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(54) **High pressure mercury vapour discharge lamp with reduced sensitivity to variations in operating parameters**

(57) A high pressure mercury vapor discharge lamp is provided. The lamp has a discharge vessel (3) formed from heat-resistant material. At least two electrodes (5) extend into the discharge vessel (3) and are electrically connected to external current supply leads (9). The lamp has a fill in the discharge vessel (3) which includes a noble gas, mercury and an additive composition of metal halides. This additive composition of metal halides comprises an alkali metal halide, wherein the alkali metal halide is a sodium halide, a cesium halide, or a mixture of sodium halide and cesium halide, at least one halide of a metal providing a line emission, at least one halide of a rare earth metal providing an emission in the purple spectral range, at least one halide of a rare earth metal providing an emission in the green spectral range.

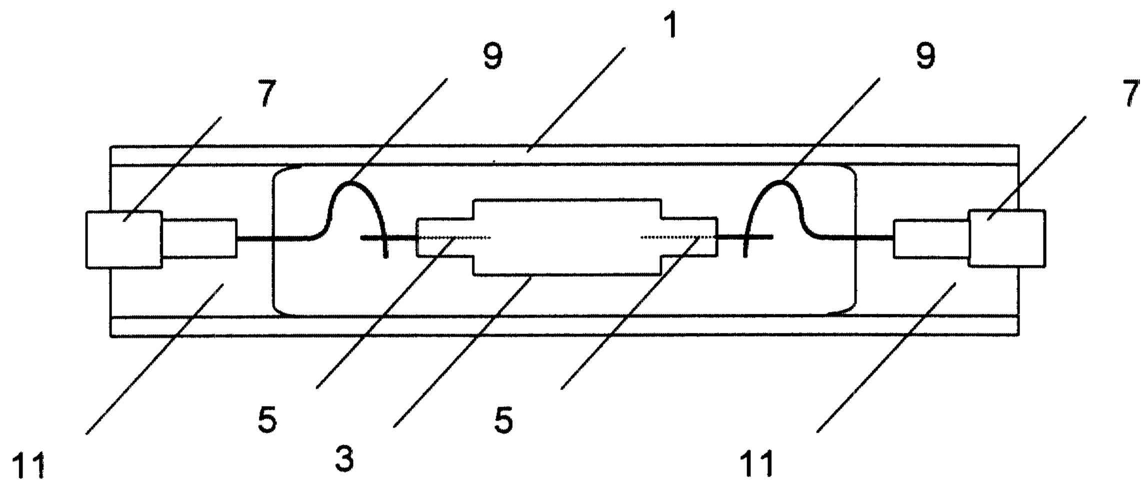

Fig. 1

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Description

[0001] This invention relates to a high pressure mercury vapor discharge lamp with an ionizable fill containing a special additive composition of metal halides, and, more particularly, to a metal halide discharge lamp having an additive composition of metal halides that reduces the color point sensitivity of the lamp to the variations in operating parameters.

[0002] Metal halide lamps have been used for general lighting purposes for several decades. The additive fill in these lamps contains metals (in the form of halides excluding fluorides) emitting intensive light in their excited energy state at a single wavelength or several wavelengths of the visible electromagnetic spectrum. These metals get excited due to the electric current passing through the lamp, after significant amount of metal halides is vaporized and dissociated. The total mass of the metal halide additive fill in the lamps is usually greater than that of the metal halide in the vapor phase at steady-state operation. As a result of this, the vapor phase is in equilibrium with the condensed phase located on the coldest spot of the discharge vessel. The composition of condensed phase of the metal halide fill, and consequently the composition of the vapor phase, due to the differences in the thermal-chemical properties of the additives in the ionizable fill, clearly depends on the temperature of the coldest spot in the discharge vessel of the lamp. Since the color of the light emitted by the lamp depends on the amount and quality of the components in the vapor phase radiating in the red, green and blue range of the visible spectrum, it is obvious that the color of the lamps is highly affected by the cold spot temperature of the discharge vessel. The value of this cold spot temperature depends on the physical characteristics of the discharge vessel itself (materials and manufacturing spread), as well as on the variations in the line voltage and the operating circuit characteristics of the lamp.

