

## Description

### Background of the invention Field of the invention

The present invention relates to high frequency excited electrodeless discharge lamps, and more particularly to improvements in the composition of the fill materials thereof which, when excited, emit light that is particularly rich in the near ultraviolet light range.

### Description of the prior art

Near ultraviolet light sources which are often used for processes involving photochemical reactions, such as photoengraving, have commonly comprised high pressure metal vapour electric discharge lamps which have a pair of discharge electrodes disposed within the envelope thereof. Such electric discharge lamps have generally comprised fill materials including halides of gallium, etc., and thus have been called metal halide lamps. This type of conventional metal halide lamps is disadvantageous, however, in that the stabilization time, i.e., the length of time that the lamp requires to attain the stable state of light emission after it is turned on, is relatively long, i.e., as long as about three minutes. Thus, when this type of conventional metal halide lamps is used in the photoengraving process in which exposure and preparation steps follow one after another at short intervals of one minute, the lamps cannot be turned off during the preparation steps between the exposure steps.

It has thus been necessary to keep the lamp continuously turned on behind a shutter during all of the operations of the photoengraving process, opening the shutter during the exposure steps in which the light is required. This causes much loss of electric power. Thus, the so-called instant stabilization type ultraviolet light sources have been much needed. Further, conventional metal halide lamps constitute high electrical loads and the life thereof has been limited to about a thousand hours. This relatively short life is due, for example, to the stains originating from the electrodes which accumulate on the inner surface of the envelope of the lamp.

Thus, light sources have already been proposed in which electrodeless lamps are exciting by high frequency waves, especially microwaves. These electrodeless discharge lamps enjoy longer life than the conventional lamps with discharge electrodes, because a main factor limiting the life of the conventional lamps has been the consumption of the electrodes and the stains resulting therefrom. A further advantage of the electrodeless lamp is that there is no thermal loss at the discharge electrodes, and that it is easier to apply greater electric power to the lamp from the time of turn-on, because the impedance of the discharge in the electrodeless lamps varies little from the time it is turned on till it attains the stable state.

Also, the stabilization time of the electrodeless lamps is shorter because the electric discharge thereof concentrates near the inner surface of the envelope of the lamp.

Although the electrodeless discharge lamps have many advantages as above described, they have not been satisfactory as near ultraviolet light sources. That is, the conventional fill materials thereof did not give enough light output in the near ultraviolet range, especially in the range of 350 to 450 nm length. Such conventional fill materials are disclosed, for example, in U.S. patent 4,001,632 issued to Haugsjaa et al. on Jan. 4, 1977 as examples I through III in column 5 thereof.

The mechanism of light emission, however, is substantially the same in the electrodeless discharge lamps as in the conventional discharge lamps having discharge electrodes. Namely, the light emitting metal contained in the fill material sealed in the envelope of the lamp is vapourized and excited by the high frequency waves to emit light. Thus, when higher light emission is required in a particular wave length range, fill materials comprising substantially the same kind of light emitting metals must be sealed in the enveloped in the electrodeless lamps as in the conventional lamps having discharge electrodes. The light emission in the case of the conventional metal halide lamps having discharge electrodes, however, concentrates near the axis between the discharge electrodes, which are situated at the two end portions of the envelope, in contrast to the case of the electrodeless discharge lamps in which the light emission extends to the neighbourhood of the inner surface of the envelope even when the vapour pressure within the envelope of the lamp is high.

Thus, the amounts of fill materials which are suitable for the conventional metal halide lamps and which are suitable for the electrodeless lamps are different even when fill materials including the same kind of metals are used.

### Summary of the invention

Thus, the object of the invention is to provide an improved high frequency excited electrodeless lamp which emits light that is particularly rich in the near ultraviolet range, especially in the range of 350 to 450 nm wavelength. More particularly, the present invention contemplates providing fill materials for the high frequency excited electrodeless discharge lamps which give sufficient light emission in the near ultraviolet range, especially in the 350 to 450 nm wave length range.

Thus, according to one aspect of the present invention, the fill material sealed within the light transmitting envelope of the electrodeless lamp comprises a rare gas, mercury, a halogen, and a metal selected from the group consisting of iron, nickel, cobalt, palladium, and the mixtures thereof. The fill material comprises, per one cubic centimeter of the volumetric content of

the envelope of the lamp, mercury in an amount from 7 to 55 preferably from 17.6 to 41.3 and more preferably around 25, micromoles, the metal selected from the group in the total amount from 0.1 to 2.3, preferably from 0.38 to 1.91 and more preferably from 0.5 to 1, micromoles, and the halogen in a total amount ranging from 0.2 to 6.2 micromoles in terms of atoms or ions thereof. Preferably, the amount of halogen atoms measured in terms of micromoles per one cubic centimeter of the content of the enveloped exceeds twice the amount of the metal selected from the group measured in the same terms, by an amount ranging from 0.02 to 2.0 micromoles. That is, it is preferable that there is enough halogen for changing all the metal selected from the group into the halide thereof. It is further preferred that the rare gas is present in the envelope at a pressure ranging from 10 to 200, preferably from 20 to 150 and more preferably from 30 to 130, torr.

The micromole unit used in the above measurements is equal to  $10^{-6}$  moles. The mole unit is the SI unit which is equivalent to the former corresponding units such as gram-atom or gram-molecule.

According to another aspect of the present invention, the fill material sealed within the envelope of the lamp comprises a rare gas, mercury, a halogen, and a rare earth metal selected from the group consisting of dysprosium, holmium, thulium, scandium, and the mixtures thereof. It is preferred that the fill material comprise, for each one cubic centimeter of the content of the envelope, mercury in an amount ranging from 5 to 55 preferably from 17.6 to 53, micromoles, a rare earth metal in a total amount ranging from 0.05 to 0.6 preferably from 0.13 to 0.39 and more preferably around 0.25, micromoles, and halogen in a total amount ranging from 0.15 to 0.62 micromoles in terms of atoms thereof. It is preferred that the amount of halogen atoms measured in terms of micromoles per one cubic centimeter of the volumetric content of the envelope exceed three times the amount of rare earth metal measured in the same terms. That is, it is preferred that there be enough halogen to combine with all the rare earth metal present in the envelope to form the halide thereof.

In both aspects of the invention, the halogen may be iodine, bromine, or a mixture thereof, and the rare gas may be argon.

#### Brief description of the drawings

Further details of the present invention will become more apparent from the following detailed description of the preferred embodiments, taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a schematic cross-sectional view of the microwave generating device in which the electrodeless discharge lamp according to the present invention may be disposed;

Fig. 2 is a cross-sectional view of an

electrodeless lamp according to the present invention;

Fig. 3 shows the curve representing the relationship between the near ultraviolet output of an electrodeless lamp and the iron iodide content sealed in the envelope thereof, wherein the fill material sealed in the envelope of the lamp comprises the elements iron, iodine, mercury, and argon, and wherein the mercury and argon contents are fixed;

Fig. 4 shows the curve representing the relationship between the near ultraviolet output of an electrodeless lamp and the mercury content sealed in the envelope thereof, wherein the fill material sealed in the envelope comprises the elements iron, iodine, mercury, and argon, and wherein the iron, iodine, and argon contents are fixed;

Fig. 5 shows the curve representing the relationship between the near ultraviolet output of an electrodeless lamp and the dysprosium iodide content sealed in the envelope thereof, wherein the fill material sealed in the envelope comprises the elements dysprosium, iodine, mercury, and argon, and wherein the mercury and argon contents are substantially fixed;

Fig. 6 shows the curve representing the relationship between the near ultraviolet light output of an electrodeless lamp and the mercury content sealed in the envelope thereof, wherein the fill material thereof comprises the elements dysprosium, iodine, mercury, and argon, and the dysprosium, iodine, and argon contents are fixed.

