

## DESCRIPTION

HEAT-RESISTANT THERMALLY CONDUCTIVE COMPOSITION AND  
HEAT-RESISTANT THERMALLY CONDUCTIVE SHEET

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## Technical Field

[0001] The present invention relates to a heat-resistant thermally conductive composition and a heat-resistant thermally conductive sheet suitable for being interposed between a heat generating part and a heat dissipater of an electrical component, an electronic component or the like.

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## Background Art

[0002] Recently, the performance of semiconductors such as CPUs has improved appreciably, and the amounts of heat generated by the semiconductors have increased enormously. To cope with this, heat dissipaters are attached to electronic components that generate heat, and thermally conductive silicone sheets are adopted to improve the contact between the semiconductors and the heat dissipaters. Further, along with the size reduction, high performance, and high integration of devices, the thermally conductive silicone sheets are required to have softness and high thermal conductive properties. Conventionally, Patent Documents 1 to 4 propose thermally conductive silicone gel sheets.

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## Prior Art Documents

## Patent Documents

25 [0003] Patent Document 1: JPWO 2018-016566 A1

Patent Document 2: JP 5931129 B2

Patent Document 3: WO 2018/074247 A1

Patent Document 4: JP 2017-210518 A

30 Disclosure of Invention

## Problem to be Solved by the Invention

[0004] However, conventional thermally conductive silicone sheets have relatively

high heat resistance, but still have been required to have higher heat resistance. Specifically, highly thermally conductive silicone sheets become hard at high temperature due to an increase in the amount of a filler filled or the use of a highly thermally conductive filler, and thus need to be improved.

5           Moreover, in the semiconductor field, the contamination by metal impurities has been a problem, and thus there has been a demand for heat-dissipating members that do not contain a heat resistance improver or a pigment made of a metal oxide or a metal complex.

[0005] To solve the above conventional problems, the present invention provides a  
10   heat-resistant thermally conductive composition and a heat-resistant thermally conductive sheet that use a heat resistance improver containing no metal atom and that are less likely to become hard at high temperature.

#### Means for Solving Problem

15   [0006] A heat-resistant thermally conductive composition of the present invention contains a matrix resin and thermally conductive particles. The heat-resistant thermally conductive composition contains a benzimidazolone compound as a heat resistance improver.

[0007] A heat-resistant thermally conductive sheet of the present invention includes  
20   the heat-resistant thermally conductive composition in the form of a sheet.

#### Effects of the Invention

[0008] In the present invention, the heat-resistant thermally conductive composition contains a matrix resin and thermally conductive particles, and contains a  
25   benzimidazolone compound as a heat resistance improver. Thus, the present invention can provide the heat-resistant thermally conductive composition and the heat-resistant thermally conductive sheet that are less likely to become hard at high temperature. The benzimidazolone compound is usually known to be added as a pigment, but exhibits unpredictable effects of improving heat resistance. Moreover,  
30   the heat-resistant thermally conductive composition and the heat-resistant thermally conductive sheet use the heat resistance improver containing no metal atom and are less likely to become hard at high temperature. Thus, they are largely advantageous

for electrical components and electronic components.

#### Brief Description of Drawings

[0009] [FIG. 1] FIGS. 1A to 1B are diagrams illustrating a method of measuring a  
5 thermal conductivity of a sample in an example of the present invention.

#### Description of the Invention

[0010] The present invention relates to a heat-resistant thermally conductive composition that contains a matrix resin and thermally conductive particles and that  
10 contains a benzimidazolone compound as a heat resistance improver. It is preferable that the matrix resin includes thermosetting resins such as silicone rubber, silicone gel, acrylic rubber, fluorocarbon rubber, epoxy resin, phenol resin, unsaturated polyester resin, melamine resin, acrylic resin, silicone resin, and fluorocarbon resin. Among these, silicone is preferred because of its high heat resistance, and may be selected  
15 from elastomer, gel, putty, grease, and oil. Any curing system such as a peroxide system, an addition system, or a condensation system may be used. Moreover, an addition-curable silicone polymer is preferred because the addition-curable silicone polymer is not corrosive to the surroundings, releases less by-products outside the system, and is cured to its core reliably.

20 [0011] It is preferable that the thermally conductive particles are inorganic particles such as alumina, zinc oxide, magnesium oxide, aluminum nitride, boron nitride, aluminum hydroxide, and silica. These inorganic particles may be added alone or in combination of two or more. If the matrix resin is 100 parts by mass, the thermally conductive particles are added preferably in an amount of 100 to 4000 parts by mass, and more preferably in an amount of 500 to 3000 parts by mass.

[0012] Part or all of the thermally conductive particles used in the present invention may be surface treated with a silane coupling agent. The silane coupling agent may be mixed with the thermally conductive particles in advance to pretreat the thermally conductive particles or may be added when the matrix resin, a curing catalyst, and the  
30 thermally conductive particles are mixed (integral blend method). In the case of the integral blend method, it is preferable that the silane coupling agent is added in an amount of 0.01 to 10 parts by mass with respect to 100 parts by mass of the thermally

conductive particles that are not surface treated and used for the heat-resistant thermally conductive composition of the present invention. The surface treated thermally conductive particles are easily incorporated into the matrix resin, prevent the curing catalyst from being adsorbed on the thermally conductive particles, and thus have the effects of preventing cure inhibition. This is useful for storage stability.

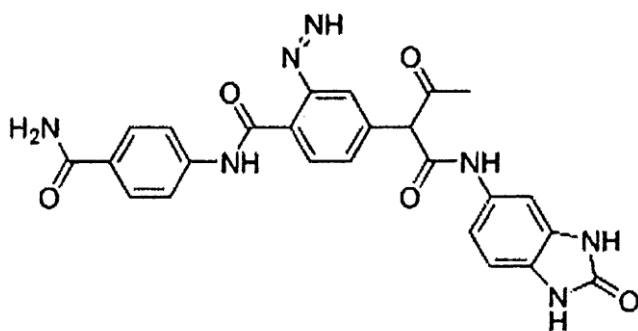
[0013] The benzimidazolone compound used in the present invention is added preferably in an amount of 0.001 to 5 parts by mass, more preferably in an amount of 0.001 to 3 parts by mass, and further preferably in an amount of 0.001 parts by mass or more and less than 0.5 parts by mass with respect to 100 parts by mass of the heat-resistant thermally conductive composition. If the amount is less than 0.001 parts by mass, the benzimidazolone compound has few effects of improving heat resistance. If the amount is more than 5 parts by mass, the benzimidazolone compound has heat resistance effects, but is disadvantageous in terms of cost.

