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## (54) A mercury-free electrodeless metal halide lamp.

(57) A mercury-free electrodeless metal halide lamp has an arc tube 21. The arc tube(21) is made of glass having an inner surface defining an arc discharge space(23). A metal oxide layer(31, 35)is coated on the inner surface of the arc tube (21). A filling gas disposed in the arc discharge space (23) includes metal halide and a rare gas. This excitation means (27,29)couples radio-frequency energy to the filling gas for generating an arc discharge. The mercury-free electrodeless metal halide lamp suppresses an increase of an arc voltage of the lamp during its lifetime.

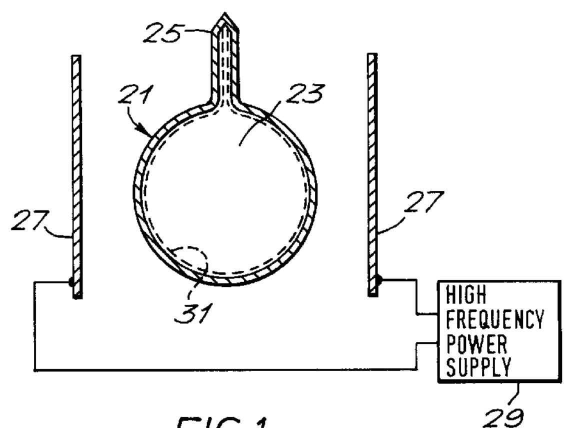


FIG.1.

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The present invention relates to a mercury-free electrodeless metal halide lamp.

Recently, mercury-free electrodeless metal halide lamps have been developed and are disclosed in U.S. Patent No. 4,810,938. The mercury-free electrodeless metal halide lamps are classified as high intensity discharge lamps (HID) because their basic operations, each of which is called a discharge, are similar to those of original HID lamps. Metal vapor in each mercury-free electrodeless metal halide lamp is caused to emit visible light upon excitation, typically caused by passage of current through an ionizable gas such as mercury or sodium vapor within the lamp.

The conventional HID lamp has a pair of electrodes in an arc discharge tube and the discharge of the conventional HID lamp is caused between the pair of electrodes. However, the mercury-free electrodeless metal halide lamp described above does not have any electrode in its arc discharge tube. It has, for example, a solenoid coil outside the arc discharge tube to generate a discharge in the arc discharge tube. Further the mercury-free electrodeless metal halide lamp does not use mercury vapor for causing the discharge, which is different from the original HID lamp.

The differences described above between the original HID lamp and the mercury-free electrodeless metal halide lamp cause new problems in the mercury-free electrodeless metal halide lamp. One of these problems is an increase of an arc voltage of the lamp during its lifetime. The inventor of the present invention has first recognized this problem in the mercury-free electrodeless metal halide lamp as more significant compared with the problem in the conventional HID lamp.

It is an object of the present invention to overcome an increase of an arc voltage of the mercury-free electrodeless metal halide lamps during their lifetime.

To accomplish the object described above, the present invention provides a mercury-free electrodeless metal halide lamp comprising an arc discharge tube. The arc discharge tube is made of glass having an inner surface defining an arc discharge space. A metal oxide layer is coated on the inner surface of the arc discharge tube. The arc discharge space is filled with a filling gas including metal halide and a rare gas. Excitation means may be provided for coupling radiofrequency energy to the filling gas for generating an arc discharge.

The present invention will be better understood with reference to the accompanying drawings and in which:

FIGURE 1 is a cross-sectional view of a metal halide lamp according to a first embodiment of the present invention, and

FIGURE 2 is a cross-sectional view of a metal halide lamp according to a second embodiment of the present invention.

The inventor of the present invention has extensively researched the reasons why the arc voltage of mercury-free electrodeless metal halide lamps more significantly increases during their lifetime as compared with that of an original HID lamp. The believed mechanism for this is as follows. The mercury-free electrodeless metal halide lamp uses a rare gas such as xenon as a replacement for mercury of the original HID lamp. This means that the density of gas in an arc tube of the mercury-free electrodeless metal halide lamp is lower than that of the original HID lamp. Thus, the energy level of the metal ions of the mercury-free electrodeless metal halide lamps is higher than that of the original HID lamps. Metal ions having high energy are likely to strike and be adsorbed into the wall of the tube, as compared with those having low energy. When the metal ions are adsorbed into the wall of the tube, halogen ions are released from the halogen content of this gas, and become eventually relatively excessive in the tube. It has been found that these excessive halogen ions cause the significant increase of the arc voltage during the lifetime.

