(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 3 065 162 A1

(12) **EUROPEAN PATENT APPLICATION**
published in accordance with Art. 153(4) EPC

(43) Date of publication:
07.09.2016 Bulletin 2016/36

(21) Application number: **14857301.7**

(22) Date of filing: **06.10.2014**

(51) Int Cl.:
H01J 61/20 *(2006.01)*

(86) International application number:
PCT/JP2014/076695

(87) International publication number:
WO 2015/064309 (07.05.2015 Gazette 2015/18)

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME

(30) Priority: **28.10.2013 JP 2013223725**

(71) Applicant: **Iwasaki Electric Co., Ltd.**
Tokyo 103-0002 (JP)

(72) Inventor: **SASAI, Yasushi**
Gyoda city, Saitama 361-8505 (JP)

(74) Representative: **Copsey, Timothy Graham et al**
Kilburn & Strode LLP
20 Red Lion Street
London WC1R 4PJ (GB)

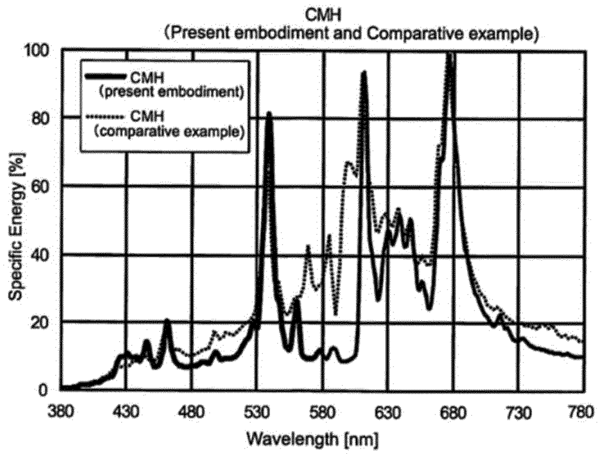
(54) LIGHT SOURCE AND MANUFACTURING METHOD THEREFOR

(57) The invention provides a light source that is favorable for the lighting of fresh foods required to show colors of meat, vegetables and the like more vividly than a high-chroma and high-color-rendering type of high-pressure sodium lamp and a method of manufacturing the same.

In a light source according to the present embodiment of the present invention comprises at least a light emitting portion to emit visible rays;
the light emitting portion is provided with such a luminous spectrum that if a wavelength region of 380 to 780 nm of visible light is split into a first wavelength region of a violet-bluish colors of wavelengths of 380 to 490 nm, a second wavelength region of greenish colors of wavelengths of 490 to 570 nm, a third wavelength region of yellowish colors of wavelengths of 570 to 590 nm, and a fourth wavelength region of orange-reddish colors of wavelengths of 590 to 780 nm, and
a distribution ratio of an integrated value of energy strength of light from the light emitting portion calculated for each of the four wavelength regions is set to be "y1 : y2 : y3 : y4" (where y1 + y2 + y3 + y4 = 100), the following formula is obtained.

$$7 \leq y1 \leq 11,\ 15 \leq y2 \leq$$

FIG. 5



EP 3 065 162 A1

Description

Technical Field

[0001] The present invention relates to a light source and a method of manufacturing the same, in particular, a super high chroma light source which is suitable for the lighting of fresh foods and a method of manufacturing the same.

Background Art

[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.

[0003] HID lamps can be roughly divided into three types, namely, a mercury lamp, a metal halide lamp and a high-pressure sodium lamp depending on the type of the additives enclosed in the luminous tube.

[0004] 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 colors of meat, vegetables and the like vividly although it is inferior to a general high-pressure sodium lamp in lifetime and luminous efficiency.

[0005] 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 ceramic metal halide lamp are said to be superior to those of high-chroma and high-color-rendering type of high-pressure sodium lamp.

[0006] However, a high-chroma and high-color-rendering type of high-pressure sodium lamp has been usually used for the lighting of fresh foods.

[0007] In a high-chroma and high-color-rendering type of high-pressure sodium lamp, the correlated color temperature is about 2500K. However, in a ceramic metal halide lamp, the correlated color temperature is relatively high and it is difficult to achieve a relatively low correlation color temperature such as about 2,500K.

[0008] A ceramic metal halide lamp having a correlated color temperature of 2000 to 4500 K is described in JP 2004-288617 A (JP 4279122 B1), and ceramic metal halide lamps having a color temperature of 2500 to 4500 K are described in JP 2003-187744 A and JP 2009-520323 A, and ceramic metal halide lamps having a color temperature of 2800 to 3700 K are 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 colors of irradiated objects such as meat, vegetables and the like vividly is disclosed.

[0009] As a condition of lighting, the wavelength spectral distribution is also important. In JP 2009-87602 A and JP 2012-113883 A, it is disclosed that in order to perform efficient growth in a plant factory, additives in a luminous tube are set so as to adjust the distribution ratio between energy strengths of wavelength regions of three colors to a predetermined value.

Prior Art documents

Patent Literature

[0010]

Patent Literature 1: JP 2004-288617 A (JP 4279122 B1)
Patent Literature 2: JP 2003-1877444 A (JP 4262968 B1)
Patent Literature 3: JP 2009-520329 A
Patent Literature 4: JP 2007-53004 A
Patent Literature 5: JP 2011-154847 A
Patent Literature 6: JP 2010-3488 A
Patent Literature 7: JP 2009-87602 A
Patent Literature 8: JP 2012-113883 A

SUMMARY OF INVENTION

Technical Problem

[0011] As described above, in the conventional technologies, any method for showing colors of irradiated objects such as meat, vegetables and the like more vividly has not been established like a high-chroma and high-color-rendering type of high-pressure sodium lamp.

[0012] An object of the present invention is to provide a light source that is favorable for the lighting of fresh foods required to show colors of meat, vegetables and the like more vividly than a high-chroma and high-color-rendering type of high-pressure sodium lamp and a method of manufacturing the same.

Means for Solving the Problem

[0013] In a light source according to the present embodiment of the present invention comprises at least a light emitting portion to emit visible rays;

the light emitting portion is provided with such a luminous spectrum that if a wavelength region of 380 to 780 nm of visible light is split into a first wavelength region of a violet-bluish colors of wavelengths of 380 to 490 nm, a second wavelength region of greenish colors of wavelengths of 490 to 570 nm, a third wavelength region of yellowish colors of wavelengths of 570 to 590 nm, and a fourth wavelength region of orange-reddish colors of wavelengths of 590 to 780 nm, and

a distribution ratio of an integrated value of energy strength of light from the light emitting portion calculated for each of the four wavelength regions is set to be "y1 : y2 : y3 : y4" (where y1 + y2 + y3 + y4 = 100), the following formula is obtained.

$$7 \leq y1 \leq 11,\ 15 \leq y2 \leq 21,\ 0 \leq y3 < 3, \text{ and } y4 = \text{residue.}$$

[0014] In the light source according to the present embodiment of the present invention,

the light emitting portion may be provided with such a luminous spectrum that if a distribution ratio of an integrated value of energy strength of light from the light emitting portion calculated for each of the four wavelength regions is set to be "y1 : y2 : y3 : y4" (where y1 + y2 + y3 + y4 = 100), the following formula is obtained.

$$8 \leq y1 \leq 9,\ 17 \leq y2 \leq 19,\ 0 \leq y3 \leq 2, \text{ and } y4 = \text{residue.}$$

[0015] In the light source according to the present embodiment of the present invention,

the light source may be a high intensity discharge light source comprising a luminous tube in which a noble gas and an additive are enclosed, and the luminous spectrum of the light emitting portion is set by adjusting a composition and amount of the additive.