[0014] The benzimidazolone compound has a benzimidazolone moiety in its skeleton and includes a benzimidazolone pigment. Examples of the benzimidazolone pigment include: Pigment Yellow 120 (hereinafter, PY), PY 151, PY 154, PY 175, PY 180, PY 181, and PY 194; Pigment Orange 36 (hereinafter, PO), PO 60, PO 62, and PO 72; Pigment Red 171 (hereinafter, PR), PR 175, PR 176, PR 185, and PR 208; Pigment Violet 32 (hereinafter, PV 32); and Pigment Brown 25 (hereinafter, PBr 25). The pigments are indicated by color index (C.I.) names and numbers jointly established by the Society of Dyers and Colourists and the American Association of Textile Chemists and Colorists. The structure of Pigment Yellow 181 as an example of the benzimidazolone pigment is expressed by the following formula (Chemical Formula 1).

The compound is expressed as

4'-carbamoyl-4-[1-(2,3-dihydro-2-oxo-1H-benzimidazol-5-ylcarbamoyl)acetonylazo]benz anilide. Although a mechanism in which the addition of the benzimidazolone compound improves heat resistance is not clear, it is considered that the compound absorbs or suppresses substances that may cause the thermal decomposition such as thermal radicals produced at high temperature.

[0015] [Chemical Formula 1]



[0016] The heat-resistant thermally conductive composition has an Asker C hardness of preferably 70 or less, and more preferably 50 or less after curing. The hardness (i.e., softness) of the composition is sufficient when the Asker C hardness is 70 or less.

5 [0017] In the present invention, the heat resistance is evaluated with a rate of increase in the Asker C hardness at a temperature of 150°C or 220°C after an exposure time of 250 hours or more. The rate of increase in the hardness is kept at preferably 80% or less, and more preferably 61% or less as compared with the case where the composition does not contain the benzimidazolone compound. If the rate of  
10 increase in the hardness is 80% or less, the heat resistance is sufficient for practical use.

[0018] It is preferable that the heat-resistant thermally conductive composition of the present invention is formed into a sheet. The heat-resistant thermally conductive composition in the form of a sheet is suitable for being mounted onto an electronic  
15 component or the like. The heat-resistant thermally conductive sheet has a thickness of preferably 0.2 to 10 mm. The heat-resistant thermally conductive sheet has a thermal conductivity of preferably 0.8 W/m·K or more, and more preferably 1.0 W/m·K or more. If the thermal conductivity is 0.8 W/m·K or more, the heat-resistant thermally conductive sheet is suitable for conducting heat from a heat generating part  
20 to a heat dissipater.

[0019] It is preferable that the heat-resistant thermally conductive composition has a dielectric breakdown voltage (JIS K6249) of 11 to 16 kV/mm. Thus, it is possible to obtain a heat-resistant thermally conductive sheet having high electrical insulation properties.

25 [0020] It is preferable that the heat-resistant thermally conductive composition has a volume resistivity (JIS K6249) of  $10^{10}$  to  $10^{14}$  Ω·cm. Thus, it is possible to obtain a

heat-resistant thermally conductive sheet having high electrical insulation properties.

[0021] It is preferable that the heat-resistant thermally conductive composition of the present invention contains the following components (A) to (E), and optionally the following components (F), (G), and (H), and is cured.

5 (A) Base polymer component: an organopolysiloxane having an average of two or more silicon atoms bonded to alkenyl groups per molecule.

(B) Crosslinking component: an organopolysiloxane having an average of two or more silicon atoms bonded to hydrogen atoms per molecule, in which the amount of the organopolysiloxane is 0.01 to 3 mol with respect to 1 mol of the alkenyl groups bonded  
10 to the silicon atoms in the component A.

(C) Catalyst component: a platinum group metal catalyst, in which the amount of the platinum group metal catalyst is 0.01 to 1000 ppm in terms of the weight unit of metal atoms with respect to the total amount of the component A and the platinum group metal catalyst.

15 (D) Thermally conductive particles: 100 to 4000 parts by mass with respect to 100 parts by mass of an addition-curable silicone polymer component (component A + component B).

(E) Benzimidazolone compound: 0.001 to 5 parts by mass with respect to 100 parts by mass of the heat-resistant thermally conductive composition.

20 (F) Alkyltrialkoxysilane may further be added in an amount of 0.1 to 10 parts by mass with respect to 100 parts by mass of the addition-curable silicone polymer component (component A + component B).

(G) An inorganic particle pigment may further be added in an amount of 0.1 to 10 parts by mass with respect to 100 parts by mass of the addition-curable silicone  
25 polymer component (component A + component B).

(H) An organopolysiloxane having no addition curing reaction group may further be added in an amount of 0.5 to 50 parts by mass with respect to 100 parts by mass of the addition-curable silicone polymer (component A + component B).

[0022] Hereinafter, each component will be described.

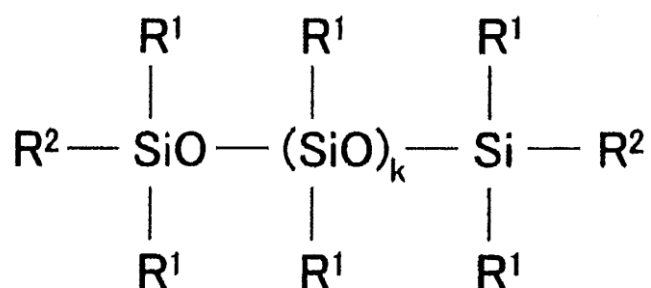
30 (1) Base polymer component (component A)

The base polymer component is an organopolysiloxane having two or more alkenyl groups bonded to silicon atoms per molecule. The organopolysiloxane

containing two alkenyl groups is the base resin (base polymer component) of a silicone gel composition of the present invention. In the organopolysiloxane, two or more alkenyl groups having 2 to 8 carbon atoms, and preferably 2 to 6 carbon atoms such as vinyl groups or allyl groups are bonded to the silicon atoms per molecule. The viscosity of the organopolysiloxane is preferably 10 to 100000 mPa·s, and more preferably 100 to 10000 mPa·s at 25°C in terms of workability and curability.

[0023] Specifically, an organopolysiloxane expressed by the following general formula (Chemical Formula 2) is used. The organopolysiloxane has an average of two or more alkenyl groups per molecule, in which the alkenyl groups are bonded to silicon atoms at both ends of the molecular chain. The organopolysiloxane is a linear organopolysiloxane whose side chains are blocked with alkyl groups. The viscosity of the linear organopolysiloxane is preferably 10 to 100000 mPa·s at 25°C in terms of workability and curability. Moreover, the linear organopolysiloxane may include a small amount of branched structure (trifunctional siloxane units) in the molecular chain.

