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[33] **Japan**

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[54] **HIGH PRESSURE DISCHARGE LAMP**
CONTAINING AN INERT GAS, MERCURY,
HALOGENS AND TIN
4 Claims, 2 Drawing Figs.

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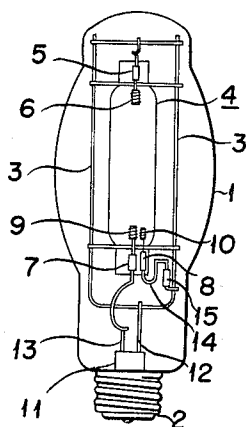
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3,279,877 10/1966 Smith et al. **313/227X**

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ABSTRACT: In a high pressure discharge lamp including a luminous sealed tube containing an ionizable inert gas, mercury, bromine, iodine, and tin, the improvement therein wherein said halogen and tin are sealed in said luminous sealed tube in such quantities that the ratio between the number of atoms of the halogen and the tin is from about 1 for the halogen to between about 0.51 to about 3.0 for the tin and the ratio between the number of atoms of the bromine and the iodine is between 1:0.1 and 1:5.0.



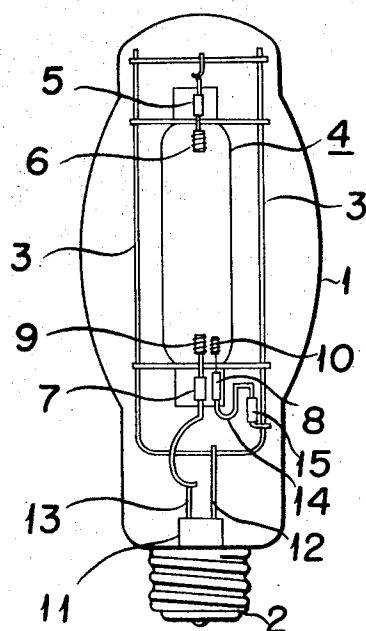
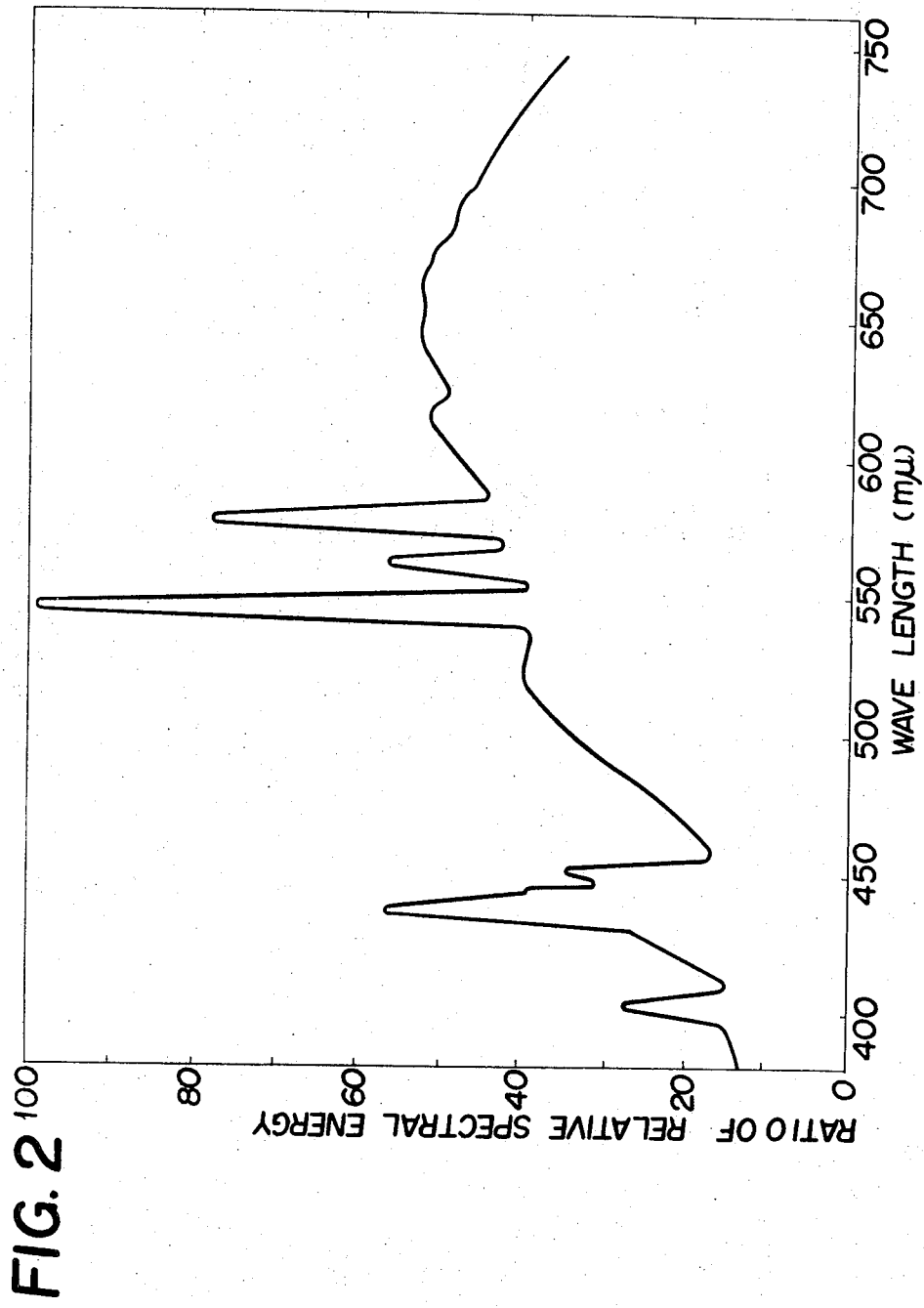


