include

imidazole-based curing accelerators such as 2-methylimidazole (trade name: 2MZ), 2-undecylimidazole (trade name: C11-Z), 2-heptadecylimidazole (trade name: C17Z), 1,2-dimethylimidazole (trade name: 1.2DMZ), 2-ethyl-4-methylimidazole (trade name: 2E4MZ), 2-phenylimidazole (trade name: 2PZ), 2-phenyl-4-methylimidazole (trade name: 2P4MZ), 1-benzyl-2-methylimidazole (trade name: 1B2MZ), 1-benzyl-2-phenylimidazole (trade name: 1B2PZ), 1-cyanoethyl-2-methylimidazole (trade name: 2MZ-CN), 1-cyanoethyl-2-undecylimidazole (trade name: C11Z-CN), 1-cyanoethyl-2-phenylimidazoliumtrimellitate (trade name: 2PZCNS-PW), 2,4-diamino-6-[2'-methylimidazolyl-(1')]-ethyl-s-triazine (trade name: 2MZ-A), 2,4-diamino-6-[2'-undecylimidazolyl-(1')]-ethyl-s-triazine (trade name: C11Z-A), 2,4-diamino-6-[2'-ethyl-4'-methylimidazolyl-(1')]-ethyl-s-triazine (trade name: 2E4MZ-A), a 2,4-diamino-6-[2'-methylimidazolyl-(1')]-ethyl-s-triazine isocyanuric acid adduct (trade name: 2MA-OK), 2-phenyl-4,5-dihydroxymethylimidazole (trade name: 2PHZ-PW), and 2-phenyl-4-methyl-5-hydroxymethylimidazole (trade name: 2P4MHZ-PW) (all manufactured by Shikoku Chemicals Corporation).

[0039]

Among these, 2-phenyl-4,5-dihydroxymethylimidazole and 2-phenyl-4-methyl-5-hydroxymethylimidazole are preferable. Since 2-phenyl-4,5-dihydroxymethylimidazole advances curing at high temperature, it can suppress curing caused by heat in an embedding step. Meanwhile, 2-phenyl-4-methyl-5-hydroxymethylimidazole advances curing at comparatively low temperature, and is suitable when thermal curing is desired to be promptly advanced after the embedding step.

[0040]

The content of the curing accelerator is preferably 0.2 parts by weight or more, more preferably 0.5 parts by weight or more, and still more preferably 0.8 parts by weight or more, based on the total of 100 parts by weight of the epoxy resin and the phenol resin. The content of the curing accelerator is preferably 5 parts by weight or less, and more preferably 2 parts by weight or less, based on the total of 100 parts by weight of the epoxy resin and the phenol resin.

[0041]

The resin sheet 11 preferably contains a thermoplastic resin. The thermoplastic resin can improve the heat resistance, flexibility, and strength of the obtained resin sheet for sealing. A thermoplastic resin capable of serving as an elastomer is preferable.

[0042]

Examples of the thermoplastic resin include an acrylic elastomer, a urethane-based elastomer, a silicone-based elastomer, and a polyester-based elastomer. Among these, from the viewpoint of easily obtaining flexibility, and providing good dispersibility with the epoxy resin, the acrylic elastomer is preferable.

[0043]

The acrylic elastomer is not particularly limited, and may be a polymer (acrylic copolymer) made from components including one or more acrylates or methacrylates (each) having a linear or branched alkyl group having 30 or less carbon atoms, particularly, 4 to 18 carbon atoms. Examples of the alkyl group include methyl, ethyl, propyl, isopropyl, n-butyl, t-butyl, isobutyl, amyl, isoamyl, hexyl, heptyl, cyclohexyl, 2-ethylhexyl, octyl, isooctyl, nonyl, isononyl, decyl, isodecyl, undecyl, lauryl, tridecyl, tetradecyl, stearyl, octadecyl, and dodecyl groups.