[0024] [Chemical Formula 2]



[0025] In the general formula, R<sup>1</sup> represents substituted or unsubstituted monovalent hydrocarbon groups that are the same as or different from each other and have no aliphatic unsaturated bond, R<sup>2</sup> represents alkenyl groups, and k represents 0 or a positive integer. The monovalent hydrocarbon groups represented by R<sup>1</sup> preferably have 1 to 10 carbon atoms, and more preferably 1 to 6 carbon atoms.

Specific examples of the monovalent hydrocarbon groups include the following: alkyl groups such as methyl, ethyl, propyl, isopropyl, butyl, isobutyl, tert-butyl, pentyl, neopentyl, hexyl, cyclohexyl, octyl, nonyl, and decyl groups; aryl groups such as phenyl, tolyl, xylyl, and naphthyl groups; aralkyl groups such as benzyl, phenylethyl, and

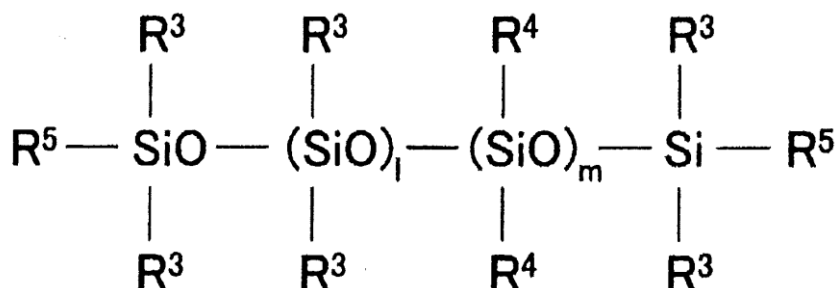
phenylpropyl groups; and substituted forms of these groups in which some or all hydrogen atoms are substituted by halogen atoms (fluorine, bromine, chlorine, etc.) or cyano groups, including halogen-substituted alkyl groups such as chloromethyl, chloropropyl, bromoethyl, and trifluoropropyl groups and cyanoethyl groups. The  
 5 alkenyl groups represented by  $R^2$  preferably have 2 to 8 carbon atoms, and more preferably 2 to 6 carbon atoms. Specific examples of the alkenyl groups include vinyl, allyl, propenyl, isopropenyl, butenyl, isobutenyl, hexenyl, and cyclohexenyl groups. In particular, the vinyl group is preferred. In the general formula (Chemical Formula 2),  $k$  is typically 0 or a positive integer satisfying  $0 \leq k \leq 10000$ , preferably  $5 \leq k \leq 2000$ ,  
 10 and more preferably  $10 \leq k \leq 1200$ .

[0026] The component A may also include an organopolysiloxane having three or more, typically 3 to 30, and preferably about 3 to 20, alkenyl groups bonded to silicon atoms per molecule. The alkenyl groups have 2 to 8 carbon atoms, and preferably 2 to 6 carbon atoms and can be, e.g., vinyl groups or allyl groups. The molecular  
 15 structure may be a linear, ring, branched, or three-dimensional network structure. The organopolysiloxane is preferably a linear organopolysiloxane in which the main chain is composed of repeating diorganosiloxane units, and both ends of the molecular chain are blocked with triorganosiloxy groups. The viscosity of the linear organopolysiloxane is preferably 10 to 100000 mPa·s, and more preferably 100 to  
 20 10000 mPa·s at 25°C.

[0027] Each of the alkenyl groups may be bonded to any part of the molecule. For example, the alkenyl group may be bonded to either a silicon atom that is at the end of the molecular chain or a silicon atom that is not at the end (but in the middle) of the molecular chain. In particular, a linear organopolysiloxane expressed by the  
 25 following general formula (Chemical Formula 3) is preferred. The linear organopolysiloxane has 1 to 3 alkenyl groups on each of the silicon atoms at both ends of the molecular chain. In this case, however, if the total number of the alkenyl groups bonded to the silicon atoms at both ends of the molecular chain is less than 3, at least one alkenyl group is bonded to the silicon atom that is not at the end (but in the  
 30 middle) of the molecular chain (e.g., as a substituent in the diorganosiloxane unit). As described above, the viscosity of the linear organopolysiloxane is preferably 10 to 100000 mPa·s at 25°C in terms of workability and curability. Moreover, the linear

organopolysiloxane may include a small amount of branched structure (trifunctional siloxane units) in the molecular chain.

[0028] [Chemical Formula 3]



[0029] In the general formula, R<sup>3</sup> represents substituted or unsubstituted monovalent hydrocarbon groups that are the same as or different from each other, and at least one of them is an alkenyl group, R<sup>4</sup> represents substituted or unsubstituted monovalent hydrocarbon groups that are the same as or different from each other and have no aliphatic unsaturated bond, R<sup>5</sup> represents alkenyl groups, and l and m represent 0 or a positive integer. The monovalent hydrocarbon groups represented by R<sup>3</sup> preferably have 1 to 10 carbon atoms, and more preferably 1 to 6 carbon atoms. Specific examples of the monovalent hydrocarbon groups include the following: alkyl groups such as methyl, ethyl, propyl, isopropyl, butyl, isobutyl, tert-butyl, pentyl, neopentyl, hexyl, cyclohexyl, octyl, nonyl, and decyl groups; aryl groups such as phenyl, tolyl, xylyl, and naphthyl groups; aralkyl groups such as benzyl, phenylethyl, and phenylpropyl groups; alkenyl groups such as vinyl, allyl, propenyl, isopropenyl, butenyl, hexenyl, cyclohexenyl, and octenyl groups; and substituted forms of these groups in which some or all hydrogen atoms are substituted by halogen atoms (fluorine, bromine, chlorine, etc.) or cyano groups, including halogen-substituted alkyl groups such as chloromethyl, chloropropyl, bromoethyl, and trifluoropropyl groups and cyanoethyl groups.

[0030] The monovalent hydrocarbon groups represented by R<sup>4</sup> also preferably have 1 to 10 carbon atoms, and more preferably 1 to 6 carbon atoms. The monovalent hydrocarbon groups may be the same as the specific examples of R<sup>1</sup>, but do not include an alkenyl group. The alkenyl groups represented by R<sup>5</sup> preferably have 2 to 8 carbon atoms, and more preferably 2 to 6 carbon atoms. Specific examples of the alkenyl groups are the same as those of R<sup>2</sup> in the general formula (Chemical Formula

2), and the vinyl group is preferred.

[0031] In the general formula,  $l$  and  $m$  are typically 0 or positive integers satisfying  $0 < l + m \leq 10000$ , preferably  $5 \leq l + m \leq 2000$ , and more preferably  $10 \leq l + m \leq 1200$ .