Additionally, metal ions of the mercury-free electrodeless metal halide lamps have higher energy near walls of the tubes than at center portions of the tubes. This relationship is different from that of the original HID lamps. Therefore, metal ions of the mercury-free electrodeless metal halide lamps are more likely to strike against and be adsorbed into the walls of the arc tube than metal ions of the original HID lamps.

After recognizing this problem, the inventor of the present invention first contemplated using a barrier of a metal oxide layer for decreasing the adsorbtion of metal ions.

Preferred embodiments of the present invention will now be described in more detail with reference to the accompanying drawings.

FIGURE 1 shows a metal halide lamp according to a typical embodiment of the present invention. The metal halide lamp has an arc tube 21 defining an arc discharge space 23 and is made of transparent quartz glass. Arc tube 21 is formed into a substantially spherical shape and has exhaust tube 25 for exhausting air from arc discharge space 23 and introducing the filling gas therethrough. Arc tube 21 is surrounded by outer electrodes 27 supplying a high frequency electric field to arc tube 21, outer electrodes are connected with high frequency power supply 29. The high frequency electric field has a frequency of 50 megahertz (MHz). A more detailed description of the structure described above is shown in U.S. patents No. 4,017,764 and No. 4,180,763, which are incorporated herein by reference.

The heat conduction of the filling gas from a positive column of an arc discharge to a wall of arc tube 21 is decreased by including the xenon in the filling gas. The low heat conduction of xenon is attributable to the improvement in efficiency. Xenon is present in arc tube 21 at a partial pressure in the range between 60 and 600 Torr at room temperature. The filling gas also includes metal halide such as sodium halide and cerium halide. The metals emit light by the arc discharge. For example, the sodium halide may be sodium iodide (NaI) and the cerium halide may be cerium chloride ($CeCl_3$). Bromide (Br) may be used as the halogen and indium (In), lithium (Li), thallium (Tl) and alkaline earth metals such as barium (Ba), dysprosium (Dy), holmium (Ho) and thulium (Th) may be used as the metals, in addition to, or instead of sodium and cerium. A more detailed description of the filling gases described above is shown in U.S. patent No. 4,810,938, which is incorporated herein by reference.

An inner surface of arc tube 11 is coated with metal oxide layer 31 made of metal oxide grains, and particularly aluminium oxide grains. Metal oxide layer 31 may be made of, for example, rare earth metal oxide grains such as cerium oxide grains or alkaline earth metal oxide grains such as magnesium oxide grains. Metal oxide layer 31 is also formed on an inner surface of exhaust tube 25. The thickness of metal oxide layer 31 is about 3 $\mu$m, but more generally it may be between 1 and 10 $\mu$m.

Metal oxide layer 31 is formed by steps as follows. first, a mixture composed of organic dispersant such as butyl acetate and aluminium oxide grains is prepared, particularly $\tau$-nlumina grains dispersed into the organic dispersant. Next, the mixture is introduced into arc tube 21 through exhaust tube 25 which is not sealed and the mixture is coated on the inner surfaces of arc tube 21 and exhaust tube 25. Then an excessive mixture is to be exhausted through exhaust tube 25. After these steps, drying the mixture coated on the inner surface and baking the mixture coated on the surface are carried out. While the mixture is baked at a temperature of about 300 °C to about 700 °C, arc discharge space 23 is ventilated by air and the organic dispersant of the coated mixture is eliminated. Metal oxide layer 31 is formed by eliminating the organic dispersant. Alter these steps described above, steps for exhausting air from arc discharge the 21, introducing a filling gas into arc discharge tube 21 and sealing exhaust tube 25 are carried out and the manufacture of the metal halide lamp is completed.

Metal oxide layer 31 of the metal halide lamp described above prevents metal ions from directly colliding into or striking against the wall of arc tube 21 and therefore reactions between the metal ions and chemical elements of arc tube 21 decrease. Metal oxide layer 31 is much less likely to react with the metal ions striking thereagainst. Thus, the shortage of metal ions and relative excess of halogen are overcome by metal oxide layer 31, and an increase ratio of a lamp voltage over the lifetime of the metal halide lamp is decreased.

The rate of increase of the lamp voltage of the metal halide lamp having metal oxide layer 31 was one third of that of a conventional metal halide lamp not having a metal oxide layer, according to an inventor's experiment. Therefore, it is considered that the rate of the reactions of metal ions with metal oxide layer 31 of the metal halide lamp of the present invention is one third of those with the wall of the arc tube of the conventional lamp. A slow increase of the lamp voltage can also extend the lifetime of the metal halide lamp, because a high voltage to be supplied to a metal halide lamp having a high lamp voltage cannot be obtained by an ordinary operation circuit. Therefore, when the necessary voltage gets higher than can be supplied by the operation circuit, the lamp will fail to begin or maintain discharge. At this time, it can no longer be used, and its useable lifetime is ompleted.