Fig. 7 shows the curves representing the variations of the near ultraviolet light output and the starting time against the mole fraction of bromine with respect to the total molar content of bromine and iodine included in the fill material of an electrodeless lamp.

In the drawings like reference numerals represent like components.

#### Detailed description of the preferred embodiments

Referring now to Fig. 1 and 2 of the drawings, a construction of an electrodeless discharge lamp according to the present invention is described, together with that of a microwave generating device in which the lamp according to the present invention may be disposed.

The microwave generating device of Fig. 1 comprises a magnetron 1 generating a microwave of 2450 MHz and having an output power of 700 W. The magnetron 1 is disposed at an end portion of a wave guide 3, and has a magnetron antenna 2 from which the microwave is radiated into the wave guide 3. The wave guide 3 opens into a cavity 4 enclosed by cavity wall 5 and a metallic mesh plate 11 at a microwave feeder opening 6. The cavity wall 5 is formed of a substantially semispherical aluminum plate and the inner surface thereof forms a light reflecting surface. The metallic mesh plate 11 is a stainless steel mesh plate

manufactured by the etching method, and transmits about 85 percent of light there-through but not the microwave generated by the magnetron 11. And electrodeless lamp 7 comprises a spherical envelope 7a formed of light transmitting quartz and a pair of rod-shaped projections 7b and 7c formed of the same material and integral therewith. The spherical envelope 7a has a thickness of 0.5 mm and an inner diameter of 30 mm, thus enclosing a spherical space of about 14.1 cm<sup>3</sup>, in which an inert gas, metals, etc., are sealed in a certain composition according to the present invention, as will be described in detail hereinafter. The projections 7b and 7c have a length of 10 mm and a diameter of 3 mm, and the electrodeless lamp 7 is supported at these projections 7b and 7c by supporting members (not shown) formed on the cavity wall 5. A ventilator fan 8 disposed at an end of a ventilating duct 9 introduces cooling air into the duct 9 from outside the housing 12 which accommodates the magnetron 1, the wave guide 3, etc., and thus cools the magnetron 1 and the electrodeless lamp 7.

The operation of the microwave generating device of Fig. 1 will be described, together with that of an electrodeless lamp according to the present invention. The microwave generated by the magnetron 1 is radiated into the wave guide 3 from the magnetron antenna 2, and then is propagated through the wave guide 3 and radiated into the cavity 4 from the feeder opening 6, thereby forming a microwave electromagnetic field in the cavity 4. Thus, the electrodeless lamp 7 is placed in the microwave electromagnetic field established in the cavity 4, and the inert gas, which is sealed in the lamp 7, for starting the electric discharge within the lamp 7, begins to discharge, thereby beating the inner surface of the envelope 7a of the electrodeless lamp 7. Thus, the metals deposited on the inner surface of the envelope 7a of the lamp 7 begin to evaporate, filling the space within the envelope 7a with metal vapor. Thus, the electric discharge within the envelope 7a is now carried out, for the main part thereof, by the metal vapor, and is stabilized when the metal vapor discharge takes place, the metal vapor emits light having the emission spectra characteristic of the metals. This light emitted from the metal vapors is utilized as a light source. Further, in order to effectively utilize the light emitted from the electrodeless lamp 7, the inner surface of the cavity wall 5 is made light reflecting, and the front of the cavity 4 is covered by the metallic mesh plate 11 which transmits light but not microwaves. Thus substantially all the light emitted from the electrodeless lamp 7 is radiated forward through the mesh plate 11. Further, as it is necessary to remove heat generated in the magnetron 1 and the lamp 7, the ventilating fan 8 takes in the outside air, which then blows through the duct 9, the opening 10, the wave guide 3, the feeder

opening 6, and the cavity 7, and is exhausted from the cavity 7 through the mesh plate 11.

We have conducted a series of experiments to determine the optimum composition of the fill material of an electrodeless discharge lamp which can be used as near an ultraviolet light source. In all the experiments described hereinbelow, the electrodeless discharge lamp 7 of Fig. 2 having the physical construction and dimensions described hereinabove was used and placed in the microwave generating device of Fig. 1. Thus, the volumetric content of the envelope 7a is 14.1 cubic centimeters, and it should be understood that when the amounts of substances contained in the fill material of the lamp 7 are expressed in terms of micromoles per cubic centimeter, the actual molar amounts of the substances contained in the fill material are obtained by multiplying the values expressed in terms of micromoles per cubic centimeter by the factor of 14.1 cubic centimeters. Further, it should be obvious that when electrodeless discharge lamps having a larger or smaller volumetric content are used, the actual amounts of the substances of the fill material should be increased or decreased in proportion to the volumetric content of the envelope. The physical construction and the dimensions of the electrodeless lamp 7 of Fig. 2 were described hereinabove only for exemplary purposes, and the scope of the invention is not limited to the particular form or dimensions of the lamps of Fig. 2.

In all the experiments described hereinbelow, except for the last one of Fig. 7, the light output of the lamp 7 in the near ultraviolet range of 355 to 425 nm has been measured on an arbitrary scale, in which the electrodeless discharge lamp formerly developed in our laboratory and including gallium as the light emitting metal scored a value 65.

Referring now to Figs. 3 and 4 of the drawings, the first series of experiments in which the fill material of the lamp 7 comprising the elements iron, iodine, mercury, and argon, is described.

Fig. 3 shows the dependence of the light output on the iron iodide content of the fill material. Namely, fixed amounts of argon and mercury, i.e., argon at pressure of 13330 pa (100 torr) as the starter rare gas and mercury in an amount of 120 mg (or 42 micromoles per cubic centimeter of the content of the envelope 7a) as the buffer gas were sealed in the envelope 7a of the lamp 7. Further, a variable amount of iron iodide (FeI<sub>2</sub>) was sealed in and the dependence of the light output of the lamp 7 on the amount of iron iodide was measured. Thus, the fill material used in this experiment comprised fixed amounts of the elements mercury and argon, and variable amounts of the elements iron and iodine. The amount of iodine in terms of moles was two times that of iron. The elements iron and iodine could of course be sealed in the form of metallic iron and mercury

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iodide ( $\text{Hgl}_2$ ), keeping the ratio of the amount of these elements in terms of moles at 1:2.

As shown in Fig. 3, the light output in the near ultraviolet range increases rapidly at first with increase in the amount of iron iodide sealed in the envelope 7a, and reaches a maximum when the amount of iron iodide is between 0.5 and 1.0 micromoles per cubic centimeter. An amount of iron iodide between 0.1 and 2.3 micromoles per cubic centimeter is practically feasible. When the amount of iron iodide sealed in the envelope 7a is less than 0.1 micromoles, it is difficult to seal in the precise predetermined amount of iron iodide due to measurement errors and fluctuations in the parameters in the manufacture of the lamp, and thus the near ultraviolet light outputs of the product lamps vary considerably from each other. Further when the amount of iron iodide sealed in the envelope 7a exceeds 2.3 micromoles per cubic centimeter, the discharge within the envelope 7a becomes unstable and fluctuates, presenting a striped pattern therein.

Fig. 4 shows the dependence of the near ultraviolet light output of the electrodeless lamp 7 upon the mercury content of the fill material thereof. The argon gas was sealed at fixed pressure of 13330 pa (100 torr) as the starter gas, and iron in the fixed amount of 0.63 micromoles per cubic centimeter was sealed in the envelope 7a as the light emitting metal, together with mercury iodide in the fixed amount of 0.62 micromoles per cubic centimeter. The amounts of these substances were fixed at these values while the amount of mercury sealed in the envelope was changed and the dependence of the light output of the lamp 7 on the amount of mercury was measured. Thus, in this experiment of Fig. 4, the fill material comprised the elements iron and iodine in the fixed amounts of 0.63 and 1.24 micromoles per cubic centimeter, respectively, and also a fixed amount of argon at a pressure of 13330 pa (100 torr) in the envelope 7a.