[0003] A great variety of metal halide lamps are described in literature, where the requirements set for the lamps were complied with by modifications in the additive composition of metal halides.

[0004] U.S. Patent No. 3 842 307 describes an additive composition of metal halides in which, in addition to one or more other types of metal halides, the halide of dysprosium and at least two other rare-earth metals of similar average (median) excitation energy is contained. Example 1 relates to an additive composition of cesium (common alkaline component for arc stabilization), thallium (line radiator providing light in the green spectral range) and dysprosium, holmium and thulium iodides. Examples 2 and 3 differ from Example 1 in a sense that either do not contain thallium, or, in addition to three different rare-earth metals, a fourth one (europium) is also added to the ionizable fill. According to this patent, the advantage of such an additive composition is the very high average color rendering index and the relatively low wall loading, that is the relatively low cold spot temperature. The material of the discharge vessel is fused silica (quartz).

[0005] European Patent No. 0 215 524, similarly to Example 1 of U.S. Patent No. 3 842 307, describes a mixture of one alkaline component (sodium halide), one line radiator component providing light in the green spectral range (thallium halide) and one rare-earth multi-line radiator providing light of basically purplish hue (dysprosium, holmium, thulium or lanthanum) as a metal halide additive fill. According to this patent, the advantages of such an additive composition are the high color rendering index at low color temperature, as well as a reduced sensitivity of the lamp characteristics to line voltage variations at low color temperatures, in accordance with the examples below 3600 K. These advantages are regarded as the results of an excessive sodium line broadening that is reached by an increased wall loading (i. e. increased cold spot temperature) and proper discharge vessel geometry. As discharge vessel materials, translucent ceramics are used, which are more durable at high temperatures than fused silica.

[0006] U.S. Patent No. 5 239 232 describes an additive composition of metal halides comprising cesium and/or sodium halide, at least one of the rare-earth metal halides providing radiation of purple hue and at least one of the rare-earth metal halides providing radiation of green hue. The advantages of such a halide fill are the increased average and red color rendering indices and the reduced lamp-to-lamp color variability. As an additional advantage, slight increase in lamp efficacy compared to this characteristic of metal halide lamps having line radiator or molecular radiator additives is also achieved. The wall loading and cold spot temperature is kept low in order to avoid the need of application of ceramic discharge vessel materials. All of the examples described in the specification relate to discharge vessels made of fused silica.

[0007] This latter patent also states the requirement that the thallium halide has to be completely avoided from the additive composition of metal halides in the lamp. According to this patent, the significant difference between the vapor pressure of thallium halide and that of the rare-earth halides can lead to dominance of the green line radiation originating from thallium and to loss of color balance if the lamp is operated at low line voltage, that is the cold spot temperature of the lamp is below its design value. The consequence of such loss of color balance is the increased lamp-to-lamp color variability. This patent implicitly assigns similarly unfavorable properties to other volatile line radiator additives, e. g. to indium halides.

[0008] As it is illustrated by the patents mentioned above, the improvements in lamp efficacy, average color rendering index and lamp life were considered much more important than the reduction of the sensitivity of lamp color to line voltage and variations of operating circuit characteristics over the past several decades of development. These factors affect lamp color by the changes in cold spot temperature which is also varied by the imperfections arising during the manufacturing process. Changes in line voltage or operating circuit characteristics are unavoidable due to unpredictable changes in line loads, manufacturing imperfections of the electrical circuits or wearing out of the electrical circuit components and the lamp itself.