Moreover,  $l$  and  $m$  are integers satisfying  $0 < l/(l + m) \leq 0.2$ , and preferably  $0.0011 \leq l/(l + m) \leq 0.1$ .

[0032] (2) Crosslinking component (component B)

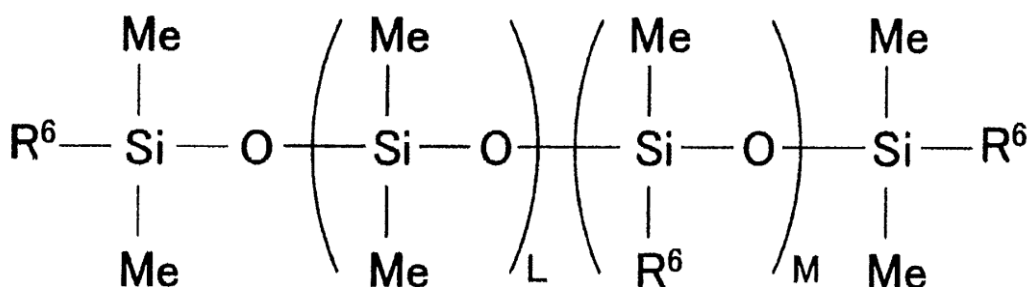
The component B is an organohydrogenpolysiloxane that acts as a crosslinking agent. The addition reaction (hydrosilylation) between SiH groups in this component and alkenyl groups in the component A produces a cured product.

Any organohydrogenpolysiloxane having two or more hydrogen atoms bonded to silicon atoms (i.e., SiH groups) per molecule may be used. The molecular structure of the organohydrogenpolysiloxane may be a linear, ring, branched, or three-dimensional network structure. The number of silicon atoms in a molecule (i.e., the degree of polymerization) may be 2 to 1000, and preferably about 2 to 300.

[0033] The locations of the silicon atoms to which the hydrogen atoms are bonded are not particularly limited. The silicon atoms may be either at the ends or not at the ends (but in the middle) of the molecular chain. The organic groups bonded to the silicon atoms other than the hydrogen atoms may be, e.g., substituted or unsubstituted monovalent hydrocarbon groups that have no aliphatic unsaturated bond, which are the same as those of  $R^1$  in the general formula (Chemical Formula 2).

[0034] An example of the organohydrogenpolysiloxane of the component B is expressed by the following general formula (Chemical Formula 4).

[Chemical Formula 4]



[0035] In the above general formula,  $R^6$  represents an alkyl group, a phenyl group, an epoxy group, an acryloyl group, a methacryloyl group, an alkoxy group, and a hydrogen atom, which are the same as or different from each other, and at least two of

them are hydrogen atoms. L is an integer of 0 to 1000, and preferably 0 to 300, and M is an integer of 1 to 200.

[0036] (3) Catalyst component (component C)

The catalyst component of the component C facilitates the curing of the present composition. The component C may be a catalyst used for a hydrosilylation reaction. Examples of the catalyst include platinum group metal catalysts such as platinum-based, palladium-based, and rhodium-based catalysts. The platinum-based catalysts include, e.g., platinum black, chloroplatinic acid (II), chloroplatinic acid, a reaction product of chloroplatinic acid and monohydric alcohol, a complex of chloroplatinic acid and olefin or vinylsiloxane, and platinum bisacetoacetate. The component C is mixed in an amount needed for curing, and the amount can be appropriately adjusted in accordance with a desired curing rate or the like. It is preferable that the component C is added in an amount of 0.01 to 1000 ppm based on the weight of metal atoms with respect to the total amount of the component A and the platinum group metal catalyst.

[0037] (4) Thermally conductive particles (component D)

The component D is added preferably in an amount of 100 to 4000 parts by mass with respect to 100 parts by mass of the addition-curable silicone polymer component (the component A + the component B). Thus, the thermal conductivities of the heat-resistant thermally conductive composition and the heat-resistant thermally conductive sheet can be set to 0.8 W/m·K or more. It is preferable that the thermally conductive particles are at least one selected from alumina, zinc oxide, magnesium oxide, aluminum nitride, boron nitride, aluminum hydroxide, and silica. The thermally conductive particles may have various shapes such as spherical, scaly, and polyhedral. The specific surface area of the thermally conductive particles is preferably 0.06 to 15 m<sup>2</sup>/g. The specific surface area is a BET specific surface area and is measured in accordance with JIS R 1626. The average particle size of the thermally conductive particles is preferably 0.1 to 100 μm. The average particle size may be measured with a laser diffraction scattering method to determine D50 (median diameter) in a volume-based cumulative particle size distribution. The measuring device may be, e.g., a laser diffraction/scattering particle size distribution analyzer LA-950 S2 manufactured by HORIBA, Ltd.

[0038] The thermally conductive particles include at least two types of inorganic particles with different average particle sizes. Thus, small-size, thermally conductive inorganic particles fill the spaces between large-size inorganic particles, which can provide nearly the closest packing and improve thermal conductive properties.

5 [0039] It is preferable that the inorganic particles are surface treated with a silane compound expressed by  $R_aSi(OR')_{3-a}$ , where R represents a substituted or unsubstituted organic group having 1 to 20 carbon atoms, R' represents an alkyl group having 1 to 4 carbon atoms, and a is 0 or 1, or with its partial hydrolysate. Examples of the alkoxy silane compound (simply referred to as "silane" in the following) include  
 10 the following: methyltrimethoxysilane; ethyltrimethoxysilane; propyltrimethoxysilane; butyltrimethoxysilane; pentyltrimethoxysilane; hexyltrimethoxysilane; hexyltriethoxysilane; octyltrimethoxysilane; octyltriethoxysilane; decyltrimethoxysilane; decyltriethoxysilane; dodecyltrimethoxysilane; dodecyltriethoxysilane; hexadecyltrimethoxysilane; hexadecyltriethoxysilane;  
 15 octadecyltrimethoxysilane; and octadecyltriethoxysilane. These silane compounds may be used alone or in combinations of two or more. The alkoxy silane and one-end silanol siloxane may be used together as the surface treatment agent. In this case, the surface treatment may include adsorption in addition to a covalent bond.

[0040] (5) Benzimidazolone compound (component E)

20 The component E may be added in powder form or mixed with a resin to form a masterbatch. The resin used for the masterbatch is preferably a silicone polymer. The resin may be a curable silicone polymer or a silicone polymer having no reactive group, or a combination of these polymers.

