

- [54] **HIGH-PRESSURE METAL-VAPOR DISCHARGE TUBE**
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[58] Field of Search.....313/47, 220, 221, 318, 317

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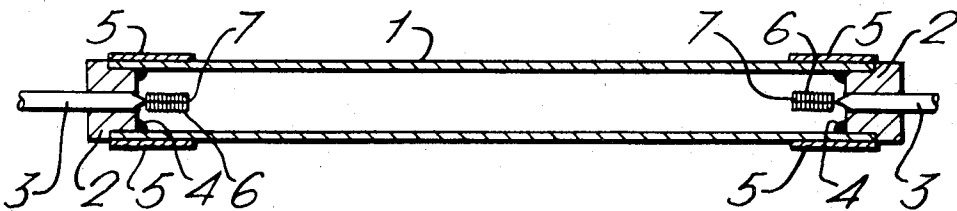
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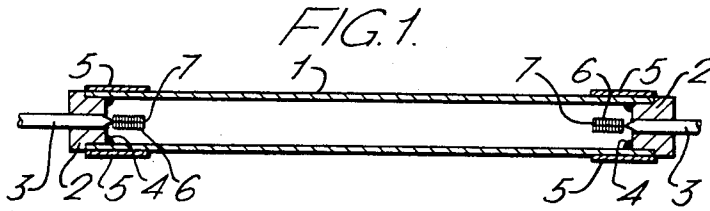
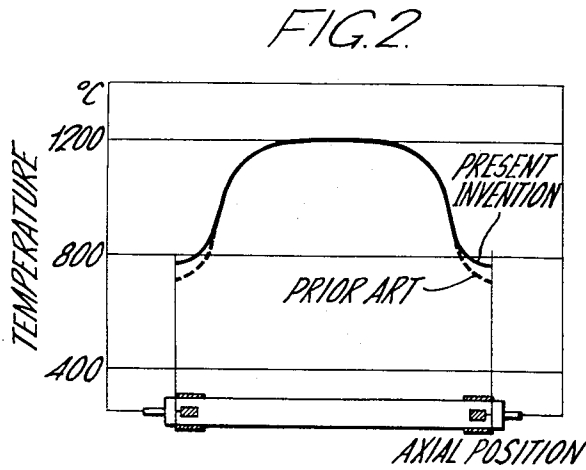
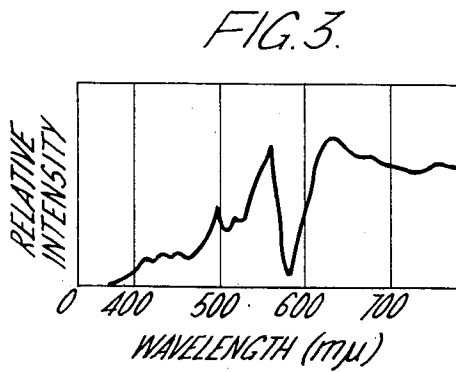
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[57] **ABSTRACT**

In a discharge tube of saturated metal vapor pressure type containing high-pressure gaseous or vaporized metals, the temperature of the coolest points existing at both ends of the discharge tube can be raised by forming a layer or layers of a metal or metals of high melting point, low vapor pressure and good thermal conductivity, such as niobium, on the outer wall at the ends of the discharge tube; thereby, providing better radiant emission, especially higher color temperature and an improved color rendering property compared with conventional high-pressure metal-vapor discharge tubes. The discharge tube of the above-mentioned construction can be manufactured easily and has a longer life under burning conditions corresponding to those for conventional type high-pressure metal-vapor discharge tubes.

10 Claims, 3 Drawing Figures





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HIGH-PRESSURE METAL-VAPOR DISCHARGE TUBE

BACKGROUND OF THE INVENTION

This invention relates to a high-pressure metal-vapor discharge tube consisting of a sealed tubular enclosure of a high-melting transparent polycrystalline ceramic, a pair of electrodes, each of which is enclosed near respective ends of said enclosure, and a small amount of metals, which are converted to the gaseous state when the tube is in operation.