FIG. 1

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HIGH PRESSURE DISCHARGE LAMP CONTAINING AN INERT GAS, MERCURY, HALOGENS AND TIN

This application is a continuation of U.S. Pat. application No. 567,281 filed Jul. 22, 1966 (now abandoned).

The present invention relates to electric discharge lamps and more particularly to an electric discharge lamp for illumination purposes having a continuous spectrum over a wide range of wavelength, thus exhibiting uniform and good color rendering property.

Discharge lamps commonly available on the market, for example, a high-pressure mercury arc discharge lamp comprises a discharge tube or sealed tube which is made of fused quartz and contains argon gas sealed therein at a pressure of several 10 millimeters Hg and mercury of a quantity of several milligrams per cubic centimeter of the inner volume of the sealed tube and an evacuated envelope containing said sealed tube. However, the conventional mercury arc discharge lamp is not suitable for general purpose illumination because the spectrum radiated by mercury atoms contains a large amount of light of shorter wavelength but less amount of light of longer wavelength in the visible range so that their color-rendering property is poor.

It is known that the color-rendering property of such mercury discharge lamps can be improved by utilizing halides of metals e.g. halides of elements of group Ia of the periodic table such as sodium iodide and lithium iodide, halides of elements of group IIb such as thallium iodide and indium iodide, or halides of lanthanide elements or actinide elements or elements of group IIIa, such as thorium iodide and scandium iodide together with mercury. Each of these halides has a sufficient vapor pressure at the wall temperature of the sealed tube during operation and undergoes dissociation at the temperature of an arc column between electrodes to form metal atoms and halogen atoms and the discharge spectrum of these free atoms is included in the visible range. Accordingly when an electric discharge is created across a pair of electrodes disposed in the sealed tube of the electric discharge lamp, metal halides contained in the tube will be vaporized and dissociated by the temperature rise of the tube wall caused by the heat of electric arc. Thus, line spectra which are characteristic of respective metal atoms are radiated to improve the color rendering property of the discharge lamp. It is also well known in the art that the color-rendering property can be further improved by utilizing several metal halides of different type.

