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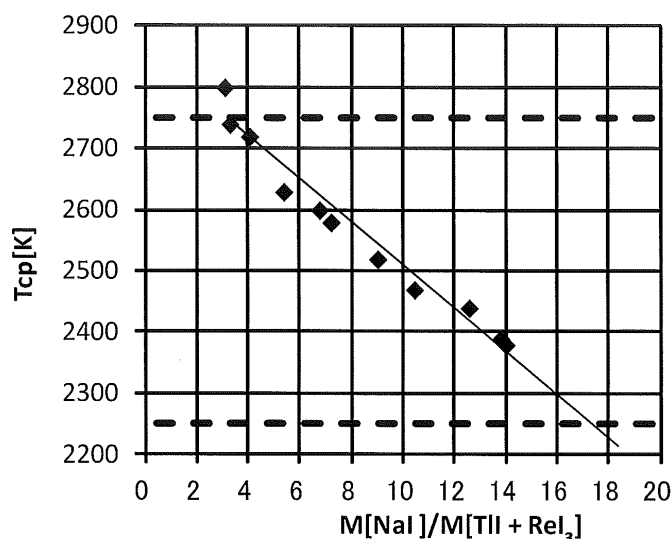
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(54) **CERAMIC METAL HALIDE LAMP**

(57) Provided is a ceramic metal halide lamp that can achieve a correlated color temperature on the order of 2500 K without sacrificing lamp life. An additive contains Thallium iodide (TII), Sodium iodide (NaI), Calcium iodide (CaI_2), Lithium iodide (LiI), and a rare earth metal iodide, and is further configured in a manner so that the correlated color temperature is 2250-2750 K, the bulb wall

loading is 20-30 W/cm², and the rated output is 35-400 W. When the mole ratio of Sodium iodide to the total number of moles of the additive is M(NaI) (in mol%) and the sum of the mole ratio of the rare earth metal iodide (ReI_3) and the mole ratio of Thallium iodide (TII) is M(ReI_3 +TII) (in mol%), $4 < \text{M(NaI)}/\text{M(ReI}_3\text{+TII)} < 16$ and $2 \text{ mol\%} < \text{M(ReI}_3\text{+TII)} < 9 \text{ mol\%}$.

FIG. 4A



Description

Technical Field

5 **[0001]** The present invention relates to a high intensity discharge lamp, in particular, relates to a ceramic metal halide lamp.

Background Art

10 **[0002]** The high intensity discharge lamp (hereinafter, referred to as "HID lamp") has been widely used because it has high efficiency and is excellent in economy. HID lamps can be roughly divided into three type of a mercury lamp, a metal halide lamp, and a high-pressure sodium lamp depending on the type of the additives sealed in the luminous tube. Generally, a high-pressure sodium lamp has a long lifetime and high luminous efficiency, while a high-chroma and high-color-rendering type of high-pressure sodium lamp is known as a light source configured to show reddish colors vividly
15 although it is inferior to a general high-pressure sodium lamp in lifetime and luminous efficiency. In recent years, a ceramic metal halide lamp using a luminous tube made of ceramic (translucent alumina: PCA) in place of a luminous tube made of quartz glass has been widely used. The lamp lifetime and luminous efficiency of a ceramic metal halide lamp are said to be superior to those of a high-chroma and high-color-rendering type of high-pressure sodium lamp.

[0003] However, a high-chroma and high-color-rendering type of high-pressure sodium lamp has been usually used
20 for the lighting of fresh foods. As the reason for this, various factors including a correlated color temperature CCT, a color rendering index CRI and a wavelength spectrum distribution can be considered, but a correlated color temperature comes first. A reason for this is that there is a demand to show reddish colors vividly when fresh foods such as vegetables, breads and meats are illuminated.

[0004] The correlated color temperature is about 2500 K in the case of a high-chroma and high-color-rendering type
25 of high-pressure sodium lamp, while the correlated color temperature in the case of a ceramic metal halide lamp is relatively high, and is difficult to reach about 2500 K.

[0005] A ceramic metal halide lamp having the correlated color temperature of 2000 to 4500 K is described in JP 2004-288617 A (JP 4279122 B1), and a ceramic metal halide lamp having the color temperature of 2500 to 4500 K is described in JP 2003-187744 A and JP 2009-520323 A, and a ceramic metal halide lamp having the color temperature
30 of 2800 to 3700 K is described in JP 2007-53004 A and JP 2011-154847 A. However, in these patent literature, neither specific technique for lowering the correlated color temperature to about 2500 K nor specific technique for showing an irradiated object of reddish color vividly is disclosed. In fact, the color temperature of ceramic metal halide lamp available in the market is 2800 K or above even if it is a low color temperature type.

35 Prior Art documents

Patent Literature

[0006]

40 Patent Literature 1: JP 2004-288617 A (JP 4279122 B1)
Patent Literature 2: JP 2003-187744 A (JP 4262968 B1)
Patent Literature 3: JP 2009-520329 A
Patent Literature 4: JP 2007-53004 A
45 Patent Literature 5: JP 2011-154847 A
Patent Literature 6: JP 2010-3488 A

Summary of Invention

50 Technical Problem

[0007] In general, in order to decrease a correlated color temperature, it is necessary to increase the content of Sodium Na in additives hermetically contained in a luminous tube. However, if the content of Sodium Na is increased, the total amount of the additives is to be increased. This results in increasing the erosion of translucent polycrystalline alumina (PCA) that forms a luminous tube, thereby shortening the lamp lifetime. For example, JP 2010-3488 A describes a ceramic metal halide lamp that exhibits a lamp lifetime of 15000 hours or longer but fails to describe the achievement of a correlated color temperature of 2500 K or so as well.

[0008] An object of the present invention is to provide a ceramic metal halide lamp that is capable of achieving a

correlated color temperature of approximately 2500 K without sacrificing its lamp lifetime.