[0016] In a method for manufacturing a light source according to the present embodiment of the present invention, the light source comprising at least a light emitting portion to emit visible rays; the method comprises:

a wavelength region splitting step for splitting wavelength region of 380 to 780 nm of visible light into a first wavelength region of violet-bluish colors of wavelengths of 380 to 490 nm, a second wavelength region of greenish colors of wavelengths of 490 to 570 nm, a third wavelength region of yellowish colors of wavelengths of 570 to 590 nm, and a fourth wavelength region of orange-reddish colors of wavelengths of 590 to 780 nm; and

a luminous spectrum setting step for setting a luminous spectrum of the light emitting portion so that if a distribution ratio of an integrated value of energy strength of light from the luminous tube calculated for each of the four wavelength regions is set to be "y1 : y2 : y3 : y4" (where y1 + y2 + y3 + y4 = 100), the following formula is obtained.

$$7 \leq y1 \leq 11,\ 15 \leq y2 \leq 21,\ 0 \leq y3 < 3, \text{ and } y4 = \text{residue.}$$

[0017] In the method for manufacturing a light source according to the present embodiment of the present invention, in the luminous spectrum setting step, the luminous spectrum of the light emitting portion may be set so that if a distribution ratio of an integrated value of energy strength of light from the light emitting portion calculated for each of the four wavelength regions is set to be "y1 : y2 : y3 : y4" (where y1 + y2 + y3 + y4 = 100), the following formula is obtained.

$$8 \leq y1 \leq 9,\ 17 \leq y2 \leq 19,\ 0 \leq y3 \leq 2, \text{ and } y4 = \text{residue.}$$

[0018] In the method for manufacturing a light source according to the present embodiment of the present invention, the light source may be a high intensity discharge lamp comprising a luminous tube in which a noble gas and an additive are enclosed, and in the luminous spectrum setting step, the luminous spectrum of the light emitting portion may be set by adjusting a composition and amount of the additive.

Effects of Invention

[0019] According to the present invention, it is possible to provide a light source that is favorable for the lighting of fresh foods required to show colors of meat, vegetables and the like more vividly than a high-chroma and high-color-rendering type of high-pressure sodium lamp and a method for manufacturing the same.

BRIEF DESCRIPTION OF DRAWINGS

[0020]

[Fig. 1]
Fig. 1 is a diagram illustrating an example of luminous tube of ceramic metal halide lamp according to the present embodiment.
[Fig. 2]
Fig. 2 is a diagram illustrating an example of ceramic metal halide lamp according to the present embodiment.
[Fig. 3]
Fig. 3 is a diagram illustrating an example of ceramic metal halide lamp according to the present embodiment.
[Fig. 4]
Fig. 4 is a diagram illustrating an example of wavelength spectrum of each high-pressure sodium lamp and conventional ceramic metal halide lamp.
[Fig. 5]
Fig. 5 is a diagram illustrating an example of wavelength spectrum of ceramic metal halide lamp according to the present embodiment.

MODES FOR CARRYING OUT THE INVENTION

[0021] In the following, embodiments of the light source and its manufacturing method according to the present invention will be described in detail with reference to the accompanying drawings. The same elements in the drawings will be denoted by the same reference numerals, and duplicate descriptions will be omitted.

[0022] Hereinafter, a ceramic metal halide lamp as an example of the light source according to the present invention is explained. However, the light source according to the present invention is not limited to the ceramic metal halide lamp and may be other high intensity discharge lamps, or other light sources, for example, a lighting device using LED or electroluminescence (EL).

[0023] 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 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 with the compression of the powder of translucent ceramic such as alumina. Electrode assemblies 6A and 6B are inserted from 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, respectively.

[0024] In the inside of light-emitting portion 3, additives are enclosed in addition to argon and mercury. The additives include a light-emitting substance such as alkali metal iodide, alkali earth metal iodide, rare earth metal iodide or the like. The additives enclosed in light-emitting portion 3 will be described below in detail.

[0025] As inner dimensions of luminous tube 2, effective length L and effective inner diameter D are defined. In case of the cylindrical luminous tube, effective length L is a distance between both the end surfaces. In case of the luminous tube in which the light-emitting portion and the capillaries are continuously formed as shown in Fig. 1, it is defined as a distance between both the outer ends of transition curved surfaces L1 and L1 which are between straight tubular capillary 4A or 4B and light-emitting portion 3. Effective inner diameter D is defined as the maximum inner diameter of the central portion between the electrodes 5A and 5B in case of the 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".

[0026] 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 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/cm^2 (rated output power: 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.

[0027] 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 according to 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 has been described with reference to Fig. 1.

[0028] 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 by each other. 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, respectively. 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.

[0029] 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 according to the present embodiment includes luminous tube 2 and outer bulb 13. The structure of luminous tube 2 has been 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.

[0030] 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, respectively. The tips of power supply leads 7A and 7B are welded to struts 15 and 16, respectively. Getter 20 is mounted to strut 15. Struts 15 and 16 are electrically connected to external terminals 9A and 9B through metal foils 8A and 8B at pinch seal portion 13B, respectively.

[0031] 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 foils 8A and 8B, respectively.

[0032] The ceramic metal halide lamp according to the present embodiment may be a reflective type of ceramic metal halide lamp with a concave reflector as an example other than those shown in Figs. 2 and 3.

[0033] 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 of fresh foods. As the reason for this, various 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 wavelength spectrum distribution.

[0034] Fig. 4 illustrates an example of wavelength spectrum of each a high-chroma and high-color-rendering type of high-pressure sodium lamp ("NH (high-chroma type) " in the figure) and a conventional ceramic metal halide lamp ("CMH (conventional)" in the figure). The vertical axis represents specific energy [%], and the horizontal axis represents wavelength [nm]. The solid line curve denotes a wavelength spectrum of a high-chroma and high-color-rendering type of high-pressure sodium lamp (NH), and the broken line curve denotes a wavelength spectrum of a conventional ceramic metal halide lamp (CMH).

[0035] As shown in the figure, in case of the conventional ceramic metal halide lamp, it has a peak around the wavelength of 600 nm indicating orange color, but the energy value of wavelength of 630 nm or more of reddish color is not high. It seems that such a wavelength spectrum is not suitable for the lighting of fresh foods. On the other hand, in case of the high chroma and high color rendering type of high-pressure sodium lamp, the energy value of wavelength of 610 nm or more of reddish color is high and it has a peak around the wavelength of 570 nm indicating yellow color but it has a hiatus around the wavelength of 590 nm indicating orange color. Therefore, it does not seem that the high-chroma and high-color-rendering type of high-pressure sodium lamp is suitable for the lighting of fresh foods which are required to show colors of meat, vegetables and the like vividly. However, as described above, actually a high-chroma and high-color-rendering type of high-pressure sodium lamp has been used favorably for the lighting of fresh foods. The reason for this cannot be understood by the wavelength spectrum of the high-chroma and high-color-rendering type of high-pressure sodium lamp shown in Fig. 4.