Since the rate of the reactions of metal ions with metal oxide layer 31 of the metal halide lamp of the present invention is lower than those with the wall of the arc tube of the conventional lamp, the disadvantage of coloring metal oxide layer 31 and arc tube 21 of the lamp of the present invention is smaller than that the conventional lamp. Therefore, absorption of light and decrease of luminous flux over the lifetime of the lamp of the present invention is smaller than those of the conventional lamp.

An arc discharge needs an initial electron for a start thereof. Metal oxide layer 11, and especially $\tau$-alumina grains, have more lattice defects on the surface thereof than the inner surface of arc tube 21 made of quartz. Sometimes, the lattice defect will diminish, and they generally can radiate an electron when the lattice defect diminishes. Electrons radiated from the lattice defects of metal oxide layer 31 work as initial electrons and facilitate the start of the arc discharge. Other metal oxide grains also have lattice defects and can radiate electrons, but aluminium oxide grains are more significant than other metal oxide grains.

FIGURE 2 shows a metal halide lamp according to a second embodiment of the present invention. The metal halide lamp of FIGURE 2 is almost the same as that of the first embodiment of Figure 1. The differences are that the metal halide lamp of FIGURE 2 has a fluorescent layer 33 and a smaller region of metal oxide layer 35. The other elements of the second embodiment are similar to those of the first embodiment and therefore, the same reference numerals as those of the first embodiment are given to similar elements to those of the first embodiment. Fluorescent layer 33 is coated on the inner surface of arc tube 21 but not on the inner surface of exhaust tube 25. Metal oxide layer 35 is coated entirely on fluorescent layer 33 and prevents fluorescent layer 33 from being exposed directly to arc discharge space 23. Fluorescent materials of fluorescent layer 33 are more likely to react with metal ions than metal oxide layer 35 and arc tube 21 made of quartz and therefore, metal oxide layer 35 protects fluorescent layer 33. Metal oxide layer 35 does not cover the inner surface of exhaust tube 25, and this facilitates the sealing of exhaust tube 25. exhaust tube 25 is grasped by supporting members 37 in order to flux arc tube 11 between outer electrodes 27.

The fluorescent material of fluorescent layer 33 is, for example $Y(PV)O_4$:Eu for the purpose of supplementing red light, which is well-knon and well-used for metal halide lamps.

The metal halide lamp of the second embodiment described above has the same advantages as the metal halide lamp of the first embodiment.

The present invention is not limited to the embodiments described above. The filling gas may include argon in addition to or instead of xenon. The arc tube is not limited to have a spherical shape and may have another shape such a cylindrical shape or an elliptical shape. A solenoid coil may be used for supplying a high frequency electric field to an arc tube of the present invention, or alternately an electronic-type ballast could be used.

Metal oxide layer 31 of the metal halide lamp of the present invention may be formed by coating and baking metal alkoxide solution such as alumina alkoxide solution instead of using mixture composed of organic dispersant and metal oxide grains.

Although only a few embodiments have been described in detail above, those having ordinary skill in the art will certainly understand that many modifications are possible in the preferred embodiment without departing from the teachings thereof.

All such modifications are intended to be encompassed within the following claims.

## Claims

**1.** A mercury-free electrodeless metal halide lamp, comprising:

an arc tube (21) made of glass having an inner surface defining an arc discharge space (23) therewithin;

a metal oxide layer (31, 35)coated on the inner surface; and

a filling gas disposed in the arc discharge space (23)to generate an arc discharge, the filling gas including metal halide and a rare gas.

**2.** A mercury-free electrodeless metal halide lamp according to claim 1, further comprising excitation means (27, 29) for coupling radio-frequency energy to the filling gas.

**3.** The mercury-free electrodeless metal halide lamp according to claim 1, wherein the metal oxide layer (31, 35) includes accumulated grains of metal oxide on the inner surface of the arc tube (21).

**4.** The mercury-free electrodeless metal halide lamp according to claim 1, wherein the metal oxide layer(31, 35)is of amorphous metal oxide.

**5.** The mercury-free electrodeless metal halide lamp according to claim 1, further comprising a fluorescent layer (33) between the metal oxide layer (31, 35)and the inner surface of the arc tube (21).