As shown in Fig. 4, the light output of the lamp 7 increases at first rapidly with an increase in the amount of mercury sealed in the envelope 7a, and reaches a maximum when the amount of mercury is at about 25 micromoles per cubic centimeter. The light output decreases gradually when the amount of mercury is increased beyond about this value. The amount of mercury in the range of from 7 to 55 micromoles is practically feasible. The reason is that when the amount of mercury is less than 7 micromoles per cubic centimeter, the light output is not sufficient, and, on the other hand, when it exceeds 55 micromoles per cubic centimeter, the light emission in the envelope 7a presents a striped pattern and becomes unstable with fluctuation.

Further experiments were conducted changing the pressure of argon gas in the envelope 7a of the lamp 7, the fill materials of which comprised the same elements as in the case of the experiments of Figs. 3 and 4.

Namely, iron in the fixed amount of 0.63 micromoles per cubic centimeter and mercury iodide in the fixed amount of 0.62 micromoles per cubic centimeter were sealed in the envelope 7a, and the pressure of argon gas in the envelope 7a was changed from 1, through 668, 1333, 5320, 13330, and 26660, to 39990 pa (5, 10, 40, 100, and 200, to 300 torr).

When the pressure of argon gas is at 1 torr, the discharge within the envelope extinguished before it reached the stable state, and when the pressure of argon gas is at 300 torr, the lamp 7 did not start light emission. Thus, it was found preferable to limit the pressure of argon in the envelope 7a within the range of from 1333 to 26660 pa (10—200 torr). As the result of further experiments, it was found that a more preferable range of the pressure of argon in the envelope 7a in the case where the fill material comprises iron, iodine, mercury and argon is between 266 and 19890 pa (20 and 150 torr), and a still more preferable range thereof is between 400 and 13790 pa (30 and 130 torr).

With regard to the iodine content in the fill material, an amount thereof necessary to form the sufficient amount of iron iodide should be sealed in the envelope 7a. When the iodine is sealed in the envelope 7a in the form of mercury iodide, the maximum amount of iodine which can be sealed in is 1.25 mg, or 6.2 micromoles per cubic centimeter. The reason of this is that when the amount of iodine in the fill material exceeds this maximum of 6.2 micromoles per cubic centimeter the light emission in the envelope 7a becomes uneven, and the discharge within the envelope 7a unstable with fluctuations. Thus, the amount of iodine in the fill material should not be less than 0.2 micromoles per cubic centimeter, which is necessary to form the minimum permissible amount of iron iodide of 0.1 micromoles per cubic centimeter, and not more than 6.2 micromoles per cubic centimeter. Further, it is preferred that the amount of iodine measured in terms of micromoles per cubic centimeter exceeds 2 times the amount of iron measured in the same terms. Namely, it is preferable that the amount of iodine exceeds the amount thereof which is necessary to combine with all the iron present in the fill material. The preferable excess amount of iodine is from 0.02 to 0.2 micromoles per cubic centimeter.

Thus, in view of the experiments described above and also in view of further experiments, we conclude as follows with regard to the fill materials of an electrodeless discharge lamp which comprises a rare gas, mercury, a halogen, and a metal selected from the group consisting of iron, nickel, cobalt, palladium, and the mixture thereof.

The fill material should comprise, per one cubic centimeter of the content of the envelope of the lamp mercury in an amount from 7 to 55 preferably from 17.6 to 41.3 and more preferably around 25, micromoles, the metal

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selected from the group in overall amount from 0.1 to 2.3, preferably from 0.38 to 1.91 and more preferably from 0.5 to 1, micromoles, and the halogen in an overall amount ranging from 0.2 to 6.2 micromoles. Preferably, the amount of halogen measured in terms of micromoles per one cubic centimeter of the content of the envelope exceeds twice the amount of the metal selected from the group measured in the same term by an amount ranging from 0.02 to 2.0 micromoles. That is, it is preferable that there is enough halogen for changing all the metal selected from the group into the halide thereof. It is further preferred that the rare gas is present in the envelope at a pressure ranging from 1333 to 26660 pa (10 to 200 torr) preferably from 2666 to 19890 pa (20 to 150 torr) and more preferably from 400 to 17330 pa (30 to 130 torr).

The micromole unit used in the above measurements of the substances involved is equal to  $10^{-6}$  moles. The mole unit is the SI unit which is equivalent to the former corresponding units such as gram-atom or gram-molecule units.

Referring now to Figs. 5 and 6 of the drawings, the second series of experiments in which the fill material of the lamp 7 comprised the elements dysprosium, iodine, mercury, and argon, is described.

Fig. 5 shows the dependence of the light output on the dysprosium iodide content of the fill material. Namely, fixed amounts of argon and mercury, i.e., argon at a pressure of 100 torr as the starter rare gas and mercury in the amount of 100 mg as the buffer gas were sealed in the envelope 7a of the lamp 7. Further, variable amounts of dysprosium and mercury iodide were sealed in and the dependence of the light output of the lamp 7 on the amount of dysprosium iodide ( $DyI_3$ ) was measured. Namely, variable amounts of dysprosium and mercury iodide were sealed in the envelope 7a, while keeping the ratio thereof in terms of moles at 1:1.5. Thus, the ratio of the amounts of dysprosium and iodine in terms of moles was kept at 1:3, i.e., there was just enough iodine to combine with all the dysprosium to form dysprosium iodide. Thus, the fill material used in this experiment comprised substantially fixed amounts of the elements mercury and argon, and variable amounts of the elements iron and iodine.

As shown in Fig. 5, the light output in the near ultraviolet range increases rapidly at first with an increase in the amount of dysprosium iodide sealed in the envelope 7a, and reaches a maximum when the amount of dysprosium iodide is about 0.25 micromoles per cubic centimeter. An amount of dysprosium iodide between 0.05 and 0.6 micromoles per cubic centimeter is practical. When the amount of dysprosium iodide sealed in the envelope 7a is outside this range, the light output does not improve conspicuously.

Fig. 6 shows the dependence of the near ultraviolet light output of the electrodeless lamp 7 upon the mercury content of the fill material thereof. The argon gas was sealed at fixed pressure of 13330 pa (100 torr) as the starter gas, and dysprosium in the fixed amount of 0.26 micromoles per cubic centimeter was sealed in the envelope 7a as the light emitting metal, together with mercury iodide in the fixed amount of 0.39 micromoles per cubic centimeter. The amounts of these substances were fixed at these values, while the amount of mercury sealed in the envelope was changed and the dependence of the light output of the lamp 7 on the amount of mercury was measured. Thus, in this experiment of Fig. 6, the fill material comprised the elements dysprosium and iodine in the fixed amounts of 0.26 and 0.78 micromoles per cubic centimeter, respectively, and also a fixed amount of argon at a pressure of 13330 pa (100 torr) in the envelope 7a.

As shown in Fig. 6, the light output of the lamp 7 increases rapidly at first with an increase in the amount of mercury sealed in the envelope 7a, and saturated when the amount of mercury is at about 50 micromoles per cubic centimeter. The light output is substantially constant when the amount of mercury is increased beyond about this value. The amount of mercury in the range of from 5 to 55 micromoles is practically feasible. The reason is that when the amount of mercury is less than 5 micromoles per cubic centimeter, the light output is not improved sufficiently, and, on the other hand, when it exceeds 55 micromoles per cubic centimeter, the light emission in the envelope 7a presents a striped pattern and becomes unstable with fluctuation.