[0036] As the result of repeating trial and error taking into consideration the wavelength spectrum of high-chroma and high-color-rendering type of high-pressure sodium lamp, the inventor of the present application has succeed in prototyping a ceramic metal halide lamp that can show colors of meat, vegetables and the like more vividly than the high-chroma and high-color-rendering type of high-pressure sodium lamp.

[0037] Table 1 shows the measurement results of color rendering indexes of the high-chroma and high-color-rendering type of high-pressure sodium lamp (NH), the conventional ceramic metal halide lamp (CMH), the prototyped ceramic metal halide lamp (CMH) and the comparative example of ceramic metal halide lamp (CMH), which were made by the inventor of the present application.

[0038] The prototyped ceramic metal halide lamp (CMH) is an example of the present embodiment, and therefore this lamp is described as "the ceramic metal halide lamp (CMH) according to the present embodiment" in Table 1. The comparative example of ceramic metal halide lamp (CMH) is disclosed in Japanese patent application No. 2012-173201 as filed by the same applicant as that of the present application.

[Table 1]

Symbol	Name	NH	CMH (Conventional)	CMH (Present embodiment)	CMH (Comparative)
Ra	**Average color rendering index (=CRI)**	**83**	**93**	**65**	**95**
R9	**Red color rendering index**	**45**	**46**	**-16**	**50**
R10	**Yellow color rendering index**	**69**	**96**	**96**	**90**
R11	**Green color rendering index**	**67**	**95**	**57**	**96**
R12	**Blue color rendering index**	**60**	**92**	**89**	**90**

[0039] In Table 1, the first column shows symbols of color rendering indexes. The second column shows names of color rendering indexes. The third column shows measurement results of color rendering indexes of the high-chroma and high-color-rendering type of high-pressure sodium lamp (NH). The fourth column shows measurement results of color rendering indexes of the conventional ceramic metal halide lamp (CMH). The fifth column and the sixth column show measurement results of color rendering indexes of the ceramic metal halide lamp (CMH) of the present embodiment and the comparative example of the ceramic metal halide lamp (CMH), respectively.

[0040] Each color rendering index represents the deviation from the color viewed under the reference light standardized by JIS. When the color rendering index is 100, it indicates that there is no deviation from the color viewed under the reference light. As the color rendering index is closer to 100, it indicates that the color deviation is smaller.

[0041] Firstly, various kinds of color rendering indexes are compared between the conventional ceramic metal halide lamp and the high-chroma and high-color-rendering type of high-pressure sodium lamp. In terms of red color rendering index (R9), the conventional ceramic metal halide lamp is almost equal to the high-chroma and high-color-rendering type of high-pressure sodium lamp, but in terms of other color rendering indexes, the conventional ceramic metal halide lamp is sufficiently large as compared with the high-chroma and high-color-rendering type of high-pressure sodium lamp.

[0042] Next, various kinds of color rendering indexes are compared between the present embodiment and the comparative example of ceramic metal halide lamp and the high-chroma and high-color-rendering type of high-pressure sodium lamp. In terms of average color rendering index (Ra), red color rendering index (R9), and green color rendering index (R11), the ceramic metal halide lamp according to the present embodiment is very low as compared with the high-chroma and high-color-rendering type of high-pressure sodium lamp. On the other hand, in terms of yellow color rendering index (R10) and the blue color rendering index (R12), the ceramic metal halide lamp according to the present embodiment is considerably large as compared with the high-chroma and high-color-rendering type of high-pressure sodium lamp.

[0043] In terms of various kinds of color rendering indexes (Ra), (R9), (R10), (R11) and (R12), the comparative example of ceramic metal halide lamp is considerably large as compared with the high-chroma and high-color-rendering type of high-pressure sodium lamp. Particularly, in terms of yellow color rendering index (R10), green color rendering index (R11) and the blue color rendering index (R12), the comparative example of ceramic metal halide lamp is considerably large as compared with the high-chroma and high-color-rendering type of high-pressure sodium lamp.

[0044] As described above, the values and the trends of various kinds of color rendering indexes of the present embodiment and the comparative example of ceramic metal halide lamp are different from those of the high-chroma and high-color-rendering type of high-pressure sodium lamp. It has been proved that the ceramic metal halide lamp according to the present embodiment is suitable for the lighting of fresh foods, and can show colors of fresh foods more vividly as compared with the high-chroma and high-color-rendering type of high-pressure sodium lamp. However, the reason for this is not understood by the comparison of various kinds of color rendering indexes. It has been proved that the comparative example of ceramic metal halide lamp is suitable for the lighting of fresh foods, but the reason for this is not understood by the comparison of various kinds of color rendering indexes.

[0045] By performing the following considerations about the present embodiment and the comparative example of ceramic metal halide lamp, the inventor of the present application has completed the present invention.

[0046] Fig. 5 illustrates an example of wavelength spectrum of each a ceramic metal halide lamp according to the present embodiment and a comparative example of ceramic metal halide lamp. The vertical axis represents specific energy [%], and the horizontal axis represents wavelength [nm]. The solid line curve denotes a wavelength spectrum of ceramic metal halide lamp (CMH) according to the present embodiment, and the broken line curve denotes a wavelength spectrum of ceramic metal halide lamp (CMH) according to the comparative example.

[0047] As shown in the figure, in case of the ceramic metal halide lamp according to the present embodiment, it has peaks around the wavelength of 610 nm indicating orange color and the wavelength of 680 nm indicating red color respectively. Further, in case of the ceramic metal halide lamp according to the present embodiment, it does not have a hiatus around the wavelength of 590 nm indicating yellow color like the case of high-chroma and high-color-rendering type of high-pressure sodium lamp, but the energy is low at wavelengths 560 to 600 indicating yellow color to orange color.

[0048] Thus, the wavelength spectrum of ceramic metal halide lamp according to the present embodiment is not similar to that of the high-chroma and high-color-rendering type of high-pressure sodium lamp shown in Fig. 4. As described above, although it has been found that the ceramic metal halide lamp according to the present embodiment is suitable for the lighting of fresh foods and can show colors of fresh foods more vividly as compared with the high-chroma and high-color-rendering type of high-pressure sodium lamp, the reason for this cannot be exactly known by the wavelength spectrums shown in Fig. 5.

[0049] In case of the ceramic metal halide lamp according to the comparative example, it does not have a hiatus around the wavelength of 580 nm like the case of high-chroma and high-color-rendering type of high-pressure sodium lamp. It has been found that the ceramic metal halide lamp according to the comparative example is suitable for the lighting of fresh foods, the reason for this cannot be understood by the wavelength spectrums shown in Fig. 5. Accordingly, the inventor of the present application has further analyzed the wavelength spectrums.