[0009] U.S. Patent No. 3 842 307 does not deal with the requirement of reduced sensitivity of the lamp characteristics to variations in operating parameters of the lamps. According to European Patent No. 0 215 524 a certain reduction of sensitivity can be accomplished, but the scope of this reduction is limited to low color temperatures. Our measurements also indicate that the additive fill of U.S. Pat. No. 5 239 232 provides reduction in color variations only in the color temperature scale. If a two dimensional, color coordinate based measurement is used for describing the amount of color shift of the lamps while parameters operating the lamp are changed, then a significant change in color coordinates and hue of the color of the emitted light is observed.

[0010] Thus there is a particular need to provide a lamp with an additive composition of metal halides the color of which is less sensitive also at high color temperatures to the variations in line voltage and operating circuit characteristics, as well as to the manufacturing imperfections and the wearing out of the operating circuit components and the lamp itself.

[0011] According to the invention, a high pressure mercury vapor discharge lamp is provided. The lamp has a discharge vessel formed from heat-resistant material. At least two electrodes extend into the discharge vessel and are electrically connected to external current supply leads. The lamp has a fill in the discharge vessel which includes a noble gas, mercury and an additive composition of metal halides. This additive composition of metal halides comprises an alkali metal halide, wherein the alkali metal halide is a sodium halide, a cesium halide, or a mixture of sodium halide and cesium halide, at least one halide of a metal providing a line emission, at least one halide of a rare earth metal providing an emission in the purple spectral range, at least one halide of a rare earth metal providing an emission in the green spectral range.

[0012] By halides, we mean any kind of halides with the exception of fluorides or a mixture thereof. By metals providing a line emission, we mean metals providing radiation within a restricted spectral range in the visible spectrum, that is metals radiating only at specific wavelength(s) or within a 10 nanometer wide spectral range centered on these specific wavelength(s). This terminology is in accordance with the common terminology used for high pressure discharge lamps with the additional restriction that sodium, cesium and mercury are not considered examples of such a line emitting metal components. Metals radiating in a wider spectral range, like calcium, are also excluded from the scope of this terminology.

[0013] The principal advantage of the present invention is the reduced sensitivity of lamp color to the variations in the operating parameters, that is to cold spot temperature variations, of the lamp. This reduction in sensitivity is achieved by adding at least one halide of a metal providing a line emission to the metal halide additive fill. The beneficial effect due to the line emitter(s) in the fill is quite surprising in the light of the statements in U.S. Patent No. 5 239 232. Based on the explanation provided in that patent, one would expect that almost equal vapor pressures of the additives in the metal halide fill is a must for insensitivity of lamp color on cold spot temperature changes. It was expected that mixing halides of green and purple rare earth radiators of almost equal vapor pressure with volatile line radiators of different vapor pressure would increase the changes in lamp color caused by the changes in cold spot temperature. Our experience with the proposed additive composition of metal halides is contradicting to these expectations.

[0014] An additional advantage of the present invention is the color temperature range widened above 4000 K in which the reduced sensitivity of lamp color to the variations in the operating parameters is accomplished.

[0015] Still another advantage of the present invention is the use of four principal metal halide additives in the fill which results in a lamp with better and more balanced set of performance parameters.

[0016] Still a further advantage of the present invention is the increased lamp efficacy compared to this property of the lamp with additive fill specified by U.S. Patent No. 3 842 307 and European Patent No. 0 215 524, respectively.

[0017] The invention will now be described in greater detail, by way of example, with reference to the drawings, the single figure of which is a schematic sectional view of a high pressure mercury vapor discharge lamp.

[0018] The drawing shows an exemplary high pressure mercury vapor metal halide discharge lamp in which the present invention is embodied. The lamp comprises a discharge vessel 3 formed from heat-resistant material and placed within an outer envelope 1. Two electrodes 5 extend into the discharge vessel 3 which are electrically connected to external current supply leads 9. The current supply leads are electrically attached to two terminals 7 suitable for connecting to an outer power supply. The two ends 11 of the outer envelope 1 are press-sealed. The fill in the discharge vessel 3 comprises four types of metal halide additives in addition to the regular components of noble gas and mercury. This additive composition of metal halides comprises an alkali metal halide, wherein the alkali metal halide is a sodium halide, a cesium halide, or a mixture of sodium halide and cesium halide, at least one halide of a metal providing a line emission, at least one halide of a rare earth metal providing an emission in the purple spectral range,at least one halide of a rare earth metal providing an emission in the green spectral range.