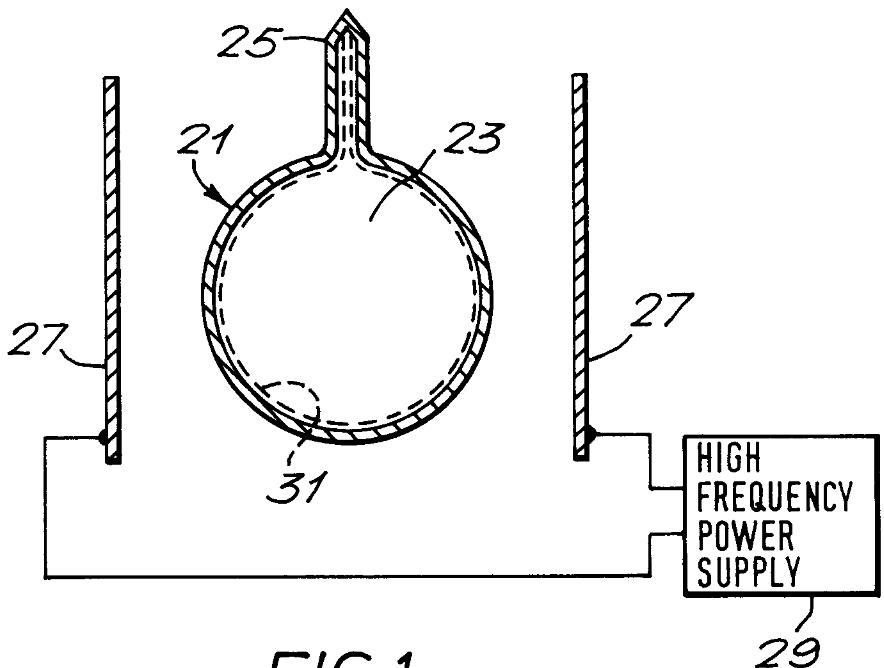
**6.** The mercury-free electrodeless metal halide lamp according to claim 1, further comprising an exhaust tube (25) attached to the arc tube (21), the exhaust tube (25) having an inner surface defining an inner space communicating with the arc discharge space 23 )and being thinner than the arc tube (21).

**7.** The mercury-free electrodeless metal halide lamp according to claim 6, wherein the inner surface of the exhaust tube (25) has a metal oxide layer (31, 35).

**8.** The mercury-free electrodeless metal halide lamp according to claim 2, further comprising supporting means (37) for supporting the arc tube (21 ) in a predetermined position,

**9.** The mercury-free electrodeless metal halide lamp according to claim 8, further comprising an exhaust tube (25) attached to the arc tube (21)and grasped by the supporting means(37) tube, the exhaust tube (25)having an inner surface defining an inner space communicating with the arc discharge space (23) and being thinner than the arc tube (21).

**10.** The mercury-free electrodeless metal halide lamp according to claim 1, wherein the filling gas comprises sodium halide.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HIGH FREQUENCY POWER SUPPLY
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FIG.1.

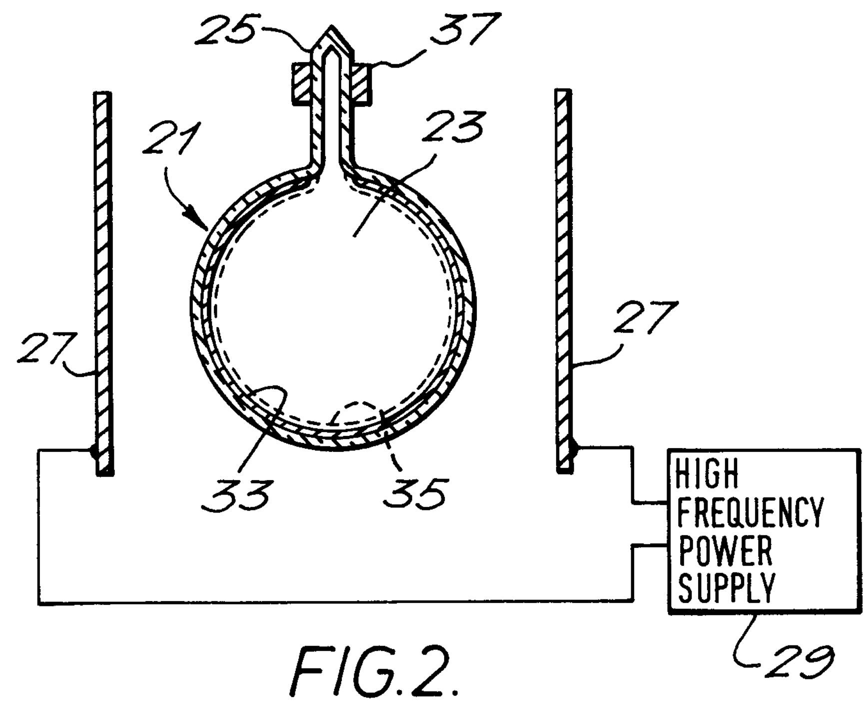
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FIG.2.