With only one type of metal halide the spectral distribution in the visible range is not uniform so that the color and color-rendering property is not satisfactory for use as a source of illumination for general purposes. Even when several types of metal halides are mixed for the purpose of producing more uniform spectral distribution as above mentioned it would also be difficult to obtain satisfactory color-rendering property because of the limitation upon spectral lines of metal caused by electric discharge. Moreover, utilization of a number of types of compounds results in the increase in the chance of contamination by impurities which greatly affects the life of the discharge lamp.

It is an object of this invention to provide a novel electric discharge lamp comprising a sealed tube in which mercury, an ionizable inert gas, halogen and tin are sealed whereby to enable to emit light rays having a spectral energy distribution which is continuous over the visible range, said discharge lamp being also characterized by having an improved color-rendering property, high efficiency, as well as improved quality and operating life.

A further object of this invention is to provide an improved electric discharge lamp wherein halogen and tin which are sealed in the tube is sealed such that the ratio between the number of atoms of the halogen and the tin is 1 : 0.51 and 1 : 3.0 whereby to prevent discharge initiating voltage from increasing during repeated turn on and off operations of the lamp.

A still further object of this invention is to utilize both bromine and iodine as halogen in the electric discharge lamp herein disclosed with the ratio of the total atom number of from 1 : 0.1 to 1 : 5 whereby to provide discharge lamps with very small decrease in the luminous flux emitted therefrom during continuous operation over a long period of time.

Further objects and advantages of the present invention will become apparent and this invention will be better understood from the following description, reference being made to the accompanying drawings, in which:

FIG. 1 is an elevation of an electric discharge lamp embodying this invention; and

FIG. 2 is a graph showing the relative spectral energy distribution of light rays emitted from an electric discharge lamp embodying this invention.

Referring now to the accompanying drawings, in FIG. 1 is shown an electric discharge lamp comprising an evacuated envelope 1 made of transparent glass having a base 2 at one end thereof. A supporting frame 3 made of metal wire is disposed within the envelope adapted to support a luminous sealed tube 4. The sealed tube 4 is made of a transparent fused quartz glass tube with its opposite ends pressed. Within the glass tube 4 are disposed a main electrode 6 at one end, and another main electrode 9 and an auxiliary electrode 10, at the opposite end, which are respectively supported by lead-in conductors 5, 7 and 8 sealed in said pressed portions. The main electrode 6 is electrically connected to one terminal of the base via the supporting frame 3, and a lead-in conductor 12 which is sealed in a stem 11, while the other main electrode 9 is connected to the other terminal of the base via a lead-in wire 13 similarly sealed in the stem 11. The auxiliary electrode 10 is connected to the supporting frame 3 through a starting resistor 15. In the sealed tube 4 are sealed an ionizable inert starting gas such as argon at a pressure of 10 to 40mm. Hg, mercury of the quantity of 0.8 to 6mg. per cubic centimeter of the inner volume of the sealed tube and tin halides.

When impressed with a starting voltage from a conventional starting device, the electric discharge lamp constructed as above described will initiate a glow discharge between the main electrode 9 and the auxiliary electrode 10 followed by an arc discharge between the main electrodes 9 and 6. The heat generated by this discharge will heat the sealed tube 4, thus increasing the vapor pressure of mercury and tin halides which are contained therein. The vaporized tin halides emit a strong continuous spectrum in the visible range, while at the same time the vaporized mercury and the vapor of dissociated tin emit line spectrum composed of 405 μ , 436 μ and 578 μ mercury lines and 453 μ and 563 μ tin lines. In this way tin halides utilized according to this invention will act to complement the light in the wavelength region in the spectrum which is not afforded by mercury, with the result that the spectral energy distribution is made more uniform and the color-rendering property is improved.

The tin halides sealed in the sealed tube may be applied in the form of either elementary substances or their compounds. Among such compounds may be mentioned stannous iodide, stannic iodide, stannous bromide, stannic bromide and the like. Further, mercury halide may be used together with tin in the form of elementary substance.