[0019] In the lamps, in which the present invention is embodied, the composition of the metal halide additive fill is specified preferably by the following molar relationship: 35-95 molar percent of the alkali metal halide, 0.5-20 molar percent of the metal halides providing a line emission, and a mixture of the rare earth metal halides providing an emission in the purple spectral range and the rare earth metal halides providing an emission in the green spectral range, wherein the molecular relationship of the rare earth metal components emitting in the purple spectral range and the green spectral range is between 10:1 and 1:1.

[0020] The additive composition of metal halides comprises more preferably 50-95 molar percent of the alkali metal halide and 1-15 molar percent of the metal halides providing a line emission.

[0021] In a preferred embodiment of the present invention, the additive composition of metal halides comprises preferably at least one of iodides, bromides and chlorides as the halides. It is more preferable if the halides are iodides.

[0022] The halides providing a line emission are preferably at least one of the halides of thallium, indium, gallium, zinc and lithium. It is more preferable if the halide providing a line emission is thallium halide.

[0023] The rare earth metal halides providing an emission in the purple spectral range are preferably at least one of the halides of dysprosium, holmium, thulium and europium. It is more preferable if the rare earth metal halide providing an emission in the purple spectral range is dysprosium halide.

[0024] The rare earth metal halides providing an emission in the green spectral range are preferably at least one of the halides of cerium, neodymium, praseodymium and lanthanum. It is more preferable if the rare earth metal halide providing an emission in the green spectral range is cerium halide.

[0025] The other components in the fill are those required for starting, run-up and stable operation of a conventional lamp driven by a standard operating circuit. The noble gas fill in the discharge vessel of the lamp is argon, xenon or a mixture of these. The other component in the fill is mercury which is a component with a particularly high electron collision cross section. This component is needed for setting the electric field in the lamp properly.

[0026] The rated power of a metal halide lamp, in which the present invention is embodied, may extend from the 10-20W power range up to several kilowatts. The shape of the outer envelope (bulb) of the lamp does not differ from the formats currently available or specified by standards, related patents or lamp data sheets. For example, the outer bulb can be compact single-ended, double-ended, tubular, elliptically shaped or other.

[0027] Further details of the present invention will be illustrated by examples.

<u>Example 1</u>

[0028] Discharge vessel of 0.3 cm^3 volume, and made of densely sintered polycrystalline alumina. 7.7 mg/cm mercury dose, 280 mbar argon as the noble gas fill, 30 mg/ cm^3 metal halide additive fill. Composition of the metal halide additive fill is NaI:TII:DyI3:CeI3 = 71.5: 4.0:17.5:7.0 in molar percents. 7.0 mm arc length, 70 W rated lamp power, 4200 K rated color temperature.

<u>Example 2</u>

[0029] Discharge vessel of 0.4 cm^3 volume, and made of densely sintered polycrystalline alumina. 7.5 mg/cm mercury dose, 280 mbar argon as the noble gas fill, 39 mg/ cm^3 metal halide additive fill. Composition of the metal halide additive fill is NaI:TII:DyI3:CeI3 = 89.0: 2.0:6.5:2.5 in molar percents. 7.9 mm arc length, 70 W rated lamp power, 3200 K rated color temperature.

<u>Example 3</u>

[0030] Discharge vessel of 0.4 cm^3 volume, and made of densely sintered polycrystalline alumina. 7.5 mg/cm mercury dose, 280 mbar argon as the noble gas fill, 39 mg/ cm^3 metal halide additive fill. Composition of the metal halide additive fill is NaI:TII:DyI3:CeI3 = 87.5: 3.5:6.5:2.5 in molar percents. 7.9 mm arc length, 70 W rated lamp power, 3000 K rated color temperature.