[0009] According to the present invention, there is provided a ceramic metal halide lamp comprising:

a luminous tube (2) containing a pair of electrodes (5A,5B), the luminous tube being made of translucent ceramic; and
a translucent outer tube (13) accommodating the luminous tube (2),
the luminous tube hermetically containing a starting inert gas, mercury and additives, the additives containing Thallium iodide TII, Sodium iodide NaI, Calcium iodide CaI_2 , Lithium iodide LiI and a rare-earth metal iodide ReI_3 ,
the luminous tube being further configured such that its correlated color temperature is 2250 to 2750 K, its tube wall load is 20 to 30 W/cm² and its rated output is 35 to 400 W,
wherein when a mole fraction of Sodium iodide relative to the total number of moles of the additives is denoted by M (NaI) [mol%] and a sum of mole fractions of the rare-earth metal iodide ReI_3 and Thallium iodide TII is denoted by M ($\text{ReI}_3 + \text{TII}$) [mol%], the M (NaI) and the M ($\text{ReI}_3 + \text{TII}$) satisfy the following equations.

$$4 < \text{M (NaI)/M (ReI}_3 + \text{TII)} < 16$$

$$2 \text{ mol\%} < \text{M (ReI}_3 + \text{TII)} < 9 \text{ mol\%}.$$

[0010] According to an embodiment of the present invention, there is provided the ceramic metal halide lamp, wherein when the total amount of the additives per luminous tube volume of 1 cm³ is denoted by G (total) [mg/cm³] and the amount of the rare-earth metal iodide contained in the additives per luminous tube volume of 1 cm³ is denoted by G (ReI_3) [mg/cm³], the G (total) and the G (ReI_3) satisfy the following equations.

$$\text{G (total)} < 44 \text{ mg/cm}^3$$

$$\text{G (ReI}_3) < 11 \text{ mg/cm}^3.$$

[0011] According to an embodiment of the present invention, there is provided the ceramic metal halide lamp, wherein when a sum of the mole fraction M (NaI) of Sodium iodide relative to the total number of moles in the additives, the mole fraction M (CaI_2) of Calcium iodide, and the mole fraction M (LiI) of Lithium iodide is denoted by M (NaI + CaI_2 + LiI), the sum satisfies the following equation.

$$50 \text{ mol\%} < \text{M (NaI + CaI}_2 + \text{LiI)} < 96 \text{ mol\%}.$$

[0012] According to an embodiment of the present invention, there is provided the ceramic metal halide lamp, wherein when the mole fraction M (NaI) of Sodium iodide relative to the total number of moles in the additives, the mole fraction M (CaI_2) of Calcium iodide, and the mole fraction M (LiI) of Lithium iodide satisfy the following respective equations.

$$30 \text{ mol\%} < \text{M (NaI)} < 70 \text{ mol\%}$$

$$10 \text{ mol\%} < \text{M (CaI}_2) < 40 \text{ mol\%}$$

$$10 \text{ mol\%} < \text{M (LiI)} < 30 \text{ mol\%}.$$

[0013] According to an embodiment of the present invention, there is provided the ceramic metal halide lamp, wherein the additives contains one or more of Thulium iodide TmI_3 , an iodide of Dysprosium (Dy), an iodide of Holmium (Ho) and an iodide of Cerium (Ce) as the rare-earth metal iodide (but Thulium iodide TmI_3 is essential).

[0014] According to an embodiment of the present invention, there is provided the ceramic metal halide lamp, wherein the correlated color temperature of the luminous tube is 2400 to 2600K, and the M (NaI) and the M ($\text{ReI}_3 + \text{TII}$) satisfy the following equation.

$$7 < M(\text{NaI})/M(\text{ReI}_3 + \text{TII}) < 13.$$

Advantageous Effects of Invention

[0015] According to the present invention, it is possible to provide a ceramic metal halide lamp that is capable of achieving a correlated color temperature of approximately 2500 K without sacrificing its lamp lifetime.

Brief Description of Drawings

[0016]

Fig. 1 is a view explaining an exemplary luminous tube of ceramic metal halide lamp according to the present invention.

Fig. 2 is a view explaining an exemplary ceramic metal halide lamp according to the present invention.

Fig. 3 is a view explaining an exemplary ceramic metal halide lamp according to the present invention.

Fig. 4A is a view explaining results of experiments of the luminous tubes of ceramic metal halide lamps according to the present invention.

Fig. 4B is a view explaining results of experiments of the luminous tubes of ceramic metal halide lamps according to the present invention.

Description of Embodiments

[0017] In the following, embodiments of the ceramic metal halide lamp according to the present invention will be described in detail with reference to the accompanying drawings. It should be noted that the same elements in the drawings will be denoted by the same reference numerals, and duplicate descriptions will be omitted.

[0018] An example of a luminous tube of ceramic metal halide lamp according to the present invention will be described with reference to Fig. 1. Luminous tube 2 includes a light-emitting portion 3 and capillaries 4A and 4B extending from both ends thereof. Light-emitting portion 3 and capillaries 4A and 4B are formed by integral molding by compressing the powder of translucent ceramic such as alumina. Electrode assemblies 6A and 6B are inserted at both ends of capillaries 4A and 4B, respectively. Both ends of capillaries 4A and 4B are sealed airtightly by frit glass having electrical insulating property. Thereby, electrode assemblies 6A and 6B are secured in place in capillaries 4A and 4B. Electrodes 5A and 5B disposed at the inner ends of electrode assemblies 6A and 6B are disposed in place in light-emitting portion 3. Power supply leads 7A and 7B are protruded from both ends of capillaries 4A and 4B.

[0019] Additives are sealed in the inside of light-emitting portion 3 in addition to argon and mercury. The additives include a light-emitting substance such as alkali metal iodide, alkali earth metal iodide, and rare earth metal iodide. The additives sealed in light-emitting portion 3 will be described below in detail.

[0020] As inner dimensions of luminous tube 2, effective length L and effective inner diameter D are defined. Effective length L is a distance between both the end faces in the cylindrical luminous tube, and is defined as the distance between the outer ends of transition curved surfaces L1 and L1 between straight tubular capillaries 4A and 4B and light-emitting portion 3 in the luminous tube where the light-emitting portion and the capillaries are continuously molded as shown in Fig. 1. Effective inner diameter D is defined as the maximum inner diameter of the central portion between the electrodes 5A and 5B in a non-cylindrical luminous tube. The effective length of luminous tube 2 is denoted by "L", and the effective inner diameter is denoted by "D", and the ratio L/D of the two is referred to as "aspect ratio".