[0044]

One or more different monomers that are combined with the (meth)acrylate(s) to produce the polymer are not particularly limited. Examples thereof include carboxyl-group-containing monomers, such as acrylic acid, methacrylic acid, carboxyethyl acrylate, carboxypentyl acrylate, itaconic acid, maleic acid, fumaric acid, and crotonic acid; acid anhydride monomers, such as maleic anhydride, and itaconic anhydride;

hydroxyl-group-containing monomers, such as 2-hydroxyethyl (meth)acrylate, 2-hydroxypropyl (meth)acrylate, 4-hydroxybutyl (meth)acrylate, 6-hydroxyhexyl (meth)acrylate, 8-hydroxyoctyl (meth)acrylate, 10-hydroxydecyl (meth)acrylate, 12-hydroxylauryl (meth)acrylate, and (4-hydroxymethylcyclohexyl)-methyl acrylate; sulfonic-acid-group-containing monomers, such as styrenesulfonic acid, allylsulfonic acid, 2-(meth)acrylamide-2-methylpropanesulfonic acid, (meth)acrylamidepropanesulfonic acid, sulfopropyl (meth)acrylate, and (meth)acryloyloxynaphthalenesulfonic acid; and phosphate-group-containing monomers, such as 2-hydroxyethylacryloyl phosphate. It is particularly preferred that the different monomer(s) is/include at least one selected from carboxyl-group-containing monomers, glycidyl-group-containing (epoxy-group-containing) monomers, and hydroxyl-group-containing monomers since the different monomer(s) can react with the epoxy resin to heighten the resin sheet 11 in viscosity.

[0045]

The thermoplastic resin may have a functional group. The functional group is preferably a carboxyl group, an epoxy group, a hydroxyl group, an amino group, and a mercapto group, and more preferably a carboxyl group.

[0046]

The weight average molecular weight of the thermoplastic resin is preferably 500,000 or more, and more preferably 800,000 or more. On the other hand, the weight average molecular weight of the thermoplastic resin is preferably 2,000,000 or less, and more preferably 1,500,000 or less. When the weight average molecular weight is within the above-mentioned range, the viscosity of the thermoplastic resin is moderate, which provides easy handling during blending.

The weight average molecular weight is measured by GPC (Gel Permeation Chromatography) and the value is expressed in terms of polystyrene.

[0047]

The content of the thermoplastic resin in 100% by weight of all the ingredients other than the filler is preferably 5% by weight or more, more preferably 10% by weight or more, still more preferably 11% by weight or more, yet still more preferably 12% by weight or more, and especially yet still more preferably 13% by weight or more. When the content is 5% by weight or more, the plasticity and flexibility of the resin sheet are obtained. On the other hand, the content of the thermoplastic resin is preferably 30% by weight or less, and more preferably 20% by weight or less. When the content is 30% by weight or less, both embedding properties and regulation of flow can be achieved without excessively increasing the storage elastic modulus of the resin sheet 11.

[0048]

The resin sheet 11 may contain a flame retardant, as required. This case makes it possible to decline burning expansion when the sheet catches fire by a short circuit or heat-generation of the member concerned. Examples of the flame retardant include various metal hydroxides such as aluminum hydroxide, magnesium hydroxide, iron hydroxide, calcium hydroxide, tin hydroxide, and complex metal hydroxides; and phosphazene flame retardants.

[0049]

The resin sheet 11 may contain a silane coupling agent. Examples of the silane coupling agent include, but are not particularly limited to, 3-glycidoxypropyltrimetoxysilane.

[0050]

The content of the silane coupling agent in the resin sheet 11 is preferably 0.1 to 3% by weight. When the content is 0.1% by weight or more, the hardness of the resin sheet after curing can be increased, and the water absorption rate thereof can be reduced. On the other hand, when the content is 3% by weight or less, the generation of the outgas can be suppressed.

[0051]

The resin sheet 11 preferably contains a pigment. The pigment is not particularly limited, and may be, for example, carbon black.

[0052]

The content by percentage of the pigment in the resin sheet 11 is preferably from 0.1 to 2% by weight. When the content by percentage is 0.1% or more by weight, the sheet gains a good marking performance. When the content by percentage is 2% or less by weight, the resin sheet can ensure strength after cured.

[0053]

An additional additive other than the above-mentioned individual components may be appropriately blended into the resin composition, as required.

[0054]

[Method for Manufacturing Resin Sheet for Sealing]

The resin sheet 11 can be formed by dissolving and dispersing a resin for forming the resin sheet 11 in a suitable solvent to prepare a varnish, applying the varnish at a predetermined thickness onto the separator 11a to form a coating film, and thereafter drying the coating film under a predetermined condition. A laminate of a plurality of resin sheets may be subjected to hot pressing (for example, 60 seconds at 90°C) as necessary to provide the resin sheet 11 having a desired thickness. Examples of the coating method include, but are not particularly limited to, roll coating, screen coating, and gravure coating. As drying conditions, the drying is performed at a drying temperature of 70 to 160°C and a drying time of 1 to 30 minutes, for example. The varnish may be applied to a separator to form a coating film, and then the coating film

may be dried in the above-mentioned drying conditions to form the resin sheet 11. Then, the resin sheet 11 is pasted on the separator 11a together with the separator. Particularly when the resin sheet 11 contains a thermoplastic resin (acrylic resin), an epoxy resin, and a phenol resin, all the resins are dissolved in a solvent to produce a solution, and the solution is applied and dried. Examples of the solvent include methyl ethyl ketone, ethyl acetate, and toluene.