With regard to the iodine content in the fill material, an amount thereof necessary to form sufficient amount of dysprosium iodide  $DyI_3$  should be sealed in the envelope 7a. When the iodine is sealed in the envelope 7a in the form of mercury iodide, the maximum amount of iodine which can be sealed in is 1.25 mg, or 6.2 micromoles per cubic centimeter. The reason of this is that when the amount of iodine in the fill material exceeds this maximum of 6.2 micromoles per cubic centimeter, the light emission in the envelope 7a becomes uneven and the discharge within the envelope 7a becomes unstable with fluctuations. Thus, the amount of iodine in the fill material should not be less than 0.15 micromoles per cubic centimeter, which is necessary to form the minimum permissible amount of dysprosium iodide of 0.05 micromoles per cubic centimeter, and not more than 6.2 micromoles per cubic centimeter. Further, it is preferred that the amount of iodine measured in terms of moles per cubic centimeter exceeds 3 times the amount of dysprosium measured in the same terms. Namely, it is preferable that the amount of iodine exceeds the amount thereof

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which is necessary to combine with all the dysprosium present in the fill material.

Thus, in view of the experiments described above and also in view of further experiments, we conclude as follows with regard to the fill materials of an electrodeless discharge lamp which comprise a rare gas, mercury, a halogen, and a metal selected from the group consisting of dysprosium, holmium, thulium, scandium, and the mixtures thereof.

The fill material should comprise for each one cubic centimeter of the content of the envelope, mercury in an amount ranging from 5 to 55 preferably exceeding 17.5, micromoles, a rare earth metal in an overall amount ranging from 0.05 to 0.6 preferably from 0.13 to 0.39 and more preferably around 0.25, micromoles, and halogen in an overall amount ranging from 0.15 to 0.62 micromoles. It is preferred that the amount of halogen measured in terms of micromoles per one cubic centimeter of the volumetric content of the envelope exceed three times the amount of the rare earth metal measured in the same terms. That is, it is preferred that there be enough halogen to combine with all the rare earth metal present in the envelope to form the halide thereof.

Referring to Fig. 7 of the drawings, a third series of experiments is now described.

In the envelope 7a of the electrodeless discharge lamp 7, a fill material was sealed which comprises mercury in the amount of 100 mg, iron in the amount of 0.3 mg, and argon as the rare gas at the pressure of 60 torr. The fill material further comprised 3 mg of mercury iodide in the first experimental example. In the second experimental example, the fill material comprised 2 mg of mercury iodide and 1 mg of mercury bromide. In the third experimental example, the fill material comprised 1 mg of mercury iodide and 2 mg of mercury bromide. In the fourth experimental example, the fill material comprised 3 mg of mercury bromide. Thus, in addition to the fixed amounts of mercury, iron, and argon, all four examples comprised, mercury iodide and/or mercury bromide in the fixed total amount of 3 mg, but in variable mole fractions thereof. The lamp 7 was placed in the microwave generating device of Fig. 1, and the light output thereof in the near ultraviolet wave length range of 350 to 450 nm and the starting time, i.e., the time required by the lamp after it is turned on to attain 80 per cent of the light output of stable light emission state thereof were measured.

The abscissa in Fig. 7 represents the mole fraction of bromine with respect to the total molar content of iodine and bromine in percent, i.e.,

$$\frac{M_1}{M_1 + M_2} \times 100,$$

wherein  $M_1$  and  $M_2$  are the amounts of bromine

and iodine respectively, in terms of moles. The ordinate of Fig. 7 represents the light output of the lamp in an arbitrary scale and the starting time in seconds. The solid line T represents the starting time and the dotted line P represents the light output.

As shown in Fig. 7, the starting times of the lamp 7 in the cases where the fill material comprises solely iodine or bromine, respectively, are 13.5 and 16.2 seconds. The starting time is reduced when both bromine and iodine are included in the fill material, and when the mole fraction of bromine is chosen between 10 and 77.5 per cent, the starting time is reduced under 10 seconds. The reason why the starting time can be reduced by utilising two halogen elements instead of only one is that the vapour pressure of the halides of the light emitting metal comes to be the sum of the vapour pressures of two kinds of halides of the metal, and thus the appropriate vapour pressure of the halides of the metal is reached at a time when the temperature of the surface of the envelope 7a of the lamp 7 is lower than that at the stable state thereof.

As shown further in Fig. 7, the light output in the wave length range of 350 to 450 nm is increased when both iodine and bromine are included in the fill material, as compared to the case in which only iodine or bromine is included. The light output of the lamp the fill material of which includes only mercury as the light emitting metal was 31.0 in this arbitrary scale, and thus the maximum light output of the lamp used in this experiment scored 3.2 times as much as that conventional lamp.

In the experiments described above, the light emitting metal was iron, and the halogen iodine and bromine. By further experiments, however, it was confirmed that the starting time is reduced when combination of halogens other than bromine and iodine are used, i.e., when, for example, the combination of iodine and chlorine, of bromine and chlorine, or of iodine, bromine, and chlorine is used. Further, the starting time of the lamp 7 is expected to be reduced when light emitting metal other than iron is used.

#### Example I

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprises iron in the amount of 0.5 mg or 0.63 micromoles per cubic centimeter, mercury iodide ( $\text{HgI}_2$ ) in the amount of 4 mg, or 0.62 micromoles per cubic centimeter, mercury in the amount of 118 mg, and argon at the pressure of 13330 pa (100 torr). Thus, the fill material comprised mercury in the total amount of 120 mg, or 42.4 micromoles per cubic centimeter. The amount of iodine in terms of atoms was 1.24 micromoles per cubic centimeter which was less than two times the amount of iron measured in the same terms, by an amount

of 0.02 micromoles per cubic centimeter. Namely, there was a shortage of 0.02 micromoles per cubic centimeter of iodine to combine with all the iron present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 206 in an arbitrary scale, which is 4.12 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 17.0 seconds.

#### Example II

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised palladium in the amount of 1.0 mg, iodine in the amount of 4 mg, mercury in the amount of 118 mg, and argon at the pressure of 13330 pa (100 torr).

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 103 in an arbitrary scale, which is 2.1 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 19.0 seconds.

#### Example III

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised iron in the amount of 0.3 mg or 0.38 micromoles per cubic centimeter, mercury iodide in the amount of 2.5 mg, of 0.39 micromoles per cubic centimeter, mercury in the amount of 99 mg, and argon at the pressure of 13330 pa (100 torr). Thus, the fill material comprised mercury in the total amount of 100 mg, or 35.3 micromoles per cubic centimeter. The amount of iodine atoms was 0.78 micromoles per cubic centimeter which exceeded two times the amount of iron measured in the same terms, by an amount of 0.01 micromoles per cubic centimeter. Namely, there was an excess of 0.01 micromoles per cubic centimeter of iodine to combine with all the iron present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the

lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 196 in an arbitrary scale, which is 3.92 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 16.5 seconds.

#### Example IV

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised iron in the amount of 0.65 mg or 0.83 micromoles per cubic centimeter, mercury iodide in the amount of 5.5 mg, or 0.86 micromoles per cubic centimeter, mercury in the amount of 98 mg, and argon at the pressure of 13330 pa (100 torr), or 35.3 micromoles per cubic centimeter. The amount of iodine atoms was 1.72 micromoles per cubic centimeter which exceeded two times the amount of iron measured in the same terms, by an amount of 0.06 micromoles per cubic centimeter. Namely, there was an excess of 0.06 micromoles per cubic centimeter of iodine to combine with all the iron present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 216 in an arbitrary scale, which is 4.32 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 17.5 seconds.