<u>Example 4</u>

[0031] Discharge vessel of 1.0 cm^3 volume, and made of densely sintered polycrystalline alumina. 6.0 mg/cm mercury dose, 260 mbar argon as the noble gas fill, 7.8 mg/ cm^3 metal halide additive fill. Composition of the metal halide additive fill is NaI:TII:DyI3:CeI3 = 52.9:2.0:32.5:12.6 in molar percents. 10.0 mm arc length, 150 W rated lamp power, 5300 K rated color temperature.

<u>Example 5</u>

[0032] Discharge vessel of 0.4 cm^3 volume, and made of densely sintered polycrystalline alumina. 4.3 mg/cm mercury dose, 280 mbar argon as the noble gas fill, 19 mg/ cm^3 metal halide additive fill. Composition of the metal halide additive fill is NaI:TII:DyI3:CeI3 = 52.9: 2.0:32.5:12.6 in molar percents. 7.9 mm arc length, 70 W rated lamp power, 5400 K rated color temperature.

[0033] Lamp samples in the nominal lamp power range of 10-400W were prepared and studied. Variations in lamp operating parameters were simulated by either varying the line voltage or the ballast impedance of the lamp circuit. Consequently, lamp operating power and cold spot temperature were affected.

[0034] The best results were accomplished by the lamp samples identical to Example 1. The results obtained for these lamps were compared to the results obtained for lamp samples with exactly the same additive composition but having no thallium iodide as the additive providing a line emission in the fill. Color shift for the lamps identical of Example1 was □C=0.006 for a +/-8% lamp power variation, and □C=0.009 for a +/-15% lamp power variation, if measured in the CIE1931 x-y color space metric. These color shift values are identical to 2.7 step and 2.9 step color shifts, if measured in the MacAdam oval metric. These results have to be compared to the results obtained for the lamps with no thallium iodide additive. Color shift values for these reference lamp samples were □C=0.012 and □C=0.029 in the x-y space metric, which are equal to 5.4 step and 13.7 step color shifts in the MacAdam metric for the same, i.e. +/-8% and +/-15% lamp power variations. Consequently, these data indicate that the lamps, in which the present invention is embodied, have significantly reduced (50-80% less) color sensitivity to the variations in the lamp operating parameters. The difference in color sensitivity can even be greater if the change in lamp power, and consequently cold spot temperature, is greater than +/-15%, and depends also on other design parameters.

[0035] The increase of efficacy of the lamps, in which the present invention is embodied, compared to the efficacy of the lamps with the fills specified by U.S. Patent No. 3 842 307 and European Patent No. 0 215 524, was also demonstrated by our experiments. For lamp samples of identical rated color temperature and rated power, the increase in efficacy of the lamps, in which the present invention is embodied, was as high as 10-15%.

Claims

1. A high pressure mercury vapor discharge lamp having a discharge vessel (3) formed from heat-resistant material; at least two electrodes (5) extending into the discharge vessel and electrically connected to external current supply leads (9); and a fill in the discharge vessel, said fill including a noble gas, mercury and an additive composition of metal halides; said additive composition of metal halides comprising

an alkali metal halide, wherein the alkali metal halide is a sodium halide, a cesium halide, or a mixture of sodium halide and cesium halide,
at least one halide of a metal providing a line emission,
at least one halide of a rare earth metal providing an emission in the purple spectral range,
at least one halide of a rare earth metal providing an emission in the green spectral range.

2. The discharge lamp of claim 1 in which said additive composition of metal halides comprises

35-95 molar percent of the alkali metal halide,
0.5-20 molar percent of the metal halides providing a line emission,
a mixture of the rare earth metal halides providing an emission in the purple spectral range and the rare earth metal halides providing an emission in the green spectral range, wherein the molecular relationship of the rare earth metal components emitting in the purple spectral range and the green spectral range is between 10:1 to 1:1.