[0055]

The thickness of the resin sheet 11 is not particularly limited, but is preferably 100 to 2000  $\mu\text{m}$ , and more preferably 110 to 1800  $\mu\text{m}$ , for example. When the thickness is within the above-mentioned range, the electronic device can be satisfactorily sealed.

[0056]

The resin sheet 11 may have a monolayer structure or a multilayer structure obtained by laminating two or more resin sheets having different compositions. However, the resin sheet 11 preferably has a monolayer structure since such a resin sheet causes no interlayer peeling, has high sheet thickness uniformity, and is easy to have low hygroscopic properties.

[0057]

The resin sheet 11 is used for sealing a SAW (Surface Acoustic Wave) filter; MEMS (Micro Electro Mechanical Systems) such as a pressure sensor and a vibration sensor; ICs such as

LSI and semiconductors such as a transistor and a semiconductor chip; capacitors; resistors; and electronic devices such as a CMOS sensor. Among these, the resin sheet 11 can be suitably used for sealing an electronic device requiring hollow sealing (specifically, a SAW filter and MEMS), and can be particularly suitably used for sealing a SAW filter.

[0058]

[Method for Manufacturing Hollow Package]

Figs. 2A to 2E each schematically show one step of a method for manufacturing an electronic device apparatus according to one embodiment of the present invention.

In the present embodiment, the case where the electronic device apparatus is a hollow package will be described. Specifically, the case where a SAW chip 13 mounted on a printed wiring board 12 is subjected to hollow sealing with a resin sheet 11 to manufacture a hollow package will be described. However, the present invention is not limited to this example, and the same method can be employed also for manufacturing an electronic device apparatus having no hollow portion.

[0059]

(SAW Chip Mounting Substrate Providing Step)

In a method for manufacturing a hollow package according to the present embodiment, first, as shown in Fig. 2A, a laminate 15 is prepared, which includes a printed wiring board 12 and a plurality of SAW chips 13 mounted on the printed wiring board

12 (step A).

The SAW chip 13 corresponds to the electronic device of the present invention. The printed wiring board 12 corresponds to a support of the present invention.

The SAW chips 13 can be formed by dicing a piezoelectric crystal, on which a predetermined comb-shaped electrode is formed, into individual pieces by a known method. For mounting the SAW chips 13 onto the printed wiring board 12, a known device such as a flip chip bonder or a die bonder can be used. The SAW chip 13 and the printed wiring board 12 are electrically connected via a projecting electrode 13a such as a bump. Between the SAW chip 13 and the printed wiring board 12, a hollow portion 14 is maintained so that the propagation of the surface elastic wave on the surface of the SAW filter is not impaired. The distance between the SAW chip 13 and the printed wiring board 12 (the width of the hollow portion) can be suitably set, and is generally about 10 to 100  $\mu\text{m}$ .

[0060]

(Resin Sheet Providing Step)

A resin sheet 11 is provided in a method for manufacturing a hollow package according to the present embodiment (step B). As described above, the resin sheet 11 contains the secondary aggregate of thermally anisotropic boron nitride crystals that have different coefficients of thermal conductivity by direction and that are aggregated so as to be isotropic.

[0061]

(Resin Sheet Disposing Step)

Next, as shown in Fig. 2B, the laminate 15 is disposed on a lower heating plate 41 in a state where a surface of the laminate 15 on which the SAW chips 13 are mounted faces up, and the resin sheet 11 is disposed on the surface of the SAW chips 13 (step C). In this step, the laminate 15 may be first disposed on the lower heating plate 41, and the resin sheet 11 may be then disposed on the laminate 15. Alternatively, the resin sheet 11 may be first laminated on the laminate 15, and a laminated product including the laminate 15 and the resin sheet 11 laminated on the laminate 15 may be then disposed on the lower heating plate 41. It is preferable that the separator 11a is not peeled off at this stage.