[0041] (6) Other additive agents

25 The composition of the present invention may include components other than the above as needed. For example, the composition may include a heat resistance improver such as colcothar, titanium oxide, or cerium oxide, a flame retardant aid, and a curing retarder. An organic or inorganic particle pigment may be added for coloring and toning. Moreover, alkoxy group-containing silicone may be added, e.g., for the  
 30 surface treatment of a filler. The organopolysiloxane having no addition curing reaction group may be added. The viscosity of the organopolysiloxane is preferably 10 to 100000 mPa·s, and more preferably 100 to 10000 mPa·s at 25°C in terms of

workability.

### Examples

[0042] Hereinafter, the present invention will be described by way of examples.

5 However, the present invention is not limited to the following examples. Various parameters were measured in the following manner.

#### <Thermal conductivity>

The thermal conductivity of a heat-resistant thermally conductive silicone gel sheet was measured by a hot disk (in accordance with ISO/CD 22007-2). As shown in  
10 FIG. 1A, using a thermal conductivity measuring apparatus 1, a polyimide film sensor 2 was sandwiched between two samples 3a, 3b, and constant power was applied to the sensor 2 to generate a certain amount of heat. Then, the thermal characteristics were analyzed from a temperature rise value of the sensor 2. The sensor 2 has a tip 4 with a diameter of 7 mm. As shown in FIG. 1B, the tip 4 has a double spiral structure of  
15 electrodes. Moreover, an electrode 5 for an applied current and an electrode 6 for a resistance value (temperature measurement electrode) are located on the lower portion of the sensor 2. The thermal conductivity was calculated by the following formula (1).

[Formula 1]

$$20 \quad \lambda = \frac{P_0 \cdot D(\tau)}{\pi^{3/2} \cdot r} \cdot \frac{D(\tau)}{\Delta T(\tau)}$$

$\lambda$ : Thermal conductivity (W/m·K)

$P_0$ : Constant power (W)

$r$ : Radius of sensor (m)

$\tau$ :  $\sqrt{\alpha \cdot t / r^2}$

25  $\alpha$ : Thermal diffusivity of sample (m<sup>2</sup>/s)

$t$ : Measuring time (s)

$D(\tau)$ : Dimensionless function of  $\tau$

$\Delta T(\tau)$ : Temperature rise of sensor (K)

#### <Hardness>

30 The Asker C hardness of the heat-resistant thermally conductive silicone gel

sheet was measured in accordance with the Society of Rubber Industry, Japan Standard (SRIS0101).

<Heat resistance>

The heat-resistant thermally conductive silicone gel sheets were stacked to  
 5 prepare a test block having a thickness of 10 mm or more. The test block was placed  
 on a wire mesh. In this state, the test block was placed in a hot air circulating oven at  
 150°C or 220°C. The test block was taken out from the oven after a predetermined  
 time and cooled to a room temperature. Then, the Asker C hardness of the test block  
 10 was measured in accordance with the Society of Rubber Industry, Japan Standard  
 (SRIS0101).

The heat resistance was evaluated with a rate of increase in the Asker C hardness after exposure at 150°C or 220°C.

The rate of increase was calculated by the following formula (Formula 2).

[Formula 2]

15 Rate of increase (%) =  $\left[ \frac{|B' - B|}{|A' - A|} \right] \times 100$

A: Initial hardness of sample without heat resistance improver

A': Hardness of sample without heat resistance improver after exposure at  
 150°C or 220°C

B: Initial hardness of sample containing heat resistance improver

20 B': Hardness of sample containing heat resistance improver after exposure at  
 150°C or 220°C for same period of time as that of A'

\*The composition and the processing method of the sample of A were the same as those of the sample of B except for the presence or absence of the heat resistance additive.

25 [0043] (Examples 1 and 2, Comparative Example 1)

1. Material components

(1) Matrix resin

A two-part addition-curable silicone polymer that becomes a silicone gel after curing was used. One solution (solution A) contained a base polymer component  
 30 (component A) and a platinum group metal catalyst (component C). The other solution (solution B) contained a base polymer component (component A) and an organohydrogenpolysiloxane that is a crosslinking agent component (component B).

[0044] (2) Thermally conductive particles

The thermally conductive particles shown in Table 1 were used. Alumina particles having an average particle size of 10  $\mu\text{m}$  or less was surface treated with a silane coupling agent. This surface treatment prevented a reduction in the curing  
5 reaction that is the catalytic ability of the platinum group metal catalyst (component C). In this case, the average particle size means D50 (median diameter) in a volume-based cumulative particle size distribution, which is determined by a particle size distribution measurement with a laser diffraction scattering method. The measuring device may be, e.g., a laser diffraction/scattering particle size distribution  
10 analyzer LA-950 S2 manufactured by HORIBA, Ltd. The values in Tables are average particle sizes of each of particles.

[0045] (3) Platinum group metal catalyst

A platinum-vinylsiloxane complex was used as a platinum group metal catalyst. As described above, the two-part addition-curable silicone polymer  
15 contained the platinum group metal catalyst. In the silicone compositions of the Examples, the amount of the platinum group metal catalyst was 0.01 to 1000 ppm expressed in terms of the weight of platinum atoms with respect to the total amount of the base polymer component (component A) and the platinum group metal catalyst.

[0046] (4) Benzimidazolone compound

20 Pigment Yellow 181 as the benzimidazolone compound was weighed in the amounts shown in Table 1 and added with respect to 100 parts by mass of the heat-resistant thermally conductive composition.

[0047] 2. Heat-resistant thermally conductive composition

The materials were weighed in the amounts shown in Table 1 and placed in a  
25 kneader to form a compound.

Table 1 indicates the amount of each material (parts by mass) with respect to 100 parts by mass (100 g) of the two-part addition-curable silicone polymer. In all the heat-resistant thermally conductive compositions, the amounts of the thermally conductive particles and the other components that were added with respect to 100  
30 parts by mass (100 g) of the two-part addition-curable silicone polymer satisfy their respective preferred amounts of the present invention, as described above.

Comparative Example 1 was performed in the same manner as Example 1 except that

the benzimidazolone compound was not added.

[0048] 3. Sheet forming process

The heat-resistant thermally conductive composition was sandwiched between polyethylene terephthalate (PET) films that had been subjected to a release treatment. The layered material was formed into a sheet with a thickness of 2.0 mm by a roller press. Subsequently, the sheet was heated and cured at 100°C for 15 minutes, resulting in a heat-resistant thermally conductive silicone gel sheet. The heat resistance thereof was evaluated at a temperature of 150°C. Table 1 shows the conditions as described above, and Table 2 shows the results.