Where tin is utilized in the form of halides, the adequate quantity of tin element is within a range of from 0.01 to 2mg. per cubic centimeter of the inner volume of the sealed tube. Within this range the color-rendering property could be effectively improved and there is no fear that, during operation of the lamp, tin halide is deposited on the inner wall of the sealed tube in the form of liquid or solid state. If the quantity of tin element exceeds 2mg. per cubic centimeter the arc column of the discharge become occasionally unstable.

When halogen and tin are used in such a quantity that the ratio of halogen to tin (ratio of their number of atoms) is 1 : 0.51 to 3.0 it is possible not only to improve the color-rendering property but also effectively prevent increase in the discharge initiation voltage at the time of restarting the lamp

after extinguishment. The ratio of halogen to tin is selected so that the proportion of tin is higher than that of the case utilizing tin halide. Since tin is divalent or tetravalent, the ratio of halogen and tin (the ratio of their number of atoms) of a stable tin halide is 0.5 or 0.25. As a result, after the lamp is turned off, free halogen will not remain in the sealed tube thus the increase in the discharge initiation voltage is prevented. In this case the upper limit of adequate quantity of tin element is 10mg. per cubic centimeter of the inner volume of the sealed tube.

Where a combination of bromine and iodine is selected as the halogen and where the ratio of the number of atoms of iodine to that of bromine is selected to be 0.1 to 5 : 1, it is very effective to improve the color-rendering property and the efficiency of the discharge lamps in addition to preventing decrease in the luminous flux after long time continuous operation. Bromine and iodine in the range specified above serve to capture the tin which is sealed in together with them to prevent the tin from depositing on the inner wall of the sealed tube under operation, thus preventing the light transmitting property of the sealed tube from decreasing and prolonging the useful life of the discharge lamps.

The following specific examples of this invention are given by way of illustration, and are not to be construed as limiting in any way the scope and spirit of the invention.

EXAMPLE 1

An electric discharge lamp was prepared by sealing in a sealed tube argon gas at a pressure of from 10 to 40mm. Hg, mercury of the quantity of from 1 to 6mg. per cubic centimeter of the inner volume of the sealed tube and a quantity of stannous iodide of the amount corresponding to 0.2mg. of tin element per cubic centimeter of the inner volume of the sealed tube. The following are the results of experiments when this lamp was operated at an input power of 400W.

1. Spectral Energy Distribution

The spectral energy distribution of light rays emitted from said discharge lamp is plotted in FIG. 2. FIG. 2 shows that the spectral energy distribution is made more uniform over the entire visible range by the reasons that by superposing light rays of wavelengths of 405μ , 436μ , 546μ and 578μ corresponding to the lines of mercury upon light rays of wavelengths of 453μ and 563μ corresponding to the resonance lines of tin and that these superposed light rays cooperate with a continuous spectrum having its maximum wavelength near about 650μ to provide nearly uniform spectral energy distribution over the entire visible range.

2. Chromaticity

It was found that the chromaticity was very close to the locus of a black body at a color temperature of about $4,200^\circ\text{K}$. Other experiments showed that by varying the quantity of incorporation of stannous iodide white light which is nearly ideal as the light source of illumination was obtained having chromaticity close to the locus of a black body at a color temperature in a range of about $6,000^\circ\text{K}$. to $4,000^\circ\text{K}$.

3. Color-rendering Property

Color-rendering indices calculated from the spectral energy distribution curve shown in FIG. 2 by a test color method as specified by the Commission Internationale de l'Eclairage (C. I. E.) showed the general color-rendering index $R_a = 86$ and a special color-rendering index for red color $R_9 = 75$. These values are comparable with those of the most excellent fluorescent lamps of deluxe color type.

4. Efficiency

The efficiency of the lamp was found to be approximately 50 lumens per watt. This value is comparable with that of conventional mercury discharge lamp with or without phosphorous. While it has been well known in the art that special mercury lamps incorporated with thallium iodide and sodium iodide often exhibit an efficiency of approximately 80 lumens per watt, it is not proper to compare the novel lamp with such lamps because their color-rendering property and chromaticity are very poor.