[0050] The inventor of the present application has split the wavelength region of 380 to 780 nm of visible light into six wavelength regions and obtained an integrated value (relative value) of energy strength of each wavelength region for the high-chroma and high-color-rendering type of high-pressure sodium lamp (NH), the conventional ceramic metal halide lamp (CMH), the ceramic metal halide lamp (CMH) according to the present embodiment and the ceramic metal halide lamp (CMH) according to the comparative example, respectively. The result is shown in Table 3. The integrated value of energy strength corresponds to the area under the waveform.

[Table2]

Wave-length region	Color	Wavelength [nm]	Integrated value of NH [%]	Integrated value of CMH (Conventional) [%]	Integrated value of CMH (Present embodiment) [%]	Integrated value of CMH (Comparative) [%]
1	Violet	380~430	1	6	2	1
2	Blue	430~490	4	11	7	5
3	Green	490~570	17	28	19	19
4	Yellow	570~590	5	9	2	6
5	Orange	590~620	9	21	11	17
6	Red	620~780	64	25	59	52
Total			100	100	100	100

[0051] In Table 2, the first column shows the six wavelength regions. The second column shows the color of each wavelength region. The third column shows the upper limit and lower limit of the wavelength of each wavelength region. The fourth column shows the integrated value of energy strength of each wavelength region in case of the high-chroma and high-color-rendering type of high-pressure sodium lamp (NH). The fifth column shows the integrated value of energy strength of each wavelength region in case of the conventional ceramic metal halide lamp (CMH). The sixth column shows the integrated value of energy strength of each wavelength region in case of the ceramic metal halide lamp (CMH) according to the present embodiment. The seventh column shows the integrated value of energy strength of each wavelength region in case of the ceramic metal halide lamp (CMH) according to the comparative example. The integrated values in the fourth, the fifth, the sixth and the seventh column are relative values.

[0052] The first wavelength region represents violetish colors with wavelengths of 380 to 430 nm. The second wavelength region represents bluish colors with wavelengths of 430 to 490 nm. The third wavelength region represents greenish colors with wavelengths of 490 to 570 nm. The fourth wavelength region represents yellowish colors with wavelengths of 570 to 590 nm. The fifth wavelength region represents orangish colors with wavelengths of 590 to 620 nm. The sixth wavelength region represents reddish colors with wavelengths of 620 to 780 nm.

[0053] In Table 2, the distribution ratio of the integrated value of energy strength in case of the conventional ceramic metal halide lamp differs greatly from that in case of the high-chroma and high-color-rendering type of high-pressure sodium lamp. Comparing the distribution ratio of the integrated value of energy strength in case of the ceramic metal halide lamp according to the present embodiment with that in case of the high-chroma and high-color-rendering type of high-pressure sodium lamp, luminous efficiency of reddish colors of the present embodiment is low. Namely, the two are not identical with each other.

[0054] Comparing the distribution ratio of the integrated value of energy strength in case of the ceramic metal halide lamp according to the comparative example with that in case of the high-chroma and high-color-rendering type of high-pressure sodium lamp, luminous efficiency of reddish colors of the comparative example is low and luminous efficiency of orangish colors of the comparative example is high. Namely, the two are not identical with each other.

[0055] Therefore, from Table 2, it is possible to explain the reason why the lighting using the conventional ceramic metal halide lamp can give different impression from that given by the lighting of the high-chroma and high-color-rendering type of high-pressure sodium lamp.

[0056] On the other hand, it is impossible to explain the reason why ceramic metal halide lamps according to the present embodiment and the comparative example are suitable for the lighting of fresh foods required to show colors of meat, vegetables and the like vividly. Particularly, it is impossible to explain the reason why the ceramic metal halide lamp according to the present embodiment can show colors of fresh foods more vividly than the high-chroma and high-color-rendering type of high-pressure sodium lamp.

[0057] Then, the inventor of the present application has split the wavelength region of 380 to 780 nm of visible light into four wavelength regions and obtained an integrated value (relative value) of the energy strength of each wavelength region for the high pressure sodium lamp (NH), the conventional ceramic metal halide lamp (CMH), the ceramic metal halide lamp (CMH) according to the present embodiment and the ceramic metal halide lamp (CMH) according to the comparative example, respectively. The result is shown in Table 3.

[Table3]

Wavelength region	Color	Wave -length [nm]	Integrated value of NH [%]	Integrated value of CMH (Conventional) [%]	Integrated value of CMH (Present embodiment) [%]	Integrated value of CMH (Comparative) [%]
1	Violet-Blue	380~490	5	17	9	6
2	Green	490~570	17	28	19	19
3	Yellow	570~590	5	9	2	6
4	Orange-red	590~780	73	46	70	69
Total			100	100	100	100

[0058] In Table 3, the first column shows the numbers of four wavelength regions. The second column shows the color of each wavelength region. The third column shows the upper limit and lower limit of the wavelength of each wavelength region. The fourth column shows the integrated value of energy strength of each wavelength region in case of the high-chroma and high-color-rendering type of high-pressure sodium lamp (NH). The fifth column shows the integrated value of energy strength of each wavelength region in case of the conventional ceramic metal halide lamp (CMH). The sixth column shows the integrated value of energy strength of each wavelength region in case of the ceramic metal halide lamp (CMH) according to the present embodiment. The seventh column shows the integrated value of energy strength of each wavelength region in case of the ceramic metal halide lamp (CMH) according to the comparative example. The integrated values in the fourth, the fifth, the sixth and the seventh column are relative values.

[0059] The first wavelength region represents violet-bluish colors with wavelengths of 380 to 490 nm. The second wavelength region represents greenish colors with wavelengths of 490 to 570 nm. The third wavelength region represents yellowish colors with wavelengths of 570 to 590 nm. The fourth wavelength region represents orange-reddish colors with wavelengths of 590 to 780 nm.

[0060] In Table 3, the distribution ratio of the integrated value of energy strength in case of the conventional ceramic metal halide lamp differs greatly from that in case of the high-chroma and high-color-rendering type of high-pressure sodium lamp.

[0061] Comparing the distribution ratio of the integrated value of energy strength in case of the ceramic metal halide lamp according to the present embodiment with that in case of the high-chroma and high-color-rendering type of high-pressure sodium lamp, luminous efficiency of violet-bluish colors of the present embodiment is relatively high but that of yellowish colors of the present embodiment is extremely low. Accordingly, the two are different from each other.

[0062] Comparing the distribution ratio of the integrated value of energy strength in case of the ceramic metal halide lamp according to the comparative example with that in case of the high-chroma and high-color-rendering type of high-pressure sodium lamp, luminous efficiency of orange-reddish colors of the comparative example is relatively low, but in terms of other colors, luminous efficiencies are almost the same.

[0063] Therefore, from Table 3, it is possible to explain the reason why the lighting using the conventional ceramic metal halide lamp can give different impression from that given by the lighting using the high-chroma and high-color-rendering type of high-pressure sodium lamp.

[0064] Further, it is possible to explain the reason why the lighting using the ceramic metal halide lamp according to the comparative example is suitable for the lighting of fresh foods required to show colors of meat, vegetables and the like vividly similarly to the high-chroma and high-color-rendering type of high-pressure sodium lamp.