10 [0049] [TABLE 1]

|                                      |                                                                                                             | Ex. 1  | Ex. 2 | Comp.<br>Ex. 1 |
|--------------------------------------|-------------------------------------------------------------------------------------------------------------|--------|-------|----------------|
| Matrix                               | Two-part addition-curable silicone polymer:<br>Solution A                                                   | 50     | 50    | 50             |
|                                      | Two-part addition-curable silicone polymer:<br>Solution B                                                   | 50     | 50    | 50             |
| Thermally<br>conductive<br>particles | Alumina<br>Average particle size: 0.3 $\mu\text{m}$<br>BET specific surface area: 6.7 $\text{m}^2/\text{g}$ | 365    | 365   | 365            |
|                                      | Alumina<br>Average particle size: 2.2 $\mu\text{m}$<br>BET specific surface area: 0.7 $\text{m}^2/\text{g}$ | 450    | 450   | 450            |
|                                      | Alumina<br>Average particle size: 35 $\mu\text{m}$<br>BET specific surface area: 0.2 $\text{m}^2/\text{g}$  | 1265   | 1265  | 1265           |
| Heat<br>resistance<br>improver       | Benzimidazolone compound                                                                                    | PY 181 | 1.7   | 3.4            |
| Result                               | Thermal conductivity ( $\text{W}/\text{m}\cdot\text{K}$ ) [Hot disk]                                        | 6.0    | 6.0   | 6.0            |
|                                      | Hardness [Asker C] after curing                                                                             | 43     | 45    | 40             |

\*-: Not added, Ex.: Example, Comp. Ex.: Comparative Example

[0050] [TABLE 2]

|                                                                      | 150°C Exposure time (hours) | 0  | 60 | 160 | 250 | 500 |
|----------------------------------------------------------------------|-----------------------------|----|----|-----|-----|-----|
| Hardness [Asker C]                                                   | Ex. 1                       | 43 | 64 | 70  | 74  | 84  |
|                                                                      | Ex. 2                       | 45 | 59 | 66  | 69  | 79  |
|                                                                      | Comp. Ex. 1                 | 40 | 79 | 86  | 91  | 91  |
| Rate of increase (%) with respect to rate of increase of Comp. Ex. 1 | Ex. 1                       | -  | 54 | 59  | 61  | 80  |
|                                                                      | Ex. 2                       | -  | 36 | 46  | 47  | 67  |

\*-: Calculation impossible, Ex.: Example, Comp. Ex.: Comparative Example

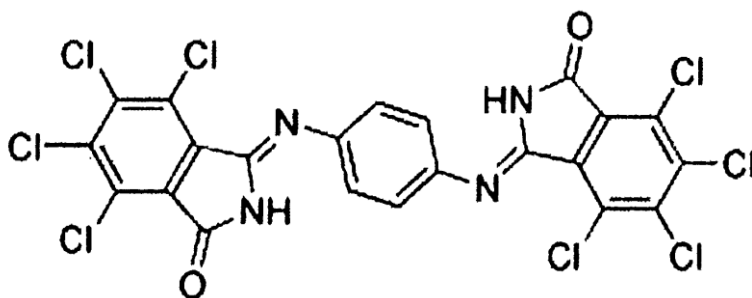
[0051] (Example 3, Comparative Example 2)

Example 3 and Comparative Example 2 were performed in the same manner as Example 1 except for the amounts of the thermally conductive particles added shown in Table 3. Table 3 shows the conditions, and Table 4 shows the results.

[0052] (Comparative Example 3)

Comparative Example 3 was performed in the same manner as Example 1 except that Pigment Yellow 110 (PY 110) that is an isoindolinone pigment expressed by the following formula (Chemical Formula 5), i.e., 4, 5, 6, 7-tetrachloro-3-[[4-[(1-oxo-4, 5, 6, 7-tetrachloro-2H-isoindol-3-ylidene)aminol]phenyl]imino]-2H-isoindol-1(3H)-one was added as a pigment. Table 3 shows the conditions, and Table 4 shows the results.

[Chemical Formula 5]



[0053] [TABLE 3]

|                                      |                                                                                                            | Ex. 3  | Comp.<br>Ex. 2 | Comp.<br>Ex. 3 |
|--------------------------------------|------------------------------------------------------------------------------------------------------------|--------|----------------|----------------|
| Matrix                               | Two-part addition-curable silicone polymer:<br>Solution A                                                  | 50     | 50             | 50             |
|                                      | Two-part addition-curable silicone polymer:<br>Solution B                                                  | 50     | 50             | 50             |
| Thermally<br>conductive<br>particles | Alumina<br>Average particle size: 2 $\mu\text{m}$<br>BET specific surface area: 0.7 $\text{m}^2/\text{g}$  | 360    | 360            | 360            |
|                                      | Alumina<br>Average particle size: 35 $\mu\text{m}$<br>BET specific surface area: 0.2 $\text{m}^2/\text{g}$ | 200    | 200            | 200            |
|                                      | Alumina<br>Average particle size: 75 $\mu\text{m}$<br>BET specific surface area: 0.2 $\text{m}^2/\text{g}$ | 80     | 80             | 80             |
| Heat<br>resistance<br>improver       | Benzimidazolone compound                                                                                   | PY 181 | 0.5            | -              |
|                                      | Isoindolinone compound                                                                                     | PY 110 | 0              | -              |
| Result                               | Thermal conductivity (W/m·K) [Hot disk]                                                                    | 1.6    | 1.6            | 1.6            |
|                                      | Hardness [Asker C] after curing                                                                            | 12     | 13             | 16             |

\*-: Not added, Ex.: Example, Comp. Ex.: Comparative Example

[0054] [TABLE 4]

|                                                                               | 150°C Exposure time<br>(hours) | 0  | 100 | 250 | 500 | 1000 |
|-------------------------------------------------------------------------------|--------------------------------|----|-----|-----|-----|------|
| Hardness [Asker C]                                                            | Ex. 3                          | 12 | 9   | 13  | 20  | 26   |
|                                                                               | Comp. Ex. 2                    | 13 | 13  | 19  | 31  | 42   |
|                                                                               | Comp. Ex. 3                    | 16 | 18  | 38  | N/A | N/A  |
| Rate of increase (%)<br>with respect to rate<br>of increase of Comp.<br>Ex. 2 | Ex. 3                          | -  | -   | 17  | 44  | 48   |
|                                                                               | Comp. Ex. 3                    | -  | -   | 367 | -   | -    |

\*N/A: No data, -: Calculation impossible, Ex.: Example, Comp. Ex.: Comparative Example

## 5 [0055] (Example 4, Comparative Example 4)

Example 4 and Comparative Example 4 were performed in the same manner as Example 1 except for the amounts of the thermally conductive particles and the additive agent that were added shown in Table 5. Table 5 shows the conditions, and Table 6 shows the results. In Example 4 and Comparative Example 4, not only alumina particles but also aluminum nitride was mixed. Moreover, a dimethyl silicone polymer (viscosity of 100 mPa·s) was added as an additive agent for adjusting the hardness properties.