#### Example V

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised iron in the amount of 1.0 mg or 1.29 micromoles per cubic centimeter, mercury iodide in the amount of 8.0 mg, or 1.24 micromoles per cubic centimeter, mercury in the amount of 97 mg, and argon at the pressure of 13330 pa (100 torr). Thus, the fill material comprised mercury in the total amount of 100 mg, or 35.3 micromoles per cubic centimeter. The amount of iodine atoms was 2.48 micromoles per cubic centimeter which was less than two times the amount of iron measured in the same terms, by an amount of 0.08 micromoles per cubic centimeter. Namely, there was a shortage of 0.08 micromoles per cubic centimeter of iodine to combine with all the iron present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and

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the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 210 in an arbitrary scale, which is 4.20 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 18.0 seconds.

#### Example VI

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised iron in the amount of 1.5 mg or 1.91 micromoles per cubic centimeter, mercury iodide in the amount of 12.0 mg, or 1.87 micromoles per cubic centimeter, mercury in the amount of 95 mg, and argon at the pressure of 13330 pa (100 torr). Thus, the fill material comprised mercury in the total amount of 100 mg, or 35.3 micromoles per cubic centimeter. The amount of iodine atoms was 3.74 micromoles per cubic centimeter which was less than two times the amount of iron measured in the same terms, by an amount of 0.08 micromoles per cubic centimeter. Namely, there was a shortage of 0.08 micromoles per cubic centimeter of iodine to combine with all the iron present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 196 in an arbitrary scale, which is 3.92 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 18.0 seconds.

#### Example VII

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised iron in the amount of 0.65 mg or 0.83 micromoles per cubic centimeter, mercury iodide in the amount of 4.0 mg, or 0.62 micromoles per cubic centimeter, mercury in the amount of 98 mg, and argon at the pressure of 13330 pa (100 torr). Thus, the fill material comprised mercury in the total amount of 100 mg, or 35.3 micromoles per cubic centimeter. The amount of iodine atoms was 1.24 micromoles per cubic centimeter which was less than two times the amount of iron measured in the same terms, by an amount of 0.42 micromoles per cubic centimeter. Namely, there was a shortage of 0.42 micromoles per cubic centimeter of iodine to combine with all the iron present in the fill material.

The lamp 7 including the fill material as

described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 206 in an arbitrary scale, which is 4.12 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 17.0 seconds.

#### Example VIII

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised iron in the amount of 0.65 mg or 0.83 micromoles per cubic centimeter, mercury iodide in the amount of 7.0 mg, or 1.10 micromoles per cubic centimeter, mercury in the amount of 97 mg, and argon at the pressure of 13330 pa (100 torr). Thus, the fill material comprised mercury in the total amount of 100 mg, 35.3 or micromoles per cubic centimeter. The amount of iodine atoms was 2.20 micromoles per cubic centimeter which exceeded two times the amount of iron measured in the same terms, by an amount of 0.54 micromoles per cubic centimeter. Namely, there was an excess of 0.54 micromoles per cubic centimeter of iodine to combine with all the iron present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 210 in an arbitrary scale, which is 4.2 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 16.5 seconds.

#### Example IX

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised iron in the amount of 0.65 mg or 0.83 micromoles per cubic centimeter, mercury iodide in the amount of 10.0 mg, or 1.56 micromoles per cubic centimeter, mercury in the amount of 96 mg, and argon at the pressure of 13330 pa (100 torr). Thus, the fill material comprised mercury in the total amount of 100 mg, or 35.3 micromoles per cubic centimeter. The amount of iodine atoms was 3.12 micromoles per cubic centimeter which exceeded two times the amount of iron measured in the same terms, by an amount of 0.73 micromoles per cubic centimeter. Namely, there was an excess of 0.73 micromoles per cubic centimeter of

iodine to combiné with all the iron present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 206 in an arbitrary scale, which is 4.12 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 15.0 seconds.

#### Example X

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised iron in the amount of 0.65 mg or 0.83 micromoles per cubic centimeter, mercury iodide in the amount of 15.0 mg, or 2.34 micromoles per cubic centimeter, mercury in the amount of 93 mg, and argon at the pressure of 13330 pa (100 torr). Thus, the fill material comprised mercury in the total amount of 100 mg, or 35.3 micromoles per cubic centimeter. The amount of iodine atoms was 4.68 micromoles per cubic centimeter which exceeded two times the amount of iron measured in the same terms, by an amount of 3.01 micromoles per cubic centimeter. Namely, there was an excess of 3.01 micromoles per cubic centimeter of iodine to combine with all the iron present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 190 in an arbitrary scale, which is 3.80 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 15.0 seconds.

#### Example XI

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised iron in the amount of 0.65 mg or 0.83 micromoles per cubic centimeter, mercury iodide in the amount of 5.5 mg, or 0.86 micromoles per cubic centimeter, mercury in the amount of 48 mg, and argon at the pressure of 13330 pa (100 torr). Thus, the fill material comprised mercury in the total amount of 50 mg, or 17.6 micromoles per cubic centimeter. The amount of iodine atoms was 1.72 micromoles per cubic centimeter which exceeded two times the amount of iron measured in the same

terms, by an amount of 0.06 micromoles per cubic centimeter. Namely, there was an excess 0.06 of micromoles per cubic centimeter of iodine to combine with all the iron present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 203 in an arbitrary scale, which is 4.06 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 13.0 seconds.

#### Example XII

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised iron in the amount of 0.65 mg or 0.83 micromoles per cubic centimeter, mercury iodide in the amount of 5.5 mg, or 0.86 micromoles per cubic centimeter, mercury in the amount of 68 mg, and argon at the pressure of 13330 pa (100 torr). Thus, the fill material comprised mercury in the total amount of 70 mg, or 24.7 micromoles per cubic centimeter. The amount of iodine atoms was 1.72 micromoles per cubic centimeter which exceeded two times the amount of iron measured in the same terms, by an amount of 0.06 micromoles per cubic centimeter. Namely, there was an excess of 0.06 micromoles per cubic centimeter of iodine to combine with all the iron present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 212 in an arbitrary scale, which is 4.24 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 16.0 seconds.

#### Example XIII

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised iron in the amount of 0.65 mg or 0.83 micromoles per cubic centimeter, mercury iodide in the amount of 5.5 mg, or 0.86 micromoles per cubic centimeter, mercury in the amount of 88 mg, and argon at the pressure of 13330 pa (100 torr). Thus, the fill material comprised mercury in the total amount of 90 mg, or 31.8 micromoles per cubic centimeter.

The amount of iodine atoms was 1.72 micromoles per cubic centimeter which exceeded two times the amount of iron measured in the same terms, by an amount of 0.06 micromoles per cubic centimeter. Namely, there was an excess of 0.06 micromoles per cubic centimeter of iodine to combine with all the iron present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 215 in an arbitrary scale, which is 4.30 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 17.5 seconds.

#### Example XIV

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised iron in the amount of 0.65 mg or 0.83 micromoles per cubic centimeter, mercury iodide in the amount of 5.5 mg, or 0.86 micromoles per cubic centimeter, mercury in the amount of 98 mg, and argon at the pressure of 2666 pa (20 torr). Thus, the fill material comprised mercury in the total amount of 100 mg, or 35.3 micromoles per cubic centimeter. The amount of iodine atoms was 1.72 micromoles per cubic centimeter which exceeded two times the amount of iron measured in the same terms, by an amount of 0.06 micromoles per cubic centimeter. Namely, there was an excess of 0.06 micromoles per cubic centimeter of iodine to combine with all the iron present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 220 in an arbitrary scale, which is 4.4 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 22.0 seconds.