[0062]

(Embedding Step)

Next, as shown in Fig. 2C, heat pressing is carried out by the lower heating plate 41 and an upper heating plate 42, to embed the SAW chips 13 in the resin sheet 11 (step D). The embedding step means a step until all the SAW chips 13 are embedded after the embedding of the SAW chips 13 is started.

[0063]

For heat pressing conditions when the SAW chips 13 are embedded in the resin sheet 11, it is preferable that the SAW chips 13 can be suitably embedded in the resin sheet 11. The

temperature is, for example, 40 to 150°C, and preferably 60 to 120°C. The pressure is, for example, 0.1 to 10 MPa, and preferably 0.5 to 8 MPa.

In view of improvements in the tackiness and followability of the resin sheet 11 to the SAW chips 13 and the printed wiring board 12, pressing is preferably carried out under decompression conditions. As the decompression conditions, the pressure is preferably 0.1 to 5 kPa, for example, and more preferably 0.1 to 100 Pa.

[0064]

(Primary Thermal Curing Step)

After the embedding step, the resin sheet 11 is heated while the laminate 15 and the resin sheet 11 are kept being pressurized in a direction in which the laminate 15 and the resin sheet 11 come closer to each other, to subject the resin sheet 11 to primary thermal curing (step E). In this way, a sealed product 16 is obtained.

The present inventors found the following. When the resin sheet for sealing is heated without the pressure after the step D, that is, after the electronic device is embedded in the resin sheet for sealing, to subject the resin sheet for sealing to primary thermal curing, the resin sheet 11 is hardly thermally cured, and therefore, the resin sheet 11 is cured to have a little larger thickness (springback state) as compared to the thickness of the resin sheet 11 when being deformed to have a smaller

thickness due to the pressure during the embedding step. It was inferred that the distance between the secondary aggregates is increased by the springback as compared with that during embedding, which inhibited an improvement in thermal conductivity.

On the other hand, according to the present embodiment, after the SAW chips 13 are embedded in the resin sheet 11, the resin sheet 11 is heated while being maintained in a state where the laminate 15 and the resin sheet 11 are pressurized in a direction in which the laminate 15 and the resin sheet 11 come closer to each other so that the springback is suppressed, to subject the resin sheet 11 to primary thermal curing. Therefore, the distance between the secondary aggregates is prevented from being increased as compared with that during embedding, which can provide an improvement in thermal conductivity.

The primary thermal curing means thermal curing causing no springback even when the pressure is released after the primary thermal curing, or thermal curing having little influence of the springback. The primary thermal curing does not have to be complete thermal curing.

As for the pressurization in the primary thermal curing step, the pressure in the embedding step may be released once, followed by performing pressurization anew. Alternatively, the pressurization in the primary thermal curing step may be performed without releasing the pressurization during the

embedding step.

As the conditions of the primary thermal curing step (step E), when the coefficient of thermal conductivity of the resin sheet 11 after being thermally cured at a temperature of 150°C under a pressure of 3 MPa for 1 hour is defined as 1, the coefficient of thermal conductivity is preferably 0.8 or more, and more preferably 0.85 or more.

The conditions of thermal curing at a temperature of 150°C under a pressure of 3 MPa for 1 hour are conditions simulating the case where the resin sheet for sealing is completely thermally cured in a pressurized condition that does not cause the springback.

If the conditions of the step E are conditions in which, when the coefficient of thermal conductivity of resin sheet 11 after being thermally cured at a temperature of 150°C under a pressure of 3 MPa for 1 hour is defined as 1, the coefficient of thermal conductivity is 0.8 or more, the coefficient of thermal conductivity can be set to 0.8 or more as compared with the case where the springback does not occur even when the springback is caused. Therefore, the thermal conductivity can be more suitably improved.

The specific numerical value of each of the conditions of the step E can be suitably set according to the constituent material of the resin sheet 11. The pressure condition is preferably 0.01 to 20 MPa, and more preferably 0.05 to 18 MPa,

for example. The temperature condition of the step E is preferably 50 to 200°C, and more preferably 60 to 180°C, for example. The thermal curing time of the step E is preferably 10 seconds to 3 hours, and more preferably 20 seconds to 2 hours, for example.