3. The discharge lamp of claim 2 in which said additive composition of metal halides comprises 50-95 molar percent of the alkali metal halide.

4. The discharge lamp of claim 2 in which said additive composition of metal halides comprises 1-15 molar percent of the metal halides providing a line emission.

5. The discharge lamp of claim 1 in which the additive composition of metal halides comprises at least one of the halides of thallium, indium, gallium, zinc and lithium as the metal halides providing a line emission.

6. The discharge lamp of claim 5 in which said additive composition of metal halides comprises thallium halide as the metal halides providing a line emission.

7. The discharge lamp of claim 1 in which said additive composition of metal halides comprises at least one of the halides of dysprosium, holmium, europium and thulium as the rare earth metal halides providing an emission in the purple spectral range.

8. The discharge lamp of claim 7 in which said additive composition of metal halides comprises dysprosium halide as the rare earth metal halide providing an emission in the purple spectral range.

9. The discharge lamp of claim 1 in which said additive composition of metal halides comprises at least one of the halides of cerium, neodymium, praseodymium and lanthanum as the rare earth metal halides providing an emission in the green spectral range.

10. The discharge lamp of claim 9 in which said additive composition of metal halides comprises cerium halide as the rare earth metal halide providing an emission in the green spectral range.

11. The discharge lamp of claim 1 in which said additive composition of metal halides comprises at least one of iodides, bromides and chlorides as the halides.

12. The discharge lamp of claim 11 in which said additive composition of metal halides comprises iodides as the halides.

13. An additive composition of metal halides for high pressure mercury vapor discharge lamps comprising

an alkali metal halide, wherein the alkali metal halide is a sodium halide, a cesium halide, or a mixture of sodium halide and cesium halide,
at least one halide of a metal providing a line emission,
at least one halide of a rare earth metal providing an emission in the purple spectral range,
at least one halide of a rare earth metal providing an emission in the green spectral range.

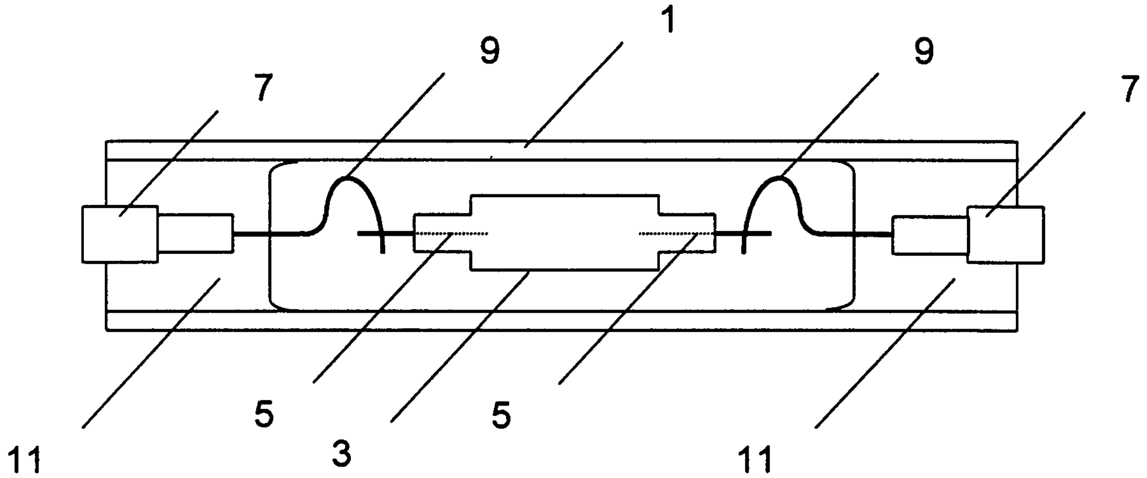

Fig. 1