High-pressure metal-vapor discharge tubes can be classified into two types; namely, the unsaturated type wherein confined metals, such as sodium, are completely vaporized to the gaseous state when the tube is in operation, and the saturated type wherein confined metals are not completely vaporized thereby retaining a part of the metals in the solid or liquid state. In the latter type, the saturated type discharge tube, said solid or liquid metals remain at the coolest points at both ends of the enclosure. Generally, the radiant emission characteristics of the discharge tube, such as color temperature and the color rendering property, depend on, and will vary with, the pressure of the vaporized metals which is determined by the temperature of the coolest points in the tube.

In an example of conventional high-pressure sodium lamps, the temperature of the coolest points are designed to be in the range around 600° to 700° C to control the sodium vapor pressure within the range around 100 to 200 torr; such high-pressure sodium lamps can only attain a color temperature of 2,100° K and a color rendering index of 25, which conditions are not quite satisfactory for general lighting applications. Any sodium vapor pressure in the range of 300 to 1,000 torr can improve the radiant emission characteristics of such lamps, especially the color rendering property.

To obtain a sodium vapor pressure higher than 300 torr, it is necessary to raise the temperature of the coolest points at both ends of the discharge tube. There has been a proposal to provide a thermal insulation coating at the coolest points of the discharge tubes for metal-halide lamps and a high-pressure mercury vapor lamps. The examples of these prior art devices employ a thermal insulating coating, such as titanium oxide or carbon, at both ends around the sealing portion of the outer surface of the discharge tube. These prior art devices attain a thermal insulating effect to raise the temperature of the coolest points, but the lack of thermal conductivity of the coating material is not suitable for obtaining an ideal heat distribution over the entire length of the tubular enclosure.

SUMMARY OF THIS INVENTION

The primary object of this invention is to obtain a high-pressure metal-vapor discharge tube with improved color temperature and a good color rendering property of radiated emission, which is desirable for general lighting applications. To obtain improved color temperature and a good color rendering property, the sodium vapor pressure of such a discharge tube must be higher than 300 torr; and, the simplest way to increase the sodium vapor pressure is to apply a larger lamp input power, which causes undesirable increase in wall loading of the discharge tube and results in thermal decomposition of the alumina ceramic tubular enclosure,

if the temperature of tubular enclosure exceeds 1,200° C.

The inventors have discovered that the temperature of the coolest points of a high-pressure metal-vapor discharge tube can be raised by providing a layer or layers of thermally conductive metal or metals having a high melting point, low vapor pressure and good thermal conductivity, by winding a metal foil or foils tightly, by chemical or vacuum deposition or by sputtering a metal or metals directly, around the coolest points located at both ends of the discharge tube of a sealed tubular enclosure of transparent polycrystalline ceramics, such as a high-density alumina, wherein a small amount of mercury and alkali metal are confined, thereby effectively insulating the thermal radiation from the coolest points and conducting the heat from the central part of tubular enclosure to the coolest points.

BRIEF DESCRIPTION OF THE DRAWINGS

Further objects and advantages will be best understood from the following detailed description when read in conjunction with the accompanying drawings, in which:

FIG. 1 is a sectional side view of a high-pressure metal-vapor discharge tube embodying this invention,

FIG. 2 is a graph indicating the outer wall temperature distribution in the longitudinal direction, and

FIG. 3 is a graph indicating the spectral distribution of the discharge tube of the above embodiment.

DETAILED DESCRIPTION

In FIG. 1, each end part of a discharge tube enclosure 1, which consists of a transparent polycrystalline ceramic tube, such as high-density alumina, is hermetically sealed at both ends by respective end discs 2, and each lead-in metal tube 3 hermetically penetrates through one end disc 2.

The surfaces between said discharge tube enclosure 1 and each end disc 2 and those between each lead-in metal tube 3 and each end disc 2 are sealed hermetically with ceramic cement, and in said tubular enclosure a starting rare gas, such as xenon gas, and a substantial quantity of a metal of a discharging medium 4, for instance, sodium, together with mercury, which serves as a buffer gas, are confined. As a material for these end discs 2, the same ceramic material as that of said tubular enclosure 1 is preferred, but such ceramics whose thermal expansion coefficient approximates that of the lead-in tubes 3 of a metal of high melting point, such as niobium, tantalum, molybdenum, etc., can be used. Also a metal end disk of a high melting metal as indicated can be used. On both end parts of the tubular enclosure, around their outer wall, thermally conductive layers 5, which characterize this invention, are provided. For such thermally conductive layers 5, a metal having a high melting point and low vapor pressure and good thermal conductivity, selected from a group consisting of titanium, vanadium, rhodium, ruthenium, molybdenum, niobium, tantalum, tungsten, platinum, iridium, rhenium and osmium, can be used.