#### Example XV

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised iron in the amount of 0.65 mg or 0.83 micromoles per cubic centimeter, mercury iodide in the amount of 5.5 mg, or 0.86 micromoles per cubic centimeter, mercury in the amount of 98 mg, and argon at the pressure of

5332 pa (40 torr). Thus, the fill material comprised mercury in the total amount of 100 mg, or 35.3 micromoles per cubic centimeter. The amount of iodine atoms was 1.72 micromoles per cubic centimeter which exceeded two times the amount of iron measured in the same terms, by an amount of 0.06 micromoles per cubic centimeter. Namely, there was an excess of 0.06 micromoles per cubic centimeter of iodine to combine with all the iron present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 218 in an arbitrary scale, which is 4.36 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 19.5 seconds.

#### Example XVI

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised iron in the amount of 0.65 mg or 0.83 micromoles per cubic centimeter, mercury iodide in the amount of 5.5 mg, or 0.86 micromoles per cubic centimeter, mercury in the amount of 98 mg, and argon at the pressure of 10664 pa (80 torr). Thus, the fill material comprised mercury in the total amount of 100 mg, or 35.3 per cubic centimeter. The amount of iodine atoms was 1.72 micromoles per cubic centimeter which exceeded two times the amount of iron measured in the same terms, by an amount of 0.06 micromoles per cubic centimeter. Namely, there was an excess of 0.06 micromoles per cubic centimeter of iodine to combine with all the iron present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 216 in an arbitrary scale, which is 4.32 as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 18.0 seconds.

#### Example XVII

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised iron in the amount of 0.65 mg or 0.83 micromoles per cubic centimeter, mercury

iodide in the amount of 5.5 mg, or 0.86 micromoles per cubic centimeter, mercury in the amount of 98 mg, and argon at the pressure of 13597 pa (120 torr). Thus, the fill material comprised mercury in the total amount of 100 mg, or 35.3 micromoles per cubic centimeter. The amount of iodine atoms was 1.72 micromoles per cubic centimeter which exceeded two times the amount of iron measured in the same terms, by an amount of 0.06 micromoles per cubic centimeter. Namely, there was an excess of 0.06 micromoles per cubic centimeter of iodine to combine with all the iron present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 214 in an arbitrary scale, which is 4.28 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 16.0 seconds.

#### Example XVIII

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised iron in the amount of 0.65 mg or 0.83 micromoles per cubic centimeter, mercury iodide in the amount of 5.5 mg, or 0.86 micromoles per cubic centimeter, mercury in the amount of 98 mg, and argon at the pressure of 19890 pa (150 torr). Thus, the fill material comprised mercury in the total amount of 100 mg, or 35.3 micromoles per cubic centimeter. The amount of iodine atoms was 1.72 micromoles per cubic centimeter which exceeded two times the amount of iron measured in the same terms, by an amount of 0.06 micromoles per cubic centimeter. Namely, there was an excess of 0.06 micromoles per cubic centimeter of iodine to combine with all the iron present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 213 in an arbitrary scale, which is 4.26 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 16.0 seconds.

#### Example XIX

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7

of Fig. 2, the fill material was sealed which comprised dysprosium in the amount of 0.6 mg or 0.26 micromoles per cubic centimeter, mercury iodide in the amount of 4.0 mg, or 0.62 micromoles per cubic centimeter, mercury in the amount of 118 mg, and argon at the pressure of 13330 pa (100 torr). Thus, the fill material comprised mercury in the total amount of 120 mg, or 42.4 micromoles per cubic centimeter. The amount of iodine in terms of atoms was 1.24 micromoles per cubic centimeter which exceeded three times the amount of dysprosium measured in the same terms, by an amount of 0.46 micromoles per cubic centimeter. Namely, there was an excess of 0.46 micromoles per cubic centimeter of iodine to combine with all the dysprosium present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 186 in an arbitrary scale, which is 3.72 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 22.0 seconds.

#### Example XX

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised scandium in the amount of 0.3 mg, mercury iodide in the amount of 4 mg, mercury in the amount of 118 mg, and argon at the pressure of 13330 pa (100 torr).

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 152 in an arbitrary scale, which is 3.04 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 20.0 seconds.

#### Example XXI

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised dysprosium in the amount of 0.3 mg or 0.13 micromoles per cubic centimeter, mercury iodide in the amount of 2.0 mg, or 0.31 micromoles per cubic centimeter, mercury in the amount of 119 mg, and argon at the pressure of 13330 pa (100 torr). Thus, the fill material comprised mercury in the total amount of 120

mg, or 42.4 micromoles per cubic centimeter. The amount of iodine atoms was 0.62 micromoles per cubic centimeter which exceeded three times the amount of dysprosium measured in the same terms, by an amount of 0.23 micromoles per cubic centimeter. Namely, there was an excess of 0.23 micromoles per cubic centimeter of iodine to combine with all the dysprosium present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 162 in an arbitrary scale, which is 3.24 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 22.0 seconds.

#### Example XXII

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised dysprosium in the amount of 0.9 mg or 0.39 micromoles per cubic centimeter, mercury iodide in the amount of 4.0 mg, or 0.62 micromoles per cubic centimeter, mercury in the amount of 118 mg, and argon at the pressure of 13330 pa (100 torr). Thus, the fill material comprised mercury in the total amount of 120 mg, or 42.4 micromoles per cubic centimeter. The amount of iodine atoms was 1.24 micromoles per cubic centimeter which exceeded three times the amount of dysprosium measured in the same terms, by an amount of 0.07 micromoles per cubic centimeter. Namely, there was an excess of 0.07 micromoles per cubic centimeter of iodine to combine with all the dysprosium present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 144 in an arbitrary scale, which is 2.88 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 17.0 seconds.

#### Example XXIII

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised dysprosium in the amount of 1.2 mg or 0.52 micromoles per cubic centimeter, mercury iodide in the amount of 6.5 mg, or 1.015 micromoles per cubic centimeter,

mercury in the amount of 117 mg, and argon at the pressure of 13330 pa (100 torr). Thus, the fill material comprised mercury in the total amount of 120 mg, or 42.4 micromoles per cubic centimeter. The amount of iodine atoms was 2.03 micromoles per cubic centimeter which exceeded three times the amount of dysprosium measured in the same terms, by an amount of 0.47 micromoles per cubic centimeter. Namely, there was an excess of 0.47 micromoles per cubic centimeter of iodine to combine with all the dysprosium present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 96 in an arbitrary scale, which is 1.92 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 15.5 seconds.

#### Example XXIV

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised dysprosium in the amount of 0.6 mg or 0.26 micromoles per cubic centimeter, mercury iodide in the amount of 4.0 mg, or 0.62 micromoles per cubic centimeter, mercury in the amount of 48 mg, and argon at the pressure of 13330 pa (100 torr). Thus, the fill material comprised mercury in the total amount of 50 mg, or 17.6 micromoles per cubic centimeter. The amount of iodine atoms was 1.24 micromoles per cubic centimeter which exceeded three times the amount of dysprosium measured in the same terms, by an amount of 0.46 micromoles per cubic centimeter. Namely, there was an excess of 0.46 micromoles per cubic centimeter of iodine to combine with all the dysprosium present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 162 in an arbitrary scale, which is 3.24 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 15.0 seconds.

#### Example XXV

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which

comprised dysprosium in the amount of 0.6 mg or 0.26 micromoles per cubic centimeter, mercury iodide in the amount of 4.0 mg, or 0.62 micromoles per cubic centimeter, mercury in the amount of 73 mg, and argon at the pressure of 13330 pa (100 torr). Thus, the fill material comprised mercury in the total amount of 75 mg, or 26.5 micromoles per cubic centimeter. The amount of iodine atoms was 1.24 micromoles per cubic centimeter which exceeded three times the amount of dysprosium measured in the same terms, by an amount of 0.46 micromoles per cubic centimeter. Namely, there was an excess of 0.46 micromoles per cubic centimeter of iodine to combine with all the dysprosium present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 170 in an arbitrary scale, which is 3.4 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 18.0 seconds.