[0065] On the other hand, it has been proved that the ceramic metal halide lamps according to the present embodiment can show colors of meat, vegetables and the like more vividly than the high-chroma and high-color-rendering type of high-pressure sodium lamp. It can be assumed that the reason for this is the difference of luminous efficacy.

[0066] Hereinafter, the distribution ratio of the integrated value of energy strength in the four wavelength regions is expressed as "y1 : y2 : y3 : y4",wherein "y1 + y2 + y3 + y4 = 100". As shown in Table 3, in the ceramic metal halide lamp according to the present embodiment, the distribution ratio of the integrated value of energy strength in the four wavelength regions is "9 : 19 : 2 : 70".

[0067] Thus, the inventor of the present application has actually measured the allowable range of the distribution ratio of the integrated value of energy strength in the four wavelength regions, as a condition to show colors of fresh foods, particularly, colors of meat, vegetables and the like more vividly than the high-chroma and high-color-rendering type of high-pressure sodium lamp. The inventor of the present application has varied the distribution ratios of the integrated value of energy strength in the four wavelength regions of the ceramic metal halide lamps according to the present embodiment, and used them for the lighting of fresh foods such as vegetables, bread, meat and the like. Further, the inventor of the present application has used the high-chroma and high-color-rendering type of high-pressure sodium lamp as a standard lighting. The inventor of the present application has counted the number of people who answered that in case of the lighting using the ceramic metal halide lamps according to the present embodiment the object can be seen more "vividly" than in case of the lighting using the high-chroma and high-color-rendering type of high-pressure sodium lamp. Respondents consist of fifty men and women of 18 to 64 years old. As a result, the following findings have been obtained.

[0068] When the distribution ratio of the integrated value of energy strength in the four wavelength regions is "y1 = 7 ~ 11, y2 = 15 ~ 21, y3 = 0 ~ 3, y4 = the residue", 90% or more of the people have answered that the colors of fresh foods are "vivid".

[0069] When the distribution ratio of the integrated value of energy strength in the four wavelength regions is "y1 = 8 ~ 9, y2 = 17 ~ 19, y3 = 0 ~ 2, y4 = the residue", 96% or more of the people have answered that the colors of fresh foods are "vivid".

[0070] From this result, it has been proved that it is desirable that the luminous efficiency ratio y1 of the wavelength region representing violet-bluish colors is set to be relatively high and the luminous efficiency ratio y3 of the wavelength region representing yellowish colors is set to be relatively low as compared with the high-chroma and high-color-rendering type of high-pressure sodium lamp. In the ceramic metal halide lamp, it is impossible that the luminous efficiency ratio y3 of the wavelength region representing yellowish colors is zero (y3 = 0). Accordingly, in the experiments described above, by using spectrum transmission filter, it has been achieved that yellowish colors is zero (y3 = 0).

[0071] From the above analysis of the wavelength spectrum, the following findings are obtained. In the light source of an object to be determined, the wavelength region of 380 to 780 nm of visible light is divided into four wavelength regions, and then the distribution ratio of the integrated value of energy strength for each wavelength region is obtained.

[0072] If the distribution ratio is "y1 = 7 ~ 11, y2 = 15 ~ 21, y3 = 0 ~ 3, y4 = the residue", it can be determined that the light source of an object to be determined is suitable for the lighting of fresh foods to be required to show colors of meat, vegetables and the like vividly, and can show colors of fresh foods more vividly than the high-chroma and high-color-rendering type of high-pressure sodium lamp.

[0073] Further, if the distribution ratio is "y1 = 8 ~ 9, y2 = 17 ~ 19, y3 = 0 ~ 2, y4 = the residue", it can be definitely determined that the light source of an object to be determined is suitable for the lighting of fresh foods to be required to show colors of meat, vegetables and the like vividly, and can show colors of fresh foods more vividly than the high-chroma and high-color-rendering type of high-pressure sodium lamp.

[0074] The light source of an object to be determined is not limited to ceramic metal halide lamp. The light source of an object to be determined may be other high intensity discharge lamps, or other light sources, for example, LED lamp or lighting apparatus including LED or electroluminescence (EL).

[0075] Hereinafter, techniques for achieving a light source which is suitable for the lighting of fresh foods to be required to show colors of meat, vegetables and the like are explained. Generally, in a high intensity discharge lamp, by adjusting types, compositions and amounts of light emitting materials enclosed in the discharge tube, a desirable distribution ratio of the integrated value of energy strength in the four wavelength regions can be obtained.

[0076] In case of the lighting apparatus including LED or electroluminescence (EL), the following techniques are used.

[0077]

(1) In case of the LED light source with a single light emitting element:

By molding a light emitting element emitting blue color or ultra violet beam with resin including fluorescence materials, or by mounting a cover including fluorescence materials around a light emitting element, a light source having a relatively broad wavelength region can be obtained.
By adjusting types, compositions, and amounts of fluorescent materials, a desirable distribution ratio of the integrated value of energy strength in the four wavelength regions can be obtained.

(2) In case of the LED lamp in which a plurality of light emitting elements are combined, or lighting apparatus in which LED elements are directly mounted:

By combining a plurality of light emitting elements (LED, EL and the like) having different wavelengths (red color or blue color), a light source having a relatively broad wavelength region can be obtained. Further, by selecting wavelengths of combined light emitting elements, a desirable distribution ratio of the integrated value of energy strength in the four wavelength regions can be obtained.

[0078] It is preferable to position a light diffusion layer (for example a cover) outside of the light emitting element, since irregularity of color becomes insensitive even when the light source is directly observed. In such a case, the aforementioned technique using fluorescence materials may be combined.

[0079] Table 4 shows the compositions of additives in the luminous tubes of the ceramic metal halide lamps used in the experiments the inventor of the present application has performed. The inventor of the present application has used the ceramic metal halide lamps according to the present embodiment for the lighting of fresh foods such as vegetables, bread, meat and the like and counted the number of people who answered that in case of the lighting using the ceramic metal halide lamps according to the present embodiment the object can be seen more "vividly" than in case of the lighting using the high-chroma and high-color-rendering type of high-pressure sodium lamp. Five types of ceramic metal halide lamps shown in Table 4 are such that the number of people is 90% or more who have answered that in case of the lighting using the ceramic metal halide lamps according to the present embodiment the object can be seen more "vividly" than in case of the lighting using the high-chroma and high-color-rendering type of high-pressure sodium lamp.

[Table4]

Test Number	M(DyI_3) [mol%]	M(TlI) [mol%]	M(NaI) [mol%]	M(CaI_2) [mol%]	M(LiI) [mol%]	Total [mol%]
1	-	7.6	-	58.4	34.0	100
2	-	7.7	-	58.8	33.5	100
3	-	7.9	-	59.5	32.6	100
4	-	6.1	-	68.7	25.2	100
5	0.3	4.9	0.4	74.1	20.3	100

[0080] In Table 4, M(DyI_3), M(TlI), M(NaI), M(CaI_2), and M(LiI) represent the mole fractions (percentage) of Dysprosium iodide DyI_3, Thallium iodide TlI, Sodium iodide NaI, Calcium iodide CaI_2, and Lithium iodide LiI, respectively. In the experiment the inventor of the present application has performed, the additives in the luminous tube includes Thallium iodide TlI, Calcium iodide CaI_2, and Lithium iodide LiI. Further Dysprosium iodide DyI_3 and Sodium iodide NaI may be added as additives in the luminous tube.