[0065]

(Secondary Thermal Curing Treatment Step)

Next, the separator 11a is peeled off, and the resin sheet 11 is subjected to a secondary thermal curing treatment (see Fig. 2D). The secondary thermal curing treatment conditions can be suitably set according to the conditions of the primary thermal curing treatment and the constituent material of the resin sheet 11, but the heating temperature is preferably 100°C or more, and more preferably 120°C or more, for example. On the other hand, the upper limit of the heating temperature is preferably 200°C or less, and more preferably 180°C or less. The heating time is preferably 10 minutes or more, and more preferably 30 minutes or more. On the other hand, the upper limit of the heating time is preferably 180 minutes or less, and more preferably 120 minutes or less. The resin sheet 11 may be pressurized as necessary. The pressure is preferably 0.1 MPa or more, and more preferably 0.5 MPa or more. On the other hand, the upper limit of the pressure is preferably 10 MPa or less, and more preferably 5 MPa or less.

When the resin sheet 11 is completely thermally cured in

the primary thermal curing step, the secondary thermal curing treatment step does not have to be performed. The time for peeling off the separator 11a is not limited to after the primary thermal curing or before the secondary thermal curing.

[0066]

(Dicing Step)

Then, the sealed product 16 may be diced (see Fig. 2E). In this way, a hollow package 18 per the SAW chip 13 can be obtained.

[0067]

(Substrate Mounting Step)

A substrate mounting step of subjecting the hollow package 18 to rewiring and bump formation, and mounting the hollow package 18 on another substrate (not shown) can be performed as necessary. For mounting the hollow package 18 on the substrate, a known device such as a flip chip bonder or a die bonder can be used.

[0068]

In the above-mentioned embodiment, the case where the support of the present invention is the printed wiring board 12 is described. However, the support of the present invention is not limited to this example, and may be a ceramic substrate, a silicon substrate, or a metal substrate, for example.

Examples

[0069]

Hereinafter, preferred working examples of the present

invention will be demonstrated in detail. However, materials, blend amounts and others that are described in the examples do not limit the scope of this invention as far as the claims do not include a restricted recitation thereabout.

[0070]

Ingredients used in examples and comparative examples will be described.

Epoxy resin: YSLV-80XY manufactured by Nippon Steel Chemical Co., Ltd. (bisphenol F type epoxy resin, epoxy equivalent: 200 g/eq., softening point: 80°C)

Phenol resin: LVR8210DL manufactured by Gunee Chemical Industry Co., Ltd. (novolac type phenol resin, hydroxyl equivalent: 104 g/eq., softening point: 60°C)

Thermoplastic resin: ME-2000M manufactured by Negami Chemical Industrial Co., Ltd. (carboxyl group-containing acrylic ester-based polymer, weight average molecular weight: about 600,000, Tg: -35°C, acid value: 20 mgKOH/g)

Carbon blank: #20 manufactured by Mitsubishi Chemical Corporation

Filler 1: secondary aggregate of boron nitride (manufactured by Mizushima Ferroalloy Co., Ltd., trade name: HP-40 (average particle size: 40  $\mu\text{m}$ , maximum particle size: 180  $\mu\text{m}$ ))

Filler 2: Alumina (manufactured by Admatechs, trade name: AE-9104SME (average particle size: 3  $\mu\text{m}$ , maximum particle size:

10  $\mu\text{m}$ ))

Curing accelerator 1: 2P4MHZ-PW manufactured by Shikoku  
Chemicals Corporation

(2-phenyl-4-methyl-5-hydroxymethylimidazole)

[0071]

[Production of Resin Sheet for Sealing]

(Manufacturing Example 1)

According to the blending ratios described in Table 1, ingredients were dissolved and dispersed in methyl ethyl ketone as a solvent to obtain a varnish having a concentration of 90% by weight. The varnish was applied to a mold release-treated film formed of a polyethylene terephthalate film subjected to a silicone mold release treatment and having a thickness of 38  $\mu\text{m}$ , and then dried at 110°C for 3 minutes. The obtained sheets were laminated to obtain a thermosetting resin sheet having a thickness of 220  $\mu\text{m}$ .

[0072]

[Table 1]

|                                                        |                                                 | Manufacturing Example 1            |
|--------------------------------------------------------|-------------------------------------------------|------------------------------------|
| Composition                                            | Epoxy resin (YSLV-80XY)                         | 6.3% by weight                     |
|                                                        | Phenol resin (LVR8210DL)                        | 3.4% by weight                     |
|                                                        | Thermoplastic resin (ME-2000)                   | 2.6% by weight                     |
|                                                        | Carbon black (#20)                              | 0.4% by weight                     |
|                                                        | Filler 1 (secondary aggregate of boron nitride) | 25% by volume<br>(20.8% by weight) |
|                                                        | Filler 2 (alumina)                              | 45% by volume<br>(66.4% by weight) |
|                                                        | Curing accelerator 1 (2P4MHZ-PW)                | 0.1% by weight                     |
| Thickness of resin sheet for sealing ( $\mu\text{m}$ ) |                                                 | 220                                |