#### Example XXVI

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised dysprosium in the amount of 0.6 mg or 0.26 micromoles per cubic centimeter, mercury iodide in the amount of 4.0 mg, or 0.62 micromoles per cubic centimeter, mercury in the amount of 98 mg, and argon at the pressure of 13330 pa (100 torr). Thus, the fill material comprised mercury in the total amount of 100 mg, or 35.3 micromoles per cubic centimeter. The amount of iodine atoms was 1.24 micromoles per cubic centimeter which exceeded three times the amount of dysprosium measured in the same terms, by an amount of 0.46 micromoles per cubic centimeter. Namely, there was an excess of 0.46 micromoles per cubic centimeter of iodine to combine with all the dysprosium present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 182 in an arbitrary scale, which is 3.64 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 22.0 seconds.

#### Example XXVII

In the envelope 7a having the volumetric

content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised dysprosium in the amount of 0.6 mg or 0.26 micromoles per cubic centimeter, mercury iodide in the amount of 4.0 mg, or 0.62 micromoles per cubic centimeter, mercury in the amount of 148 mg, and argon at the pressure of 13330 pa (100 torr). Thus, the fill material comprised mercury in the total amount of 150 mg, or 53.0 micromoles per cubic centimeter. The amount of iodine atoms was 1.24 micromoles per cubic centimeter which exceeded three times the amount of dysprosium measured in the same terms, by an amount of 0.46 micromoles per cubic centimeter. Namely, there was an excess of 0.46 micromoles per cubic centimeter of iodine to combine with all the dysprosium present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 194 in an arbitrary scale, which is 3.88 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 23.0 seconds.

#### Example XXVIII

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised dysprosium in the amount of 0.6 mg or 0.26 micromoles per cubic centimeter, mercury iodide in the amount of 2.0 mg, or 0.31 micromoles per cubic centimeter, mercury in the amount of 119 mg, and argon at the pressure of 13330 pa (100 torr). Thus, the fill material comprised mercury in the total amount of 120 mg, or 42.4 micromoles per cubic centimeter. The amount of iodine atoms was 0.62 micromoles per cubic centimeter which was less than three times the amount of dysprosium measured in the same terms, by an amount of 0.16 micromoles per cubic centimeter. Namely, there was a shortage of 0.16 micromoles per cubic centimeter of iodine to combine with all the dysprosium present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 183 in an arbitrary scale, which is 3.66 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 22.0 seconds.

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## Example XXIX

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised dysprosium in the amount of 0.6 mg or 0.26 micromoles per cubic centimeter, mercury iodide in the amount of 6.0 mg, or 0.935 micromoles per cubic centimeter, mercury in the amount of 1.17 mg, and argon at the pressure of 13330 pa (100 torr). Thus, the fill material comprised mercury in the total amount of 120 mg, or 42.4 micromoles per cubic centimeter. The amount of iodine atoms was 1.87 micromoles per cubic centimeter which exceeded three times the amount of dysprosium measured in the same terms, by an amount of 1.35 micromoles per cubic centimeter. Namely, there was an excess of 1.35 micromoles per cubic centimeter of iodine to combine with all the dysprosium present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 186 in an arbitrary scale, which is 3.72 times as much as that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 22.0 seconds.

## Example XXX

In the envelope 7a having the volumetric content of 14.1 cubic centimeters of the lamp 7 of Fig. 2, the fill material was sealed which comprised dysprosium in the amount of 0.6 mg, or 0.26 micromoles per cubic centimeter, mercury iodide in the amount of 12.0 mg, or 1.875 micromoles per cubic centimeter, mercury in the amount of 1.15 mg, and argon at the pressure of 13330 pa (100 torr). Thus, the fill material comprised mercury in the total amount of 120 mg, or 42.4 micromoles per cubic centimeter. The amount of iodine atoms was 3.75 micromoles per cubic centimeter which exceeded three times the amount of dysprosium measured in the same terms, by an amount of 2.97 micromoles per cubic centimeter. Namely, there was an excess of 2.97 micromoles per cubic centimeter of iodine to combine with all the dysprosium present in the fill material.

The lamp 7 including the fill material as described above was placed in the microwave generating device of Fig. 1, and the light output in the wave length range of 350 to 425 nm and the starting time, i.e., the length of time that the lamp 7 required to attain 80 percent light emission of the stable state light emission, were measured. The light output thus measured during the stable state scored 160 in an arbitrary scale, which is 3.2 times as much as

that of the lamp 7 the fill material of which includes only mercury. The starting time on the other hand was 22.0 seconds.

In the examples described above, examples I and III through XVIII relates to the case in which the fill material comprises iron as the light emitting metal, and examples XIX and XXI through XXX to the case in which the fill material comprises dysprosium as the light emitting metal.

In the examples I and III through VI, the iron content of the fill material was changed, and iodine was included in the fill material in the form of mercury iodide ( $\text{HgI}_2$ ), in the amount substantially sufficient to combine with all the iron present in the fill material to form iron iodide ( $\text{FeI}_2$ ). Namely, when the lamp is excited by the microwave and turned on, the iodine contained in the mercury iodide reacts with iron and forms iron iodide. When the iron iodide thus formed ranges from 0.38 to 1.91 micromoles per cubic centimeter, the light output scored not less than 90 percent of the maximum light output attainable (example XIV) in the case in which the fill material contains iron as the light emitting metal.

In the examples I and VII through X, the content of iron was fixed, while that of mercury iodide was varied so that the amount of iodine varied from the cases in which there was a shortage of iodine to combine with all the iron present, to the cases in which there was an excess of iodine to combine with all the iron present. When the excess amount of iodine in terms of atoms is not more than 2.0 micromoles per cubic centimeter, the light outputs not less than 90 percent of the maximum light output were scored.

When the amount of iodine is less than the amount thereof sufficient to combine with all the iron present in the fill material, there remains the metallic iron, as the amount of iron iodide formed is limited by the amount of iodine present in the fill material. In this case, the light output is proportional to the amount of iron iodide formed in the envelope 7a, and the inner surface of the envelope 7a formed of quartz of the lamp 7 tends to lose transparency in less operation time thereof than in the case in which an excess iodine is present. Thus, the preferred amount of iodine in excess of the amount necessary to combine with all the iron present in the fill material is from 0.02 to 0.2 micromoles per cubic centimeter of the volumetric content of the envelope 7a.

In the examples XI through XIII, the contents of iron and mercury iodide in the fill material were fixed, while that of mercury was changed. When the amount of mercury in the fill material was from 17.6 to 41.3 micromoles per cubic centimeter, the light output of the lamp 7 scored not less than 90 percent of the maximum light output attainable in the case in which the fill material includes iron as the light emitting metal.

In the examples I and XIV through XVIII, the contents of iron, mercury iodide, and mercury in the fill material were fixed, while the pressure of argon was changed. When the pressure of argon was from 267 to 19890 pa (20 to 150 torr), the light output of the lamp 7 was not less than 95 percent of the maximum light output attainable in the case in which the light emitting metal is iron, which maximum is attained in example XIV. In example XIV, however, the discharge in the envelope 7a tended to be extinguished before it reaches the stable state of light emission. It was found that the preferred pressure of argon in the envelope 7a was from 30 to 130 torr.