[0056] [TABLE 5]

|                                |                                                                                                                     | Ex. 4  | Comp. Ex. 4 |
|--------------------------------|---------------------------------------------------------------------------------------------------------------------|--------|-------------|
| Matrix                         | Two-part addition-curable silicone polymer: Solution A                                                              | 50     | 50          |
|                                | Two-part addition-curable silicone polymer: Solution B                                                              | 50     | 50          |
| Thermally conductive particles | Alumina<br>Average particle size: 0.3 $\mu\text{m}$<br>BET specific surface area: 6.7 $\text{m}^2/\text{g}$         | 375    | 375         |
|                                | Alumina<br>Average particle size: 2 $\mu\text{m}$<br>BET specific surface area: 0.7 $\text{m}^2/\text{g}$           | 680    | 680         |
|                                | Alumina<br>Average particle size: 75 $\mu\text{m}$<br>BET specific surface area: 0.2 $\text{m}^2/\text{g}$          | 1335   | 1335        |
|                                | Aluminum nitride<br>Average particle size: 15 $\mu\text{m}$<br>BET specific surface area: 0.5 $\text{m}^2/\text{g}$ | 375    | 375         |
| Additive agent                 | Dimethyl silicone polymer                                                                                           | 40     | 40          |
| Heat resistance improver       | Benzimidazolone compound                                                                                            | PY 181 | 4.0         |
| Result                         | Thermal conductivity ( $\text{W}/\text{m}\cdot\text{K}$ ) [Hot disk]                                                | 8.0    | 8.0         |
|                                | Hardness [Asker C] after curing                                                                                     | 38     | 41          |

\*-: Not added, Ex.: Example, Comp. Ex.: Comparative Example

[0057] [TABLE 6]

|                                                                      | 150°C Exposure time (hours) | 0  | 100 | 250 | 500 |
|----------------------------------------------------------------------|-----------------------------|----|-----|-----|-----|
| Hardness [Asker C]                                                   | Ex. 4                       | 38 | 72  | 76  | 80  |
|                                                                      | Comp. Ex. 4                 | 41 | 87  | 93  | N/A |
| Rate of increase (%) with respect to rate of increase of Comp. Ex. 4 | Ex. 4                       | -  | 74  | 73  | -   |

\*N/A: No data, -: Calculation impossible, Ex.: Example, Comp. Ex.: Comparative Example

## 5 [0058] (Examples 5-9, Comparative Examples 5-7)

In Examples 5-9 and Comparative Examples 5-7, sheets were produced in the same manner as in Example 1 except for the types and the amounts of the thermally conductive particles and the heat resistance improver that were added shown in Table 7. The heat resistances thereof were evaluated at a temperature of 220°C. Tables 7 and 8 show the conditions, and Table 9 shows the results.

In Comparative Example 5 (an anthraquinone compound was added), curing

failure occurred, and the sheet hardness was decreased.

[0059] [TABLE 7]

|                                |                                                                                                            | Ex. 5  | Ex. 6 | Ex. 7 | Ex. 8 | Ex. 9 |
|--------------------------------|------------------------------------------------------------------------------------------------------------|--------|-------|-------|-------|-------|
| Matrix                         | Two-part addition-curable silicone polymer: Solution A                                                     | 50     | 50    | 50    | 50    | 50    |
|                                | Two-part addition-curable silicone polymer: Solution B                                                     | 50     | 50    | 50    | 50    | 50    |
| Thermally conductive particles | Alumina<br>Average particle size: 35 $\mu\text{m}$<br>BET specific surface area: 0.2 $\text{m}^2/\text{g}$ | 600    | 600   | 600   | 600   | 600   |
| Heat resistance improver       | Benzimidazolone compound                                                                                   | PY 181 | 1.5   | -     | -     | -     |
|                                |                                                                                                            | PR 176 | -     | 1.5   | -     | -     |
|                                |                                                                                                            | PR 208 | -     | -     | 1.5   | -     |
|                                |                                                                                                            | PBr 25 | -     | -     | -     | 1.5   |
|                                |                                                                                                            | PO 36  | -     | -     | -     | 1.5   |
| Result                         | Thermal conductivity (W/m·K) [Hot disk]                                                                    | 1.7    | 1.7   | 1.7   | 1.7   | 1.7   |
|                                | Hardness [Asker C] after curing                                                                            | 32     | 33    | 33    | 33    | 33    |

\*-: Not added, Ex.: Example

[0060] [TABLE 8]

|                                |                                                                                                            | Comp. Ex. 5 | Comp. Ex. 6 | Comp. Ex. 7 |
|--------------------------------|------------------------------------------------------------------------------------------------------------|-------------|-------------|-------------|
| Matrix                         | Two-part addition-curable silicone polymer: Solution A                                                     | 50          | 50          | 50          |
|                                | Two-part addition-curable silicone polymer: Solution B                                                     | 50          | 50          | 50          |
| Thermally conductive particles | Alumina<br>Average particle size: 35 $\mu\text{m}$<br>BET specific surface area: 0.2 $\text{m}^2/\text{g}$ | 600         | 600         | 600         |
| Heat resistance improver       | Anthraquinone compound                                                                                     | PB 60       | 1.5         | -           |
|                                | Phthalocyanine                                                                                             | PB 16       | -           | 1.0         |
| Result                         | Thermal conductivity (W/m·K) [Hot disk]                                                                    | 1.7         | 1.7         | 1.7         |
|                                | Hardness [Asker C] after curing                                                                            | 13          | 33          | 25          |

5 \*-: Not added, Comp. Ex.: Comparative Example

[0061] [TABLE 9]

|                                                                      | 220°C Exposure time (hours) | 0  | 100 | 250 | 500 | 1000 |
|----------------------------------------------------------------------|-----------------------------|----|-----|-----|-----|------|
| Hardness [Asker C]                                                   | Ex. 5                       | 32 | 31  | 31  | 41  | 58   |
|                                                                      | Ex. 6                       | 33 | 32  | 31  | 30  | 36   |
|                                                                      | Ex. 7                       | 33 | 30  | 29  | 37  | 55   |
|                                                                      | Ex. 8                       | 33 | 30  | 26  | 26  | 28   |
|                                                                      | Ex. 9                       | 33 | 30  | 27  | 25  | 27   |
|                                                                      | Comp. Ex. 5                 | 13 | 13  | 20  | 30  | 48   |
|                                                                      | Comp. Ex. 6                 | 33 | 22  | 55  | 77  | 86   |
|                                                                      | Comp. Ex. 7                 | 25 | 19  | 92  | 94  | 95   |
| Rate of increase (%) with respect to rate of increase of Comp. Ex. 7 | Ex. 5                       | -  | 17  | 1   | 13  | 37   |
|                                                                      | Ex. 6                       | -  | 17  | 3   | 4   | 4    |
|                                                                      | Ex. 7                       | -  | 50  | 6   | 6   | 31   |
|                                                                      | Ex. 8                       | -  | 50  | 10  | 10  | 7    |
|                                                                      | Ex. 9                       | -  | 50  | 9   | 12  | 9    |
|                                                                      | Comp. Ex. 5                 | -  | 0   | 10  | 25  | 50   |
|                                                                      | Comp. Ex. 6                 | -  | 183 | 33  | 64  | 76   |