[0073]

(Measurement of Thermal Conductivity after Thermal Curing in Primary Thermal Curing Condition)

The resin sheet for sealing manufactured in Manufacturing Example 1 was thermally cured by heating the resin sheet for sealing while pressing the resin sheet for sealing in the primary thermal curing condition shown in Table 2. Examples and Comparative Examples were the same except that the primary thermal curing condition was changed, and the resin sheet for sealing manufactured in Manufacturing Example 1 was used.

Next, the coefficients of thermal conductivity of the resin sheets for sealing after thermal curing were measured. The

coefficient of thermal conductivity was obtained from the following formula. The results are shown in Table 2.

(Coefficient of thermal conductivity) = (thermal diffusion coefficient) × (specific heat) × (specific gravity)

[0074]

<Thermal Diffusion Coefficient>

Each of the resins sheets for sealing was heated in the primary thermal curing condition shown in Table 2. The thermal diffusion coefficient was measured using a xenon flash process heat measuring device ("LFA447 NanoFlash" manufactured by NETZSCH Japan K.K.) using this sample.

[0075]

<Specific Heat>

The specific heat was obtained by a measuring method according to the standard of JIS-7123 using a DSC (Q-2000 manufactured by TA Instruments).

[0076]

<Specific Gravity>

The specific gravity was measured by the Archimedes method using an electronic balance (AEL-200 manufactured by Shimadzu Corporation).

[0077]

(Evaluation of Thermal Conductivity)

The condition of thermal curing at a temperature of 150°C under pressure of 3 MPa for 1 hour in Example 1 is a condition

supposing the case where the resin sheet for sealing is completely thermally cured in a pressurizing condition in which the spring back does not occur.

Then, when the resin sheet for sealing having the same composition was used and only the primary thermal curing condition was changed, the extent of the thermal conductivity of the resin sheet for sealing was evaluated as compared with Example 1. Specifically, as compared with Example 1, i.e., the case where the resin sheet for sealing was completely thermally cured in primary thermal curing, the case where the thermal conductivity was 0.8 times or more was evaluated as O, and the case where the thermal conductivity was smaller than 0.8 times was evaluated as x. The results are shown in Table 2.

[0078]

[Table 2]

|                                                   |                  | Example 1 | Example 2 | Example 3 | Comparative Example 1 |
|---------------------------------------------------|------------------|-----------|-----------|-----------|-----------------------|
| Primary thermal curing condition                  | Temperature (°C) | 150       | 150       | 90        | 150                   |
|                                                   | Pressure (MPa)   | 3         | 1         | 3         | 0                     |
|                                                   | Time (hour)      | 1         | 1         | 0.1       | 1                     |
| Thermal conductivity after thermal curing (W/m·K) |                  | 5.1       | 4.6       | 4.6       | 3.9                   |
| Ratio to thermal conductivity of Example 1        |                  | 1.00      | 0.90      | 0.90      | 0.76                  |
| Evaluation of thermal conductivity                |                  | O         | O         | O         | x                     |

#### DESCRIPTION OF REFERENCE SIGNS

[0079]

11: resin sheet for hollow sealing

11a: support

13: SAW Chip

16: sealed product

18: hollow package

## CLAIMS

1. A method for manufacturing an electronic device apparatus, the method comprising:

a step A of preparing a laminated product including a support and an electronic device fixed on the support;

a step B of preparing a resin sheet for sealing containing a secondary aggregate formed by aggregating thermally anisotropic boron nitride crystals, in which thermal conductivity differs depending on a direction, so as to be isotropic;

a step C of disposing the resin sheet for sealing on the electronic device of the laminated product;

a step D of embedding the electronic device into the resin sheet for sealing; and

a step E of, after the step D, heating the resin sheet for sealing while maintaining the laminated product and the resin sheet for sealing in a pressurized state in a direction in which the laminated product and the resin sheet for sealing are moved closer to each other, to subject the resin sheet for sealing to primary thermal curing.

2. The method for manufacturing an electronic device apparatus according to claim 1, wherein the step E includes a condition in which the thermal conductivity is 0.8 or more when

the thermal conductivity of the resin sheet for sealing after being thermally cured at a temperature of 150°C under pressure of 3 MPa for 1 hour is defined as 1.