[0021] The temperature of each part of light-emitting portion 3 depends on the wall load of luminous tube, the gas pressure in the translucent outer tube, the material of the luminous tube and the aspect ratio (L/D) of the luminous tube, and is in particular highly dependent on the wall load. The wall load is defined as a value obtained by dividing the lamp power by the total internal area of light-emitting portion 3. In the present embodiment, light-emitting portion 3 is designed so that the wall load is 20 to 30 W/cm² (rated output 35 to 400 W). Thus, in the present embodiment, the chemical reaction rate between a material constituting the inner wall of the light-emitting portion and rare earth metal iodide can be kept low, and the lamp can have a longer lifetime.

[0022] An example of a ceramic metal halide lamp according to the present invention will be described with reference to Fig. 2. Ceramic metal halide lamp 1 of the present embodiment includes luminous tube 2, cylindrical translucent sleeve 18 disposed so as to surround light-emitting portion 3, and outer bulb 13 having base 12 disposed at one end of the outer bulb. The structure of luminous tube 2 is described with reference to Fig. 1.

[0023] Two struts 15 and 16 are mounted on stem 14 of base 12. On the struts, two support disks 17A and 17B are mounted at a predetermined interval. In addition, cylindrical translucent sleeve 18 is fixed to disks 17A and 17B. Getter 20 is mounted on disk 17B. Power supply leads 7A and 7B are protruded from both ends of capillaries 4A and 4B. The

tips of power supply leads 7A and 7B are welded to struts 15 and 16 directly or through nickel wires 19A and 19B, respectively. Thus, electrodes 5A and 5B of luminous tube 2 are electrically connected to base 12 through power supply leads 7A and 7B and struts 15 and 16.

[0024] An example of a ceramic metal halide lamp according to the present invention will be described with reference to Fig. 3. Ceramic metal halide lamp 1 of the present embodiment includes luminous tube 2 and outer bulb 13. The structure of luminous tube 2 is described with reference to FIG. 1. At one end of outer bulb 13, outer bulb chip-off portion 13A is formed, and at the other end, pinch seal portion 13B is formed. Base 12 is mounted to an end portion of pinch seal portion 13B. External terminals 9A and 9B are mounted to base 12.

[0025] Two struts 15 and 16 are fixed to pinch seal portion 13B. Power supply leads 7A and 7B are protruded from both ends of capillaries 4A and 4B. The tips of power supply leads 7A and 7B are respectively welded to struts 15 and 16. Getter 20 is mounted to strut 15. Struts 15 and 16 are electrically connected to external terminals 9A and 9B through metal foil 8A and 8B at pinch seal portion 13B.

[0026] Thus, electrodes 5A and 5B of luminous tube 2 are electrically connected to external terminals 9A and 9B through power supply leads 7A and 7B, struts 15 and 16, and metal foil 8A and 8B.

[0027] The ceramic metal halide lamp according to the present invention may be a reflective ceramic metal halide lamp with a concave reflector in addition to the examples shown in Figs. 2 and 3.

[0028] The inventor of the present application has studied the reason why a high-chroma and high-color-rendering type of high-pressure sodium lamp has been used favorably for the lighting for fresh foods. As the reasons for this, a variety of factors such as correlated color temperature CCT, color-rendering index CRI, and wavelength spectral distribution can be considered, but the inventor of the present application has focused on the correlated color temperature CCT at first. A reason for this is that there is a demand to show reddish colors vividly when fresh foods such as vegetables, breads and meats are illuminated.

[0029] The correlated color temperature of high-chroma and high-color-rendering type of high-pressure sodium lamps is usually 2500 K or so. In contrast, in conventional ceramic metal halide lamps, it is difficult to achieve such correlated color temperature or so and usually higher correlated color temperatures are provided. The inventor of the present application has attempted to create a ceramic metal halide lamp that could provide substantially the same correlated color temperature as high-chroma and high-color-rendering type of high-pressure sodium lamps. However, even if a desired correlated color temperature is achieved, if the lamp lifetime, the chromaticity deviation Duv, the color rendering index CRI, the luminous efficiency η or the like is deteriorated, it is meaningless. Therefore, the inventor of the present application has set targets listed below.

[0030] (1) The target of the correlated color temperature is approximately 2500 K, or $2500\text{ K} \pm 10\%$ (2250 to 2750 K), and preferably 2400 to 2600 K.

[0031] (2) The target of the lamp lifetime is 15000 hours or longer.

[0032] (3) The target of a chromaticity deviation Duv is $-2 < \text{Duv} < +1$. The color rendering index CRI and the luminous efficiency η are to be equal to or greater than respective preset values. The chromaticity deviation Duv refers to a deviation from the black body locus (BBL) on a chromaticity diagram. The BBL on a chromaticity diagram represents a natural hue of solar light; Duv = 0 indicates that a chromaticity is on the BBL.

[0033] In order to achieve the targets, the inventor of the present application has studied earnestly additives hermetically contained in the luminous tube of ceramic metal halide lamp and made various compositions of additives to conduct experiments. A rare-earth metal iodide, an alkali metal iodide and an alkaline-earth metal iodide were used as the additive components.

[0034] In the experiments conducted by the inventor of the present application, the rare-earth metal iodide includes respective iodides of Dysprosium (Dy), Holmium (Ho), Thulium (Tm), Cerium (Ce) and the like. The alkali metal iodide includes respective iodides of Sodium (Na), Lithium (Li) and the like. The alkaline-earth metal iodide includes respective iodides of Calcium (Ca) and the like. Furthermore, in the experiments conducted by the inventor of the present application, the additives contain an iodide of Thallium (Tl). In this case, indium, barium and the like were not used. In the experiments conducted by the inventor, the iodides were used, but other halides may have been used as halides.

[0035] In general, it is known that by adding Sodium Na, a correlated color temperature decreases. In this embodiment, Lithium Li is further added to adjust the balance of red. It is known that by adding Dysprosium iodide DyI_3 , color rendering properties are improved but a luminous efficiency decreases, and that by adding Holmium iodide HoI_3 or Thulium iodide TmI_3 , a luminous efficiency increases. It is known that by adding Cerium iodide CeI_3 or Thallium iodide TlI , a luminous efficiency increases and a value of a chromaticity deviation Duv is shifted in the increasing direction. It is known that by adding Calcium iodide CaI_2 , a value of a chromaticity deviation Duv is shifted in the decreasing direction but a special color rendering index (reddish color) R9 is improved.