[0081] 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 can be obtained by adding Sodium iodide NaI, Calcium iodide CaI_2, and Lithium iodide LiI of the respective predetermined mole fractions.

[0082] By adding Dysprosium iodide DyI_3 and Thallium iodide TlI, luminous efficiency is improved, but chromaticity deviation Duv is deviated in the increasing trend. However, in the present embodiment, by adding Calcium iodide CaI_2, the increase of chromaticity deviation Duv is suppressed.

[0083] Table 5 shows the results of measuring correlated color temperature CCT, chromaticity deviation Duv, average color-rendering index Ra, red color-rendering index R9 and luminous efficiency η for these five types of ceramic metal halide lamps. All the correlated color temperatures CCT are 2900~3100 K, chromaticity deviations Duv are 0~-4 except experiment number 5. Average color-rendering index Ra, red color-rendering index R9 and luminous efficiency η are not all good.

[0084] However, it has been proved that these ceramic metal halide lamps are suitable for the lighting of fresh foods required to show colors of meat, vegetables and the like vividly. In other words, according to the conventional technique, there is a low possibility that such light sources having relatively low color-rendering index and low luminous efficiency are actually used, but the inventor of the present application has found for the first time that even such a light source that color-rendering index and luminous efficiency are relatively low is suitable for the lighting of fresh foods to be required to show colors of meat, vegetables and the like vividly.

[Table5]

Test Number	CCT [K]	Duv	Ra	R9	η [lm/W]
1	2910	0	64	-14	59
2	2950	-1	64	-13	59
3	3080	-1	65	-12	61
4	3060	-4	60	-32	63
5	2930	-8	64	-12	64

[0085] In the above, the light source and method of manufacturing the same according to the present invention has 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.

EXPLANATION OF REFERENCE NUMERALS

[0086]

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
9A, 9B	external terminal
12	base
13	outer bulb
14	stem
15, 16	strut
17A, 17B	support disk
18	translucent sleeve
19A, 19B	nickel wire
20	getter
13A	outer bulb chip-off portion
13B	pinch seal portion

Claims

1. A light source comprising at least a light emitting portion to emit visible rays; wherein the light emitting portion is provided with such a luminous spectrum that if a wavelength region of 380 to 780 nm of visible light is split into a

first wavelength region of a violet-bluish colors of wavelengths of 380 to 490 nm, a second wavelength region of greenish colors of wavelengths of 490 to 570 nm, a third wavelength region of yellowish colors of wavelengths of 570 to 590 nm, and a fourth wavelength region of orange-reddish colors of wavelengths of 590 to 780 nm, and
a distribution ratio of an integrated value of energy strength of light from the light emitting portion calculated for each of the four wavelength regions is set to be "y1 : y2 : y3 : y4" (where y1 + y2 + y3 + y4 = 100), the following formula is obtained.

$$7 \leq y1 \leq 11,\ 15 \leq y2 \leq 21,\ 0 \leq y3 < 3, \text{ and } y4 = \text{residue}.$$

2. The light source according to claim 1,
wherein the light emitting portion is provided with such a luminous spectrum that if a distribution ratio of an integrated value of energy strength of light from the light emitting portion calculated for each of the four wavelength regions is set to be "y1 : y2 : y3 : y4" (where y1 + y2 + y3 + y4 = 100), the following formula is obtained.

$$8 \leq y1 \leq 9,\ 17 \leq y2 \leq 19,\ 0 \leq y3 \leq 2, \text{ and } y4 = \text{residue}.$$

3. The light source according to claim 1 or 2,
wherein the light source is a high intensity discharge light source comprising a luminous tube in which a noble gas and an additive are enclosed, and the luminous spectrum of the light emitting portion is set by adjusting a composition and amount of the additive.

4. A method for manufacturing a light source comprising at least a light emitting portion to emit visible rays;
the method comprising:

a wavelength region splitting step for splitting wavelength region of 380 to 780 nm of visible light into a first wavelength region of violet-bluish colors of wavelengths of 380 to 490 nm, a second wavelength region of greenish colors of wavelengths of 490 to 570 nm, a third wavelength region of yellowish colors of wavelengths of 570 to 590 nm, and a fourth wavelength region of orange-reddish colors of wavelengths of 590 to 780 nm; and
a luminous spectrum setting step for setting a luminous spectrum of the light emitting portion so that if a distribution ratio of an integrated value of energy strength of light from the luminous tube calculated for each of the four wavelength regions is set to be "y1 : y2 : y3 : y4" (where y1 + y2 + y3 + y4 = 100), the following formula is obtained.

$$7 \leq y1 \leq 11,\ 15 \leq y2 \leq 21,\ 0 \leq y3 < 3, \text{ and } y4 = \text{residue}.$$

5. The method for manufacturing a light source according to claim 4,
wherein in the luminous spectrum setting step, the luminous spectrum of the light emitting portion is set so that if a distribution ratio of an integrated value of energy strength of light from the light emitting portion calculated for each of the four wavelength regions is set to be "y1 : y2 : y3 : y4" (where y1 + y2 + y3 + y4 = 100), the following formula is obtained.

$$8 \leq y1 \leq 9,\ 17 \leq y2 \leq 19,\ 0 \leq y3 \leq 2, \text{ and } y4 = \text{residue}.$$

6. The method for manufacturing a light source according to claim 4 or 5, wherein the light source is a high intensity discharge lamp comprising a luminous tube in which a noble gas and an additive are enclosed,
and in the luminous spectrum setting step, the luminous spectrum of the light emitting portion is set by adjusting a composition and amount of the additive.