5. Performance

Since stannous iodide contained in the sealed tube and elementary substances dissociated therefrom by the action of electric discharge are all chemically stable, the lumen maintenance and life characteristic of the discharge lamps embodying this invention are superior to those of discharge lamps containing sodium iodide or indium iodide.

6. Flickering of Light Output

In this example, although the discharge lamp was energized from an AC source, flickering of light output was very slight. This is because in the discharge lamp of this invention, fluctuation in the continuous spectrum in which light rays are emitted at a relatively low temperature ranges of from 20 to 30 percent and such light rays comprise the major portion of the light output.

EXAMPLE 2

An electric discharge lamp was prepared by sealing a mixture in a sealed tube made of quartz glass, having a diameter of 18mm. and a spacing between discharge electrodes of 65mm., said mixture consisting of argon gas at a pressure of 20mm. Hg, 40mg. of mercury, 16mg. of stannous bromide and 5mg. of metallic tin (the ratio between the numbers of bromine atom and tin atom being approximately 1 : 1). This discharge lamp readily started at a discharge initiating voltage of from 300. to 400., and it was noted that there was no appreciable rise in the discharge initiating voltage after repeating turning on and off operations many times. The spectral energy distribution of light rays emitted from this lamp was a uniform spectrum consisting of a major continuous spectrum having its maximum wavelength near 500μ and line spectrum of mercury having wavelengths of 405μ , 436μ , 546μ and 578μ and line spectrum of tin having wavelengths of 452μ and 563μ , which are superposed upon said continuous spectrum portion. Color-rendering indices calculated from this spectrum energy distribution curve by using the test color method specified by the Commission Internationale de l'Eclairage were the general color-rendering index $R_a = 94$ and the special color-rendering index for red $R_9 = 75$. These values are comparable with those of especially high quality fluorescent lamps of super deluxe type. The efficiency of the discharge lamp of this example was found to be about 60 to 65 lumens per watt which is higher than the conventional mercury mercury lamps with or without phosphorous.

EXAMPLE 3

Another electric discharge lamp was prepared by sealing a mixture in a sealed tube made of quartz glass and having a diameter of 18mm., and a spacing of 65mm. between discharge electrodes, said mixture consisting of argon gas at a pressure of 25mm. Hg, 40mg. of mercury, 10mg. of stannous bromide and 8mg. of stannous iodide (the ratio of atom numbers of bromine and iodine being about 1 to 0.6). After continuous operation of 1,000 hours at an input of 400 watts no metallic deposit was noted on the inner wall of the sealed tube thus the lamp radiated 95 to 98 percent of the initial light fluxes. Further, no appreciable wear of discharge electrodes was noted. The color-rendering indices of this lamp were high, that is, the general color-rendering index $R_a = 91$ and the special color-rendering to red color $R_9 = 70$. The efficiency of this lamp was about 65 lumens per watt.

We claim:

1. A high-pressure discharge lamp with enhanced color rendition and free of internal metal deposition during the service life of the lamp, including a luminous sealed tube containing a pair of discharge electrodes an ionizable inert gas, mercury, tin, bromine, and iodine, the relative proportions of bromine and iodine being such that the ratio between the number of atoms of the bromine and the iodine is between 1 : 0.1 and 1 : 5.0 to prevent metal deposition on the inner wall of said sealed tube and wear of said discharge electrodes.
2. A high-pressure discharge lamp according to claim 1 wherein the amount of tin contained in said luminous sealed

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tube is between about 0.01 mg. and about 2 mg. per cubic centimeter of the inner volume of said luminous sealed tube.

3. A high-pressure discharge lamp according to claim 1 wherein the ratio of the number of atoms of bromine and iodine to the number of atoms of tin is between 1 : 0.51 and 1 : 3.0.

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4. A high-pressure discharge lamp according to claim 3 wherein the amount of tin contained in said luminous sealed tube is between about 0.01 m.g. and about 10 mg. per cubic centimeter of the inner volume of said luminous sealed tube.

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