Such thermally conductive layers 5 are formed by winding a metal foil or foils tightly, by chemical or vacuum deposition or by a sputtering method. Said thermally conductive layers 5 function to raise the tem-

perature of the coolest points at both ends of the tubular enclosure.

Namely, as a general rule of this kind of discharge tube, the discharge tube 1 is a straight tube of 6 to 15 mm inner diameter. While in operation, its central outer wall surface is heated to about 1,200° C, from which area the outer wall surface temperature decreases toward the ends of the tube in a curve as shown in FIG. 2. Owing to said thermally conductive layers 5 provided on the coolest points located further toward the ends than discharge electrodes 6, positioned near both ends in the tubular enclosure 1 on the tips of the lead-in tubes 3, the temperature of said coolest points indicated by the solid line in FIG. 2 is raised by 50° C or more, as compared with the conventional discharge tube indicated by the dotted line in FIG. 2. This is as a result of the following functions.

1. Heat accumulation on the outer wall surface at the high temperature portion between the pair of electrodes 6 is efficiently conducted to the tube end portions.

2. Thermal radiation generated inside the tube, especially at the inner end portions of the tube, is reflected inward and confined in each inner end portion without radiating outward, resulting in a rise in the temperature at the coolest points. Accordingly, a temperature of 650° to 800° C at the coolest point can be obtained while keeping the highest temperature at the central outer wall surface of the tube at 1,200° C.

The use of metal end caps, instead of said ceramic end discs 2 and 2 produces the same effect in this invention.

According to the experiments of the inventors of this invention, a practical discharge tube of high color rendering property has been obtained by providing each of said thermally conductive layers 5 around the outer wall surface of the tube. Such thermally conductive layers 5 on the outer wall surface are preferably limited within an area between the ends of the tubular enclosure and 5 mm from the front tip 7 of each electrode 6 toward the center of the enclosure 1 at both ends of tube.

In an example, when a tantalum foil of 0.02 mm thickness with a width of 12 mm is wound tightly around the tubular enclosure at both ends of the tube between the position 5 mm from the front tip of the electrode toward the central part and the tube end, a spectral distribution shown in FIG. 3 was obtained at a tube wall loading of 20 watts/cm². Lamp characteristics of this discharge tube are summarized as a lamp voltage of 320 volts, color temperature of 3,000° K and color rendering index of 78 per the C.I.E. (Commission Internationale de l'Eclairage) recommendation. In the conventional high-pressure sodium discharge lamp for the same input power rating as this example, the lamp voltage of 100 volts, color temperature of 2,100° K and color rendering index of 25 per the C.I.E. recommendation were attained. Therefore, the embodiment of this invention has an outstanding superiority to said prior art device with respect to the color rendering property.

In the present example, if the thermally conductive layers 5 are extended beyond said limit of 5 mm toward the center of the enclosure from the front tip of the electrode 6, it would shield a part of the radiant emis-

sion, reducing the luminous efficacy of the discharge tube. Therefore, for practical purposes, the layers should be limited, as mentioned above, between the further-most end of the tube and 5 mm from the front tip of the electrode 6 toward the center of the enclosure 1.

For the thermally conductive layers 5, any metal selected from the aforementioned group can be used in place of tantalum. As an example, in the case of applying a molybdenum film by chemical deposition, the end part of a ceramic tube is preparatorily heated in 600° to 700° C, and a mixed gas of molybdenum pentachloride (MoCl₅) and hydrogen is made to contact the desired parts of the tube, whereon molybdenum is deposited to form films. Such a tube can be employed as a discharge tube.

For making a titanium film by vacuum deposition, titanium is evaporated by heating at, for instance, about 2,000° C, and is deposited for making the film layers on the necessary parts of a required ceramic tube.