FIG. 1

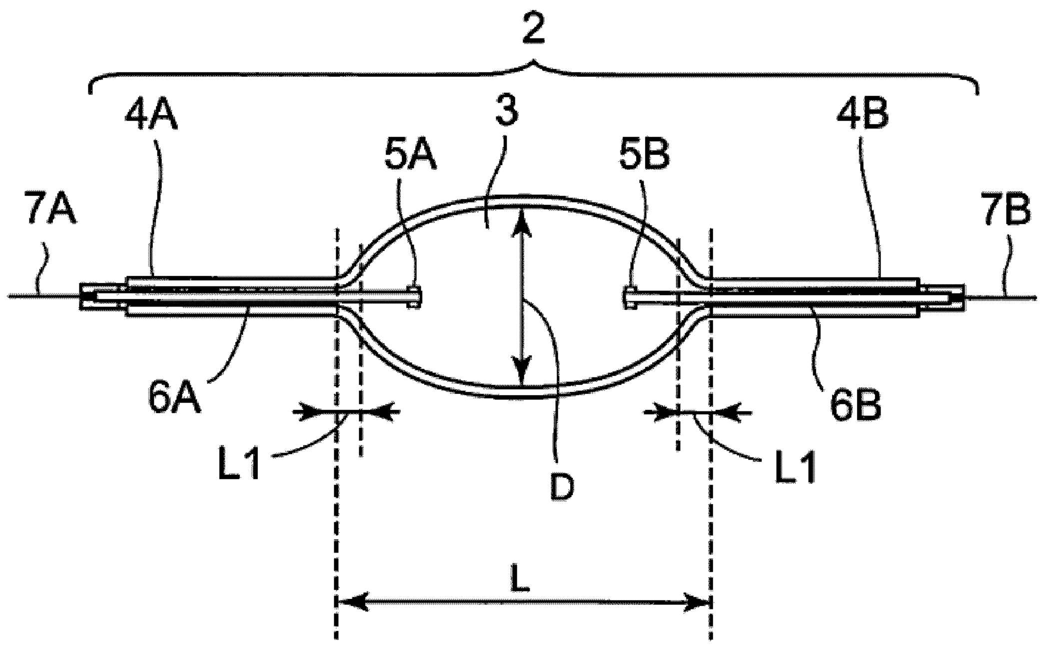


FIG. 2

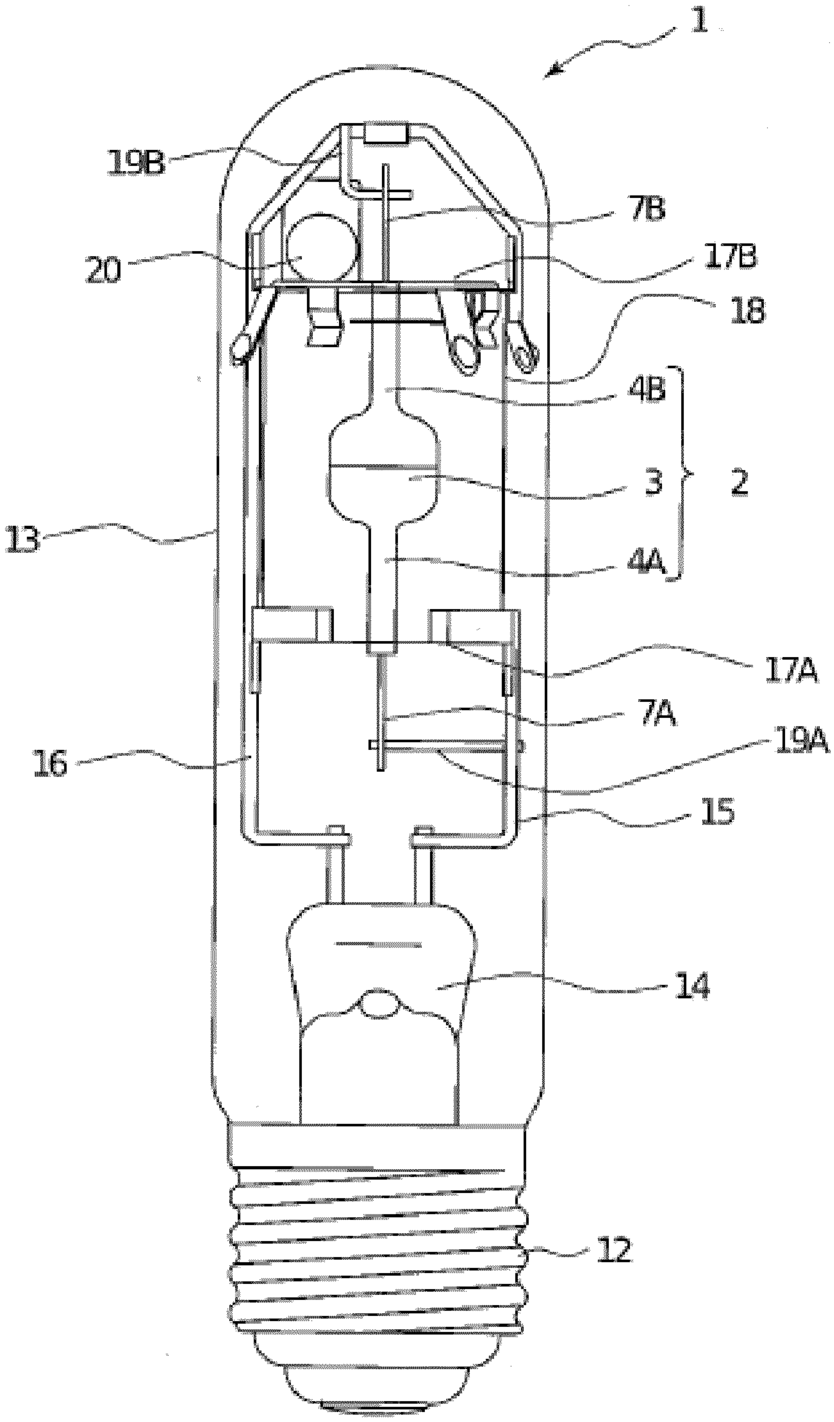


FIG. 3

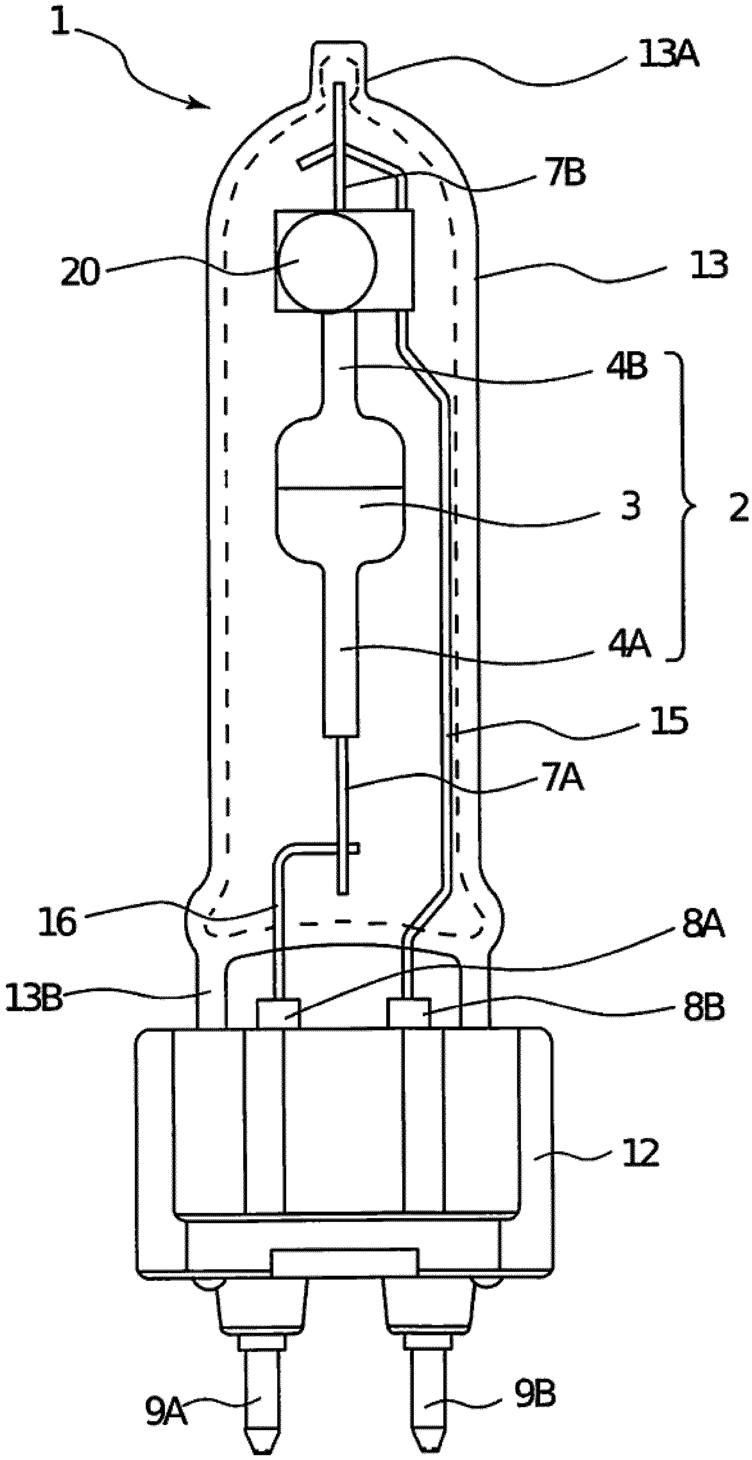


FIG. 4

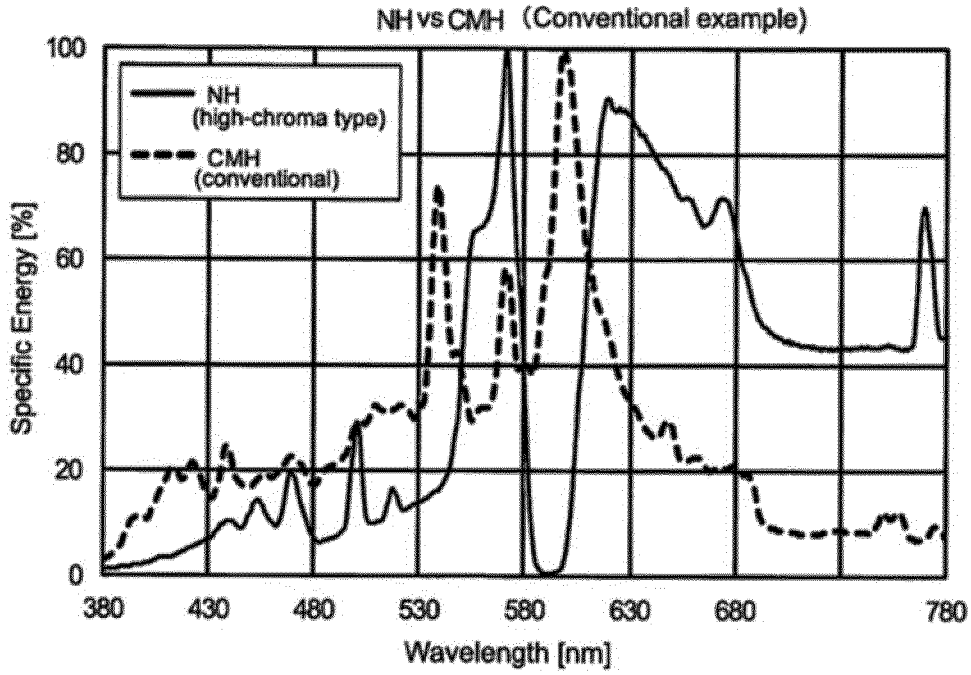
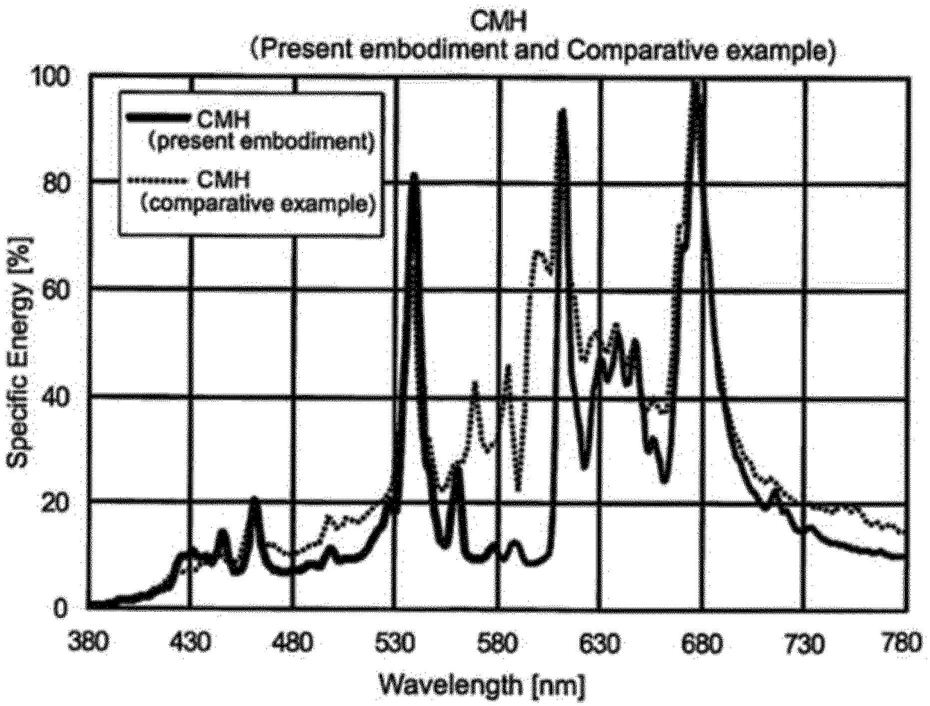

NH vs CMH (Conventional example)
NH
(high-chroma type)
CMH
(conventional)
Specific Energy [%]
100
80
60
40
20
0
380
430
480
530
580
630
680
780
Wavelength [nm]

FIG. 5


CMH
(Present embodiment and Comparative example)
CMH
(present embodiment)
CMH
(comparative example)
Specific Energy [%]
100
80
60
40
20
0
380
430
480
530
580
630
680
730
780
Wavelength [nm]

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2014/076695

A. CLASSIFICATION OF SUBJECT MATTER
H01J61/20(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)
H01J61/20

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	1996-2014
Kokai Jitsuyo Shinan Koho	1971-2014	Toroku Jitsuyo Shinan Koho	1994-2014

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.
X	JP 2003-217507 A (Matsushita Electric Works, Ltd.), 31 July 2003 (31.07.2003), claim 3; paragraphs [0006], [0030] to [0037], [0043] & US 2003/0141818 A1	1-6

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 November, 2014 (07.11.14)	25 November, 2014 (25.11.14)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- JP 2004288617 A **[0008] [0010]**
- JP 4279122 B **[0008] [0010]**
- JP 2003187744 A **[0008]**
- JP 2009520323 A **[0008]**
- JP 2007053004 A **[0008] [0010]**
- JP 2011154847 A **[0008] [0010]**
- JP 2009087602 A **[0009] [0010]**
- JP 2012113883 A **[0009] [0010]**
- JP 20031877444 A **[0010]**
- JP 4262968 B **[0010]**
- JP 2009520329 A **[0010]**
- JP 2010003488 A **[0010]**
- JP 2012173201 A **[0038]**