\*-: Calculation impossible, Ex.: Example, Comp. Ex.: Comparative Example

[0062] (Examples 10-14, Comparative Example 7)

5 Examples 10-14 and Comparative Example 7 were performed in the same manner as Example 1 except for the amounts of the thermally conductive particles and the heat resistance improver that were added shown in Table 7. The heat resistances thereof were evaluated at a temperature of 220°C. Table 10 shows the conditions, and Table 11 shows the results.

[0063] [TABLE 10]

|                                |                                                                                                            | Ex. 10 | Ex. 11 | Ex. 12 | Ex. 13 | Comp. Ex. 7 |
|--------------------------------|------------------------------------------------------------------------------------------------------------|--------|--------|--------|--------|-------------|
| Matrix                         | Two-part addition-curable silicone polymer: Solution A                                                     | 50     | 50     | 50     | 50     | 50          |
|                                | Two-part addition-curable silicone polymer: Solution B                                                     | 50     | 50     | 50     | 50     | 50          |
| Thermally conductive particles | Alumina<br>Average particle size: 35 $\mu\text{m}$<br>BET specific surface area: 0.2 $\text{m}^2/\text{g}$ | 600    | 600    | 600    | 600    | 600         |
| Heat resistance improver       | Benzimidazolone compound                                                                                   | PR 176 | 0.05   | 0.10   | 0.50   | 5.0         |
| Result                         | Thermal conductivity (W/m·K) [Hot disk]                                                                    | 1.7    | 1.7    | 1.7    | 1.7    | 1.7         |
|                                | Hardness [Asker C] after curing                                                                            | 30     | 29     | 29     | 29     | 25          |

10 \*Ex.: Example, Comp. Ex.: Comparative Example

[0064] [TABLE 11]

|                                                                      | 220°C Exposure time (hours) | 0  | 100 | 250 | 500 | 1000 |
|----------------------------------------------------------------------|-----------------------------|----|-----|-----|-----|------|
| Hardness [Asker C]                                                   | Ex. 10                      | 30 | 24  | 18  | 18  | 25   |
|                                                                      | Ex. 11                      | 29 | 26  | 21  | 20  | 22   |
|                                                                      | Ex. 12                      | 29 | 26  | 20  | 18  | 23   |
|                                                                      | Ex. 13                      | 29 | 30  | 30  | 33  | 55   |
|                                                                      | Comp. Ex. 7                 | 25 | 19  | 92  | 94  | 95   |
| Rate of increase (%) with respect to rate of increase of Comp. Ex. 7 | Ex. 10                      | -  | 100 | 18  | 17  | 7    |
|                                                                      | Ex. 11                      | -  | 50  | 12  | 13  | 10   |
|                                                                      | Ex. 12                      | -  | 50  | 13  | 16  | 9    |
|                                                                      | Ex. 13                      | -  | 17  | 1   | 6   | 37   |

\*-: Calculation impossible, Ex.: Example, Comp. Ex.: Comparative Example

[0065] As in the above examples, it was confirmed that the heat resistances of the thermally conductive compositions and the thermally conductive sheets were improved by adding the benzimidazolone compound.

5

#### Industrial Applicability

[0066] The heat-resistant thermally conductive composition and the heat-resistant thermally conductive sheet of the present invention are suitable for being interposed between a heat generating part and a heat dissipater of an electrical component, an electronic component or the like. In particular, the heat-resistant thermally conductive composition and the heat-resistant thermally conductive sheet use the heat resistance improver containing no metal atom and are less likely to become hard at high temperature. Thus, they are largely advantageous for electrical components and electronic components.

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#### Description of Reference Numerals

[0067] 1 Thermal conductivity measuring apparatus  
2 Sensor  
3a, 3b Sample  
20 4 Tip of the sensor  
5 Electrode for applied current  
6 Electrode for resistance value (temperature measurement electrode)

## CLAIMS

- [1] A heat-resistant thermally conductive composition comprising:  
a matrix resin; and  
thermally conductive particles,  
5 wherein the heat-resistant thermally conductive composition contains a  
benzimidazolone compound as a heat resistance improver.
- [2] The heat-resistant thermally conductive composition according to claim 1,  
wherein the benzimidazolone compound is added in an amount of 0.001 to 5 parts by  
10 mass with respect to 100 parts by mass of the heat-resistant thermally conductive  
composition.
- [3] The heat-resistant thermally conductive composition according to claim 1 or 2,  
wherein the matrix resin component is a silicone polymer.  
15
- [4] The heat-resistant thermally conductive composition according to any of  
claims 1 to 3, wherein the benzimidazolone compound is a benzimidazolone pigment.
- [5] The heat-resistant thermally conductive composition according to any of  
20 claims 1 to 4, wherein if the matrix resin is 100 parts by mass, the heat-resistant  
thermally conductive particles are added in an amount of 100 to 4000 parts by mass.
- [6] The heat-resistant thermally conductive composition according to any of  
claims 1 to 5, further comprising a curing catalyst,  
25 wherein the matrix resin component is an addition-curable silicone polymer.
- [7] The heat-resistant thermally conductive composition according to any of  
claims 1 to 6, wherein the heat-resistant thermally conductive composition has an  
Asker C hardness of 70 or less after curing.  
30
- [8] The heat-resistant thermally conductive composition according to any of  
claims 1 to 7, wherein the thermally conductive particles are at least one selected from

alumina, zinc oxide, magnesium oxide, aluminum nitride, boron nitride, aluminum hydroxide, and silica.

[9] A heat-resistant thermally conductive sheet comprising the heat-resistant  
5 thermally conductive composition, according to any of claims 1 to 8, in the form of a sheet.

[10] The heat-resistant thermally conductive sheet according to claim 9, wherein  
the heat-resistant thermally conductive sheet has a thermal conductivity of 0.8 W/m·K  
10 or more.