In case of depositing niobium or tantalum by a sputtering method, both end parts of the tube are wound with foils of niobium or tantalum, and the central part of the tube is covered with an electric insulating substance such as a porcelain tube, on which a tungsten positive electrode is provided, and discharging is made in the vacuum using said niobium or tantalum foils as a negative electrode so as to sputter and deposit said niobium or tantalum onto the tube. As for the metal, any of the aforementioned group can be applied in the manner of the said examples.

As the material of the tubular enclosure for the discharge tube of this invention, transparent polycrystalline high-density ceramics, such as high-density alumina, beryllia or magnesia, which are chemically stable against sodium vapor and have a high melting point, can be used.

As fully described above, according to this invention, a high-pressure metal-vapor discharge tube having a high color rendering property is obtainable by an easily practicable method, such as providing thermally conductive layers constituted with a metal or metals having high melting point and low vapor pressure and good thermal conductivity around both ends of the tubular enclosure, thus enabling attainment of great industrial and practical efficiency.

While we have shown and described several embodiments in accordance with the present invention, it is understood that the same is not limited thereto but is susceptible of numerous changes and modifications as known to a person skilled in the art, and we therefore do not wish to be limited to the details shown and described herein but intend to cover all such changes and modifications as are obvious to one of ordinary skill in the art.

We claim:

1. High-pressure metal-vapor discharge tube comprising a sealed tubular enclosure of transparent polycrystalline high-density ceramic, a pair of electrodes having rear tip and front tip portions, each of said electrodes being enclosed near a respective end of said enclosure, a starting rare gas, and a small amount of mercury plus at least one ionizable medium of alkali metal sufficient to form a saturated metal vapor confined in said enclosure, and characterized in that:

layers of thermally conductive, heat durable metal are formed on the outer wall of the tubular enclosure proximate to the ends thereof, said layers extending from the end of the tubular enclosure beyond the rear tip of the electrode to a position of no more than 5 mm from the front tip of the electrode toward the central part of the tubular enclosure.

2. High-pressure metal-vapor discharge tube of claim 1, wherein said thermally conductive metal is a metal selected from a group consisting of titanium, vanadium, rhodium, ruthenium, molybdenum, niobium, tantalum, tungsten, platinum, iridium, rhenium and osmium.

3. High-pressure metal-vapor discharge tube of claim 2, wherein each said layer of thermally conductive metal is in the form of a metal foil wound around each end part of the tubular enclosure.

4. High-pressure metal-vapor discharge tube of claim 2, wherein said layers are in the form of a chemically decomposed chemical compound of said thermally conductive metal.

5. High-pressure metal-vapor discharge tube of claim 2, wherein said layers are in the form of a vacuum deposited thermally conductive metal.

6. High-pressure metal-vapor discharge tube of claim 2, wherein said layers are in the form of sputtered thermally conductive metal.

7. High-pressure metal-vapor discharge tube of claim

1, wherein a pair of end discs is hermetically sealed in the ends of said tubular enclosure, respectively, said pair of electrodes being carried by said end discs, said end discs being formed from a heat durable metal.

8. High-pressure metal-vapor discharge tube of claim 7, wherein said end discs are formed from a material selected from the group consisting of niobium, tantalum, and molybdenum.

9. High-pressure metal-vapor discharge tube comprising a sealed tubular enclosure of transparent polycrystalline high-density ceramic, a pair of electrodes, each of which is enclosed near a respective end of said enclosure, a starting rare gas, a small amount of mercury plus at least one ionizable medium of alkali metal sufficient to form a saturated metal vapor confined in said enclosure, and at least one layer of a thermally conductive heat durable metal formed on the outer wall of the tubular enclosure proximate to the ends thereof, each layer being in the form of a metal foil wound around the tubular enclosure, said at least one layer extending from the end of the tubular enclosure beyond the tip of the electrode a distance of no more than 5 mm from the front tip of the electrode toward the central part of the tubular enclosure.

10. High-pressure metal-vapor discharge tube of claim 9, wherein a pair of ceramic end disks is hermetically sealed in the ends of said tubular enclosure.

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