[0036] In general, Na (e.g., an amalgam of sodium and mercury) is used as an additive in a high-pressure sodium lamp, whereas Sodium iodide NaI is used in a ceramic metal halide lamp. The saturated vapor pressures of liquid sodium and liquid sodium iodide are expressed by respective equations described below.

$$\log P(\text{Na}) = -5269 (1/T) + 4.555 \quad : \text{Formula 1}$$

$$\log P(\text{NaI}) = -8046 (1/T) + 5.084 \quad : \text{Formula 2}$$

where: $P(\text{Na})$ denotes the saturated vapor pressure [atm] of liquid sodium; $P(\text{NaI})$ denotes the saturated vapor pressure [atm] of liquid sodium iodide; $\log$ denotes a common logarithm; and T denotes an absolute temperature [K].

[0037] By using these equations, the respective saturated vapor pressures P [atm] of liquid sodium and liquid sodium iodide, for example, at a temperature of 800°C can be determined. Substituting $T = 800^\circ\text{C} = 1073 \text{ K}$ into equations 1 and 2 yields $P(\text{Na}) = 0.441 \text{ atm}$ and $P(\text{NaI}) = 0.00385 \text{ atm}$, respectively. The saturated vapor pressure $P(\text{NaI})$ of liquid sodium iodide at a temperature of 800°C is equal to or less than 1/100 the saturated vapor pressure $P(\text{Na})$ of liquid sodium. Accordingly, in comparison with the amount of sodium vaporized in the luminous tube of a high-pressure sodium lamp, only an extremely small amount of sodium iodide is vaporized in the luminous tube of ceramic metal halide lamp.

[0038] Therefore, as opposed to high-chroma and high-color-rendering type of high-pressure sodium lamps, in case of ceramic metal halide lamps such a technique as to enhance reddish colors in order to increase a color rendering index CRI by excessively increasing the absorption of a sodium emission line at 589 nm cannot be used. In addition, even if the absolute amount of Sodium iodide hermetically contained is increased, there are cases where the correlated color temperature CCT of the entire lamp is not decreased. This is because if a large amount of Thallium iodide or rare-earth metal iodide is hermetically contained, emissions of bluish light and greenish light are to be increased.

[0039] In the light of the above, the inventor of the present application has focused attention on the content of Sodium iodide in the additives, and selected parameters described below.

[0040] Assume that the amount of rare earth metal iodide is denoted by $G(\text{ReI}_3)$, and that the amount of alkaline metal iodide is denoted by $G(\text{Al})$, and that the amount of alkaline earth metal iodide is denoted by $G(\text{AeI}_2)$. Assume that the amount of Thallium iodide is denoted by $G(\text{TII})$, and that the total amount of the additives is denoted by $G(\text{total})$. The total amount $G(\text{total})$ of the additives is represented by the following equation.

$$G(\text{total}) = G(\text{ReI}_3) + G(\text{Al}) + G(\text{AeI}_2) + G(\text{TII}) : \text{Formula 3}$$

,where each of $G(\text{total})$, $G(\text{ReI}_3)$, $G(\text{Al})$, $G(\text{AeI}_2)$, and $G(\text{TII})$ is the mass per luminous tube volume of 1 cm^3 , and the unit is $[\text{mg}/\text{cm}^3]$.

[0041] Assume that the mole fraction of Sodium iodide to the total number of moles of the additives is represented as $M(\text{NaI})$ [mol%], and that the sum of the mole fraction of rare earth metal iodide and the mole fraction of Thallium iodide is represented as $M(\text{ReI}_3 + \text{TII})$ [mol%]. Assume that the distribution ratio of the mole fraction of Sodium iodide $M(\text{NaI})$ to the sum of this mole fraction $M(\text{ReI}_3 + \text{TII})$ is represented as α . The α is represented by the following equation.

$$\alpha = M(\text{NaI}) / M(\text{ReI}_3 + \text{TII}) \quad : \text{Formula 4}$$

Fig. 4A is a view showing the results of the experiments conducted by the inventor of the present application. Its vertical axis represents a correlated color temperature; its horizontal axis represents the ratio α determined by Formula 4. When $4 < \alpha < 16$, the correlated color temperature reaches the target, or becomes approximately $2500 \text{ K} \pm 10\%$ (2250 to 2750 K). Further, when $7 < \alpha < 13$, the correlated color temperature becomes 2400 to 2600 K.

[0042] Fig. 4B is a view showing the results of the experiments conducted by the inventor of the present application. Its vertical axis represents a chromaticity deviation Duv; its horizontal axis represents the sum $M(\text{ReI}_3 + \text{TII})$ [mol%] of the mole fractions of a rare-earth metal iodide and a Thallium iodide relative to the total number of moles in additives. When $2 \text{ mol}\% < M(\text{ReI}_3 + \text{TII}) < 9 \text{ mol}\%$, the chromaticity deviation Duv reaches the target, or becomes -2 to 1.

[0043] As can be seen from Figs. 4A and 4B, the condition that the correlated color temperature reaches the target, or becomes approximately $2500 \text{ K} \pm 10\%$ (2250 to 2750 K) and the chromaticity deviation Duv reaches the target, or -2 to +1 is expressed by the following equations.

$$4 < M(\text{NaI})/M(\text{ReI}_3 + \text{TII}) < 16 \quad : \text{Formula 5}$$

$$2 \text{ mol}\% < M(\text{ReI}_3 + \text{TII}) < 9 \text{ mol}\% \quad : \text{Formula 6}$$

The condition that the correlated color temperature reaches the target, or becomes 2400 to 2600 K and the chromaticity deviation Duv reaches the target, or becomes -2 to +1 is expressed by the following equations.

$$7 < M(\text{NaI})/M(\text{ReI}_3 + \text{TII}) < 13 \quad : \text{Formula 7}$$

$$2 \text{ mol\%} < M(\text{ReI}_3 + \text{TII}) < 9 \text{ mol\%} \quad : \text{Formula 8}$$

[0044] Table 1 shows the compositions of the additives in the luminous tube of the ceramic metal halide lamp used in the experiments the inventor of the present application has performed. Here, examples of the five type of ceramic metal halide lamps which have achieved the targets of correlated color temperature and chromaticity deviation Duv are shown.

[Table 1]

Test number	M(TmI ₃) [mol %]	M(HoI ₃) [mol %]	M(TII) [mol %]	M(NaI) [mol %]	M(CaI ₂) [mol %]	M(LiI) [mol %]	Total [mol %]
1	2.8	0.0	4.0	62.2	14.1	16.9	100
2	2.7	0.0	4.2	61.7	14.2	17.3	100
3	2.7	0.0	4.3	61.9	14.1	17.1	100
4	1.6	0.0	2.6	57.5	14.7	23.6	100
5	0.9	0.9	6.7	34.7	33.7	23.1	100

[0045] In Table 1, M(TmI₃), M(HoI₃), M(TII), M(NaI), M(CaI₂), and M(LiI) represent the mole fractions (percentage) of Thulium iodide TmI₃, Holmium iodide HoI₃, Thallium iodide TII, Sodium iodide NaI, Calcium iodide CaI₂, and Lithium iodide LiI, respectively. In the experiments the inventor of the present application has performed, the additives in the luminous tube includes Thallium iodide TII, Sodium iodide NaI, Calcium iodide CaI₂, and Lithium iodide LiI. Sodium Na contributes to orangish colors, and Calcium Ca contributes to reddish colors, and Lithium Li contributes to ruby-reddish colors. A desired correlated color temperature is obtained by adding Sodium iodide NaI, Calcium iodide CaI₂, and Lithium iodide LiI in the respective predetermined mole fractions.

[0046] By adding Thallium iodide TII, luminous efficiency is improved, but chromaticity deviation Duv is deviated in the direction of increasing. However, in the present embodiment, the increase of chromaticity deviation Duv is suppressed by adding Calcium iodide CaI₂.

[0047] Furthermore, the additives may include Thulium iodide TmI₃, and further may include Holmium iodide HoI₃ as rare earth metal iodide ReI₃. By adding Thulium iodide TmI₃ and Holmium iodide HoI₃, luminous efficiency is improved individually.

[0048] From Table 1, the following findings are obtained. According to the present embodiment, the additives in the luminous tube include Sodium iodide NaI, Calcium iodide CaI₂, and Lithium iodide LiI, and these mole fractions can be expressed as follows.

$$30 \text{ mol\%} < M(\text{NaI}) < 70 \text{ mol\%} \quad : \text{Formula 9}$$

$$10 \text{ mol\%} < M(\text{CaI}_2) < 40 \text{ mol\%} \quad : \text{Formula 10}$$

$$10 \text{ mol\%} < M(\text{LiI}) < 30 \text{ mol\%} \quad : \text{Formula 11}$$

Furthermore, assuming that the sum of the mole fraction of Sodium iodide, the mole fraction of Calcium iodide, and the mole fraction of Lithium iodide is $M(\text{NaI} + \text{CaI}_2 + \text{LiI})$, this value satisfies the following equation.

$$50 \text{ mol\%} < M(\text{NaI} + \text{CaI}_2 + \text{LiI}) < 96 \text{ mol\%} \quad : \text{Formula 12}$$

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Numerical values of Table 2 show the calculated results of the value of α represented by Formula 4, the sum $M(\text{Rel}_3 + \text{TII})$ of the mole fraction of rare earth metal iodide and the mole fraction of Thallium iodide, the total amount $G(\text{total})$ of the additives per luminous tube volume of 1 cm^3 represented by Formula 3, and the amount $G(\text{Rel}_3)$ of rare earth metal iodide per luminous tube volume of 1 cm^3 , for the additives shown in Table 1. Rare earth metal iodide Rel_3 includes Thulium iodide TmI_3 and Holmium iodide HoI_3 as shown in Table 1.

[Table 2]

Test number	$\alpha = M(\text{NaI}) / M(\text{Rel}_3 + \text{TII})$	$M(\text{Rel}_3 + \text{TII})$ [mol %]	$G(\text{total})$ [mg/cm ³]	$G(\text{Rel}_3)$ [mg/cm ³]
1	9.1	6.8	26	2.9
2	9.0	6.9	38	4.1
3	8.9	6.9	32	3.4
4	13.8	4.2	31	1.5
5	4.1	8.5	44	2.0

[0049] Table 3 shows the results of measuring correlated color temperature CCT, chromaticity deviation Duv, average color-rendering index Ra, and luminous efficiency η for these five type of ceramic metal halide lamps. All the average color-rendering indexes Ra are larger than 90, and all the luminous efficiencies are larger than 75 lm/W.

[Table 3]

Test number	CCT [K]	Duv	Ra	η [lm/W]
1	2520	0.0	93	82.7
2	2490	-0.7	93	82.7
3	2520	-2.1	93	79.9
4	2380	-0.7	95	76.8
5	2720	0.5	92	75.3

[0050] Next, the inventor of the present application has found a condition so that the lamp lifetime L [h] reaches 15000 hours or longer using additives as parameters hermetically contained in the luminous tubes of ceramic metal halide lamps. Table 4 summarizes the specifications of some lamps that the applicant has ever developed. In this table, ten types of ceramic metal halide lamps Nos. 11 to 20 are summarized.

[Table 4]

Test number	$G(\text{total})$ [mg/cm ³]	$G(\text{Rel}_3)$ [mg/cm ³]	L [h]
No.11	78	14	9000
No.12	58	14	12000
No.13	61	5.2	12000
No.14	51	7.8	12000
No.15	45	16	12000
No.16	44	11	15000
No.17	19	3.5	21000
No.18	19	5.2	21000
No.19	5.4	2.7	24000
No.20	6.8	2.5	24000

[0051] In Table 4, the G (total) denotes the total amounts of the additives per luminous tube volume of 1cm^3 which is expressed by Formula 3. G (ReI_3) denotes the amount of the rare-earth metal iodide per luminous tube volume of 1cm^3 . Both of their units are mg/cm^3 . It can be found from the results that it is necessary to limit the total amount of additives and the amount of rare-earth metal iodides in order to prolong the lamp lifetime. The test numbers Nos. 16 to 20 exhibit a lamp lifetime L [h] longer than 15000 hours. In consideration of the results, the following conditions are required in order to achieve a lamp lifetime L[h] longer than 15000 hours with the conditions of the equations 5 to 11.

$$G(\text{total}) < 44 \text{ mg}/\text{cm}^3 \quad : \text{Formula 13}$$

$$G(\text{ReI}_3) < 11 \text{ mg}/\text{cm}^3 \quad : \text{Formula 14}$$

In the above, the ceramic metal halide lamp according to the present embodiments have been described, but these are illustrative, and are not intended to limit the scope of the invention. Any additions, deletions, variations, improvements and the like to the present embodiment, which those skilled in the art can easily perform, are within the scope of the invention. The technical scope of the present invention is determined by the description of the attached claims.

Reference Signs List

[0052]

1	ceramic metal halide lamp
2	luminous tube
4A, 4B	capillary
5A, 5B	electrode
6A, 6B	electrode assembly
7A, 7B	power supply lead
8A, 8B	metal foil piece
9A, 9B	external terminal
12	base
13	outer bulb
14	stem
15, 16	strut
17A, 17B	support disc
18	translucent sleeve
19A, 19B	nickel wire
20	getter
13A	outer bulb chip-off section,
13B	pinch seal section

Claims

1. A ceramic metal halide lamp comprising:

a luminous tube (2) containing a pair of electrodes (5A,5B), the luminous tube being made of translucent ceramic; and

a translucent outer tube (13) accommodating the luminous tube (2), the luminous tube hermetically containing a starting inert gas, mercury and additives, the additives containing Thallium iodide TII, Sodium iodide NaI, Calcium iodide CaI_2 , Lithium iodide LiI and a rare-earth metal iodide ReI_3 , the luminous tube being further configured such that its correlated color temperature is 2250 to 2750 K, its tube wall load is 20 to $30 \text{ W}/\text{cm}^2$ and its rated output is 35 to 400 W, wherein when a mole fraction of Sodium iodide relative to the total number of moles of the additives is denoted by M (NaI) [mol%] and a sum of mole fractions of the rare-earth metal iodide ReI_3 and Thallium iodide TII is denoted by M ($\text{ReI}_3 + \text{TII}$) [mol%], the M (NaI) and the M ($\text{ReI}_3 + \text{TII}$) satisfy the following equations,

$$4 < M(\text{NaI})/M(\text{ReI}_3 + \text{TII}) < 16$$

5

$$2 \text{ mol}\% < M(\text{ReI}_3 + \text{TII}) < 9 \text{ mol}\%.$$

2. The ceramic metal halide lamp according to claim 1, wherein
when the total amount of the additives per luminous tube volume of 1 cm³ is denoted by G (total) [mg/cm³] and the
amount of the rare-earth metal iodide contained in the additives per luminous tube volume of 1 cm³ is denoted by
G (ReI₃) [mg/cm³], the G (total) and the G (ReI₃) satisfy the following equations,

10

$$G(\text{total}) < 44 \text{ mg/cm}^3$$

15

$$G(\text{ReI}_3) < 11 \text{ mg/cm}^3.$$

3. The ceramic metal halide lamp according to claim 1 or 2, wherein
when a sum of the mole fraction M (NaI) of Sodium iodide relative to the total number of moles in the additives, the
mole fraction M (CaI₂) of Calcium iodide, and the mole fraction M (LiI) of Lithium iodide is denoted by M (NaI + CaI₂
+ LiI), the sum satisfies the following equation,

20

$$50 \text{ mol}\% < M(\text{NaI} + \text{CaI}_2 + \text{LiI}) < 96 \text{ mol}\%.$$

25

4. The ceramic metal halide lamp according to any one of claims 1 to 3, wherein
when the mole fraction M (NaI) of Sodium iodide relative to the total number of moles in the additives, the mole
fraction M (CaI₂) of Calcium iodide, and the mole fraction M (LiI) of Lithium iodide satisfy the following respective
equations,

30

$$30 \text{ mol}\% < M(\text{NaI}) < 70 \text{ mol}\%$$

35

$$10 \text{ mol}\% < M(\text{CaI}_2) < 40 \text{ mol}\%$$

$$10 \text{ mol}\% < M(\text{LiI}) < 30 \text{ mol}\%.$$

40

5. The ceramic metal halide lamp according to any one of claims 1 to 4, wherein
the additives contains one or more of Thulium iodide TmI₃, an iodide of Dysprosium (Dy), an iodide of Holmium (Ho)
and an iodide of Cerium (Ce) as the rare-earth metal iodide (but Thulium iodide TmI₃ is essential).

45

6. The ceramic metal halide lamp according to any one of claims 1 to 5, wherein
the correlated color temperature of the luminous tube is 2400 to 2600K, and
the M (NaI) and the M (ReI₃ + TII) satisfy the following equation,

50

$$7 < M(\text{NaI})/M(\text{ReI}_3 + \text{TII}) < 13.$$

55

FIG. 1

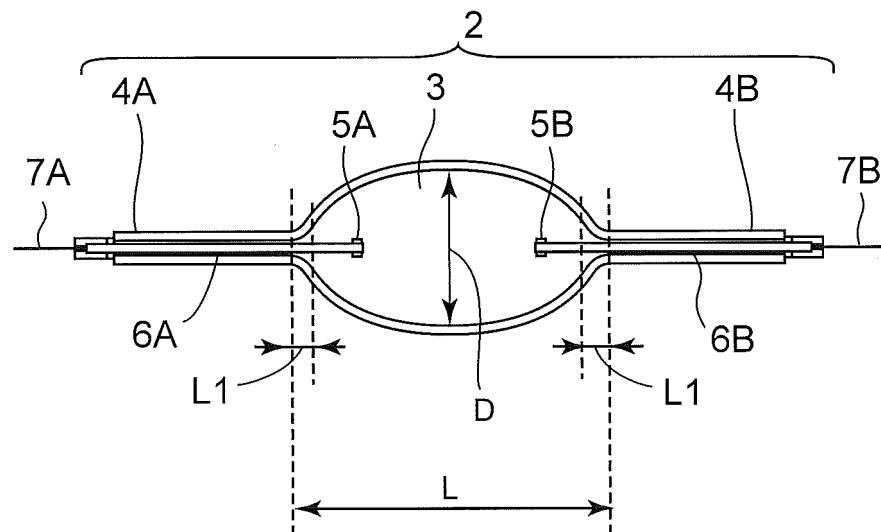


FIG. 2

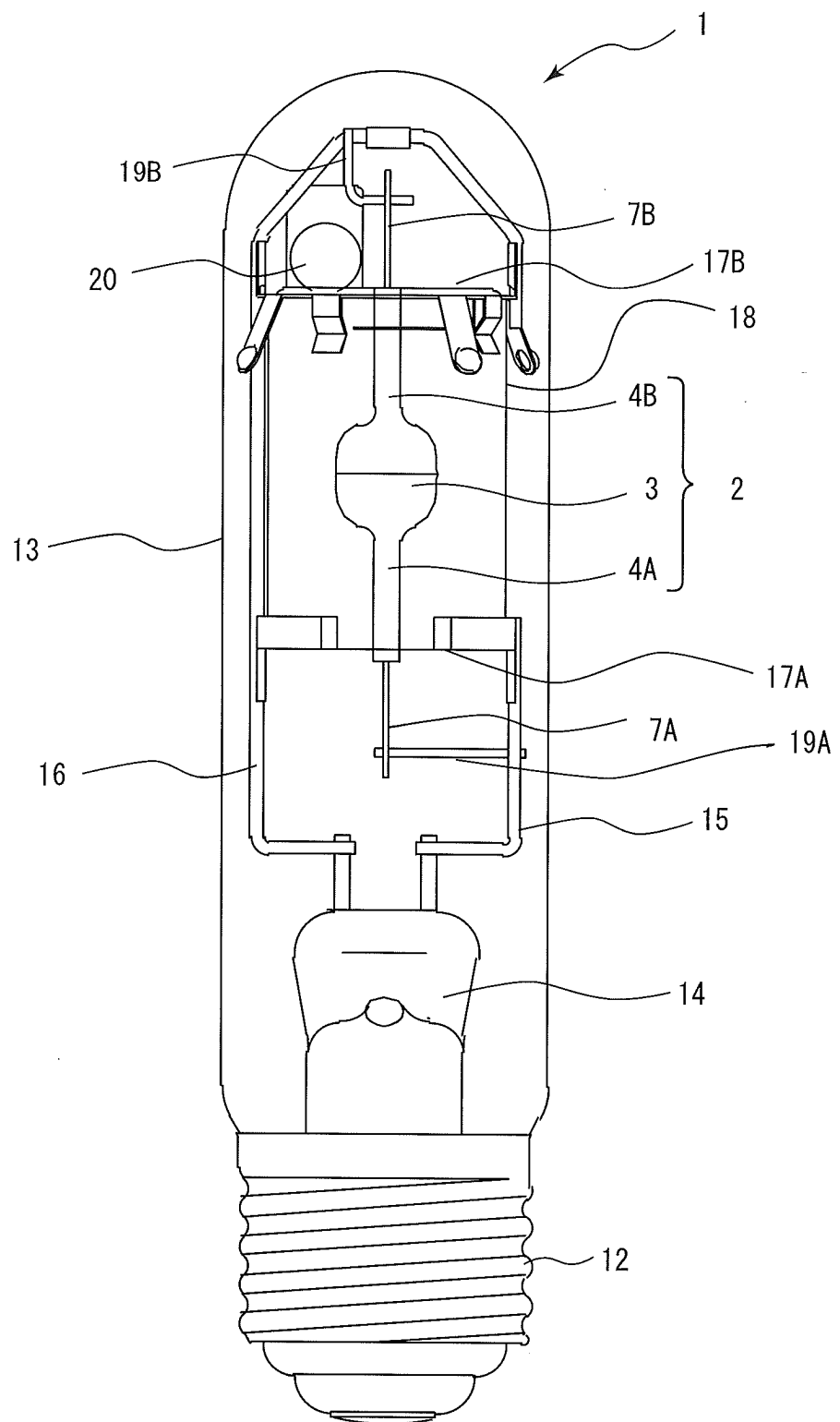


FIG. 3

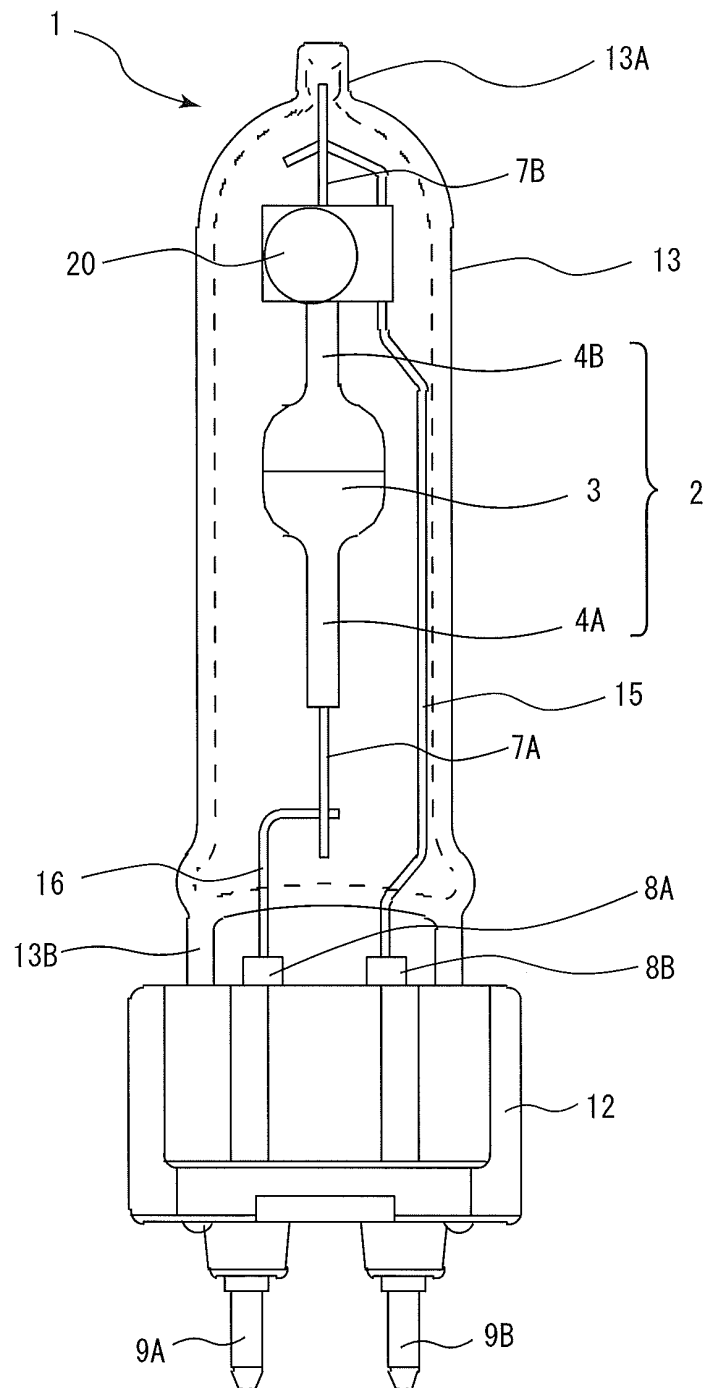


FIG. 4A

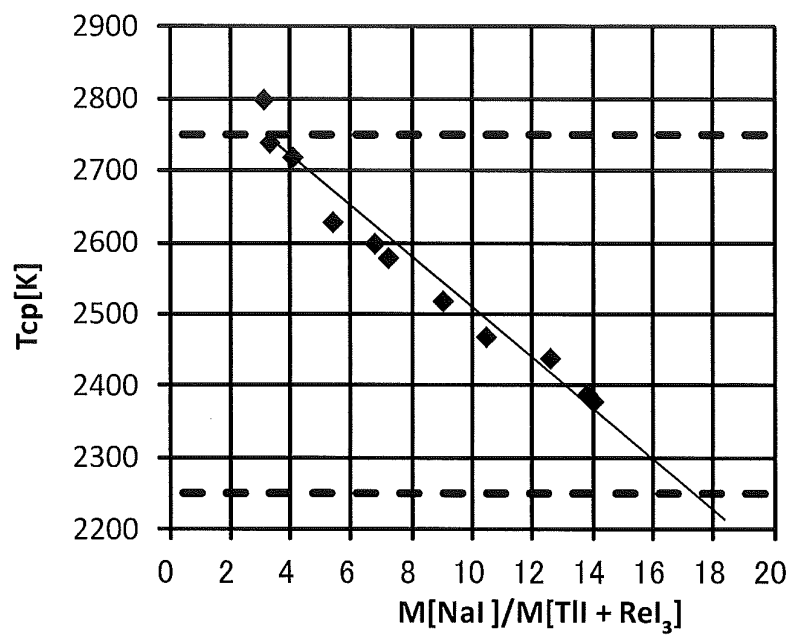
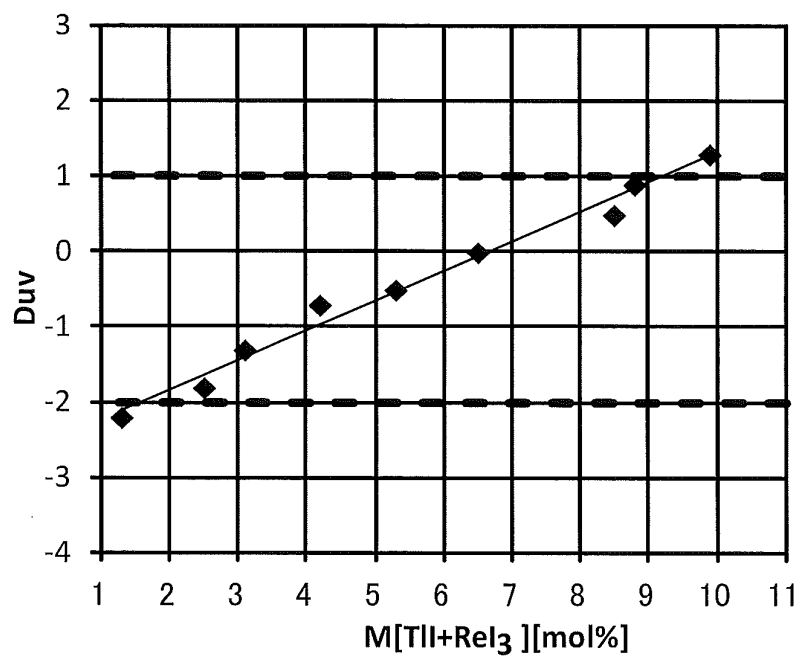


FIG. 4B



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/068359

A. CLASSIFICATION OF SUBJECT MATTER

H01J61/20(2006.01)i, H01J61/88(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01J61/00-65/08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2013

Kokai Jitsuyo Shinan Koho 1971-2013 Toroku Jitsuyo Shinan Koho 1994-2013

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 7-130331 A (Matsushita Electronics Corp.), 19 May 1995 (19.05.1995), entire text; all drawings (Family: none)	1-6
A	JP 2006-339156 A (Patent Treuhand Gesellschaft fur elektrische Gluhlampen mbH), 14 December 2006 (14.12.2006), entire text; all drawings & JP 2006-339156 A & US 2006/0273726 A1	1-6
A	JP 2003-187744 A (General Electric Co.), 04 July 2003 (04.07.2003), entire text; all drawings & US 2003/0102808 A1	1-6

☒ Further documents are listed in the continuation of Box C.
 ☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search
19 July, 2013 (19.07.13)Date of mailing of the international search report
30 July, 2013 (30.07.13)Name and mailing address of the ISA/
Japanese Patent Office

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2013/068359

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2009-512969 A (Panasonic Corp.), 26 March 2009 (26.03.2009), entire text; all drawings & US 2007/0085482 A1 & WO 2007/046529 A2	1-6
A	JP 2009-87602 A (Iwasaki Electric Co., Ltd.), 23 April 2009 (23.04.2009), entire text; all drawings (Family: none)	1-6

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REFERENCES CITED IN THE DESCRIPTION

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- JP 2010003488 A [0006] [0007]