In the examples XIX and XXI to XXIII, dysprosium content was varied, while iodine in the form of mercury iodide was sealed in the envelope 7a in an amount sufficient to combine with all the dysprosium present in the fill material. When the amount of dysprosium was not less than 0.13 micromoles per cubic centimeter and not more than 0.39 micromoles per cubic centimeter, the lamp 7 scored not less than about 70 percent of the maximum light output attainable in the case in which the fill material included dysprosium as the light emitting metal.

In the examples XIX, and XXIV through XXVII, the dysprosium and the mercury iodide contents were fixed, while the mercury content was varied. When the amount of mercury in the fill material is from 17.6 to 53.0 micromoles per cubic centimeter, then the lamp 7 scored not less than about 80 percent of the maximum light output attainable in the case in which the fill material comprised dysprosium as the light emitting metal.

In the examples XIX and XXVIII through XXX, the amount of dysprosium and the total amount of mercury were fixed, while the excess amount of iodine was varied. These examples also scored not less than 80 percent of the maximum light output attainable in these cases. When the mercury iodide content was less than the amount which contains sufficient amount of iodide to combine with all the dysprosium present in the fill material, i.e., when an excess amount of dysprosium is present with respect to the amount of iodine, the envelope 7a formed of quartz lost transparency thereof in a shorter operational time than in the case in which iodine is sealed in excess with respect to the amount of dysprosium. Thus, it is preferred that iodine is sealed in excess of the amount necessary to combine with all the dysprosium present in the fill material.

#### Claims

1. An electrodeless discharge lamp (7) for use in a high frequency electromagnetic field for emitting light rich in the near-ultraviolet range, comprising an envelope (7a) formed of a light-transmitting material, and a fill material sealed

in said envelope including a rare gas, mercury, halogen, and a metal, characterised in that the metal is selected from the group consisting of iron, nickel, cobalt, palladium, and mixtures thereof, the amount of mercury per cubic centimeter of the space enclosed by the envelope is not less than 7 micromoles and not more than 55 micromoles, the amount of halogen in terms of atoms per cubic centimeter of said space enclosed by said envelope is not less than 0.2 micromoles and not more than 6.2 micromoles, and the total amount of said metal per cubic centimeter of said space enclosed by said envelope is not less than 0.1 micromoles and not more than 2.3 micromoles.

2. An electrodeless discharge lamp as claimed in claim 1, characterised in that the amount of mercury per cubic centimeter of said space enclosed by the envelope is not less than 17.6 micromoles and not more than 41.3 micromoles, and the total amount of said metal per cubic centimeter of said space enclosed by said envelope is not less than 0.38 micromoles and not more than 1.91 micromoles.

3. An electrodeless discharge lamp as claimed in claim 1, characterised in that the amount of mercury per cubic centimeter of said space enclosed by the envelope is substantially 25 micromoles, the amount of halogen in terms of atoms per cubic centimeter of said space enclosed by said envelope is not less than 0.2 micromoles and not more than 6.2 micromoles, and the total amount of said metal per cubic centimeter of said space enclosed by said envelope is not less than 0.5 micromoles and not more than 1 micromole.

4. An electrodeless discharge lamp as claimed in claim 1, 2, or 3, wherein said rare gas is present in said space enclosed by said envelope at a pressure not less than 1333 pa (10 torr) and not more than 26660 pa (200 torr).

5. An electrodeless discharge lamp as claimed in claim 1, 2, or 3, wherein the rare gas is present in said space enclosed by said envelope at a pressure not less than 2666 pa (20 torr) and not more than 19890 pa (150 torr).

6. An electrodeless discharge lamp as claimed in claim 1, 2, or 3, wherein said rare gas is present in said space enclosed by said envelope at a pressure not less than 400 pa (30 torr) and not more than 17330 pa (130 torr).

7. An electrodeless discharge lamp as claimed in claim 1, wherein the amount of halogen atoms measured in terms of micromoles per cubic centimeter is not less than two times the amount of said metal measured in terms of micromoles per cubic centimeter.

8. An electrodeless discharge lamp as claimed in claim 7, wherein the amount of halogen atoms measured in terms of micromoles per cubic centimeter exceeds two times of said metal measured in terms of micromoles per cubic centimeter, by an amount not less

In the examples I and XIV through XVIII, the contents of iron, mercury iodide, and mercury in the fill material were fixed, while the pressure of argon was changed. When the pressure of argon was from 267 to 19890 pa (20 to 150 torr), the light output of the lamp 7 was not less than 95 percent of the maximum light output attainable in the case in which the light emitting metal is iron, which maximum is attained in example XIV. In example XIV, however, the discharge in the envelope 7a tended to be extinguished before it reaches the stable state of light emission. It was found that the preferred pressure of argon in the envelope 7a was from 30 to 130 torr.

In the examples XIX and XXI to XXIII, dysprosium content was varied, while iodine in the form of mercury iodide was sealed in the envelope 7a in an amount sufficient to combine with all the dysprosium present in the fill material. When the amount of dysprosium was not less than 0.13 micromoles per cubic centimeter and not more than 0.39 micromoles per cubic centimeter, the lamp 7 scored not less than about 70 percent of the maximum light output attainable in the case in which the fill material included dysprosium as the light emitting metal.

In the examples XIX, and XXIV through XXVII, the dysprosium and the mercury iodide contents were fixed, while the mercury content was varied. When the amount of mercury in the fill material is from 17.6 to 53.0 micromoles per cubic centimeter, then the lamp 7 scored not less than about 80 percent of the maximum light output attainable in the case in which the fill material comprised dysprosium as the light emitting metal.

In the examples XIX and XXVIII through XXX, the amount of dysprosium and the total amount of mercury were fixed, while the excess amount of iodine was varied. These examples also scored not less than 80 percent of the maximum light output attainable in these cases. When the mercury iodide content was less than the amount which contains sufficient amount of iodide to combine with all the dysprosium present in the fill material, i.e., when an excess amount of dysprosium is present with respect to the amount of iodine, the envelope 7a formed of quartz lost transparency thereof in a shorter operational time than in the case in which iodine is sealed in excess with respect to the amount of dysprosium. Thus, it is preferred that iodine is sealed in excess of the amount necessary to combine with all the dysprosium present in the fill material.

#### Claims

1. An electrodeless discharge lamp (7) for use in a high frequency electromagnetic field for emitting light rich in the near-ultraviolet range, comprising an envelope (7a) formed of a light-transmitting material, and a fill material sealed

in said envelope including a rare gas, mercury, halogen, and a metal, characterised in that the metal is selected from the group consisting of iron, nickel, cobalt, palladium, and mixtures thereof, the amount of mercury per cubic centimeter of the space enclosed by the envelope is not less than 7 micromoles and not more than 55 micromoles, the amount of halogen in terms of atoms per cubic centimeter of said space enclosed by said envelope is not less than 0.2 micromoles and not more than 6.2 micromoles, and the total amount of said metal per cubic centimeter of said space enclosed by said envelope is not less than 0.1 micromoles and not more than 2.3 micromoles.

2. An electrodeless discharge lamp as claimed in claim 1, characterised in that the amount of mercury per cubic centimeter of said space enclosed by the envelope is not less than 17.6 micromoles and not more than 41.3 micromoles, and the total amount of said metal per cubic centimeter of said space enclosed by said envelope is not less than 0.38 micromoles and not more than 1.91 micromoles.

3. An electrodeless discharge lamp as claimed in claim 1, characterised in that the amount of mercury per cubic centimeter of said space enclosed by the envelope is substantially 25 micromoles, the amount of halogen in terms of atoms per cubic centimeter of said space enclosed by said envelope is not less than 0.2 micromoles and not more than 6.2 micromoles, and the total amount of said metal per cubic centimeter of said space enclosed by said envelope is not less than 0.5 micromoles and not more than 1 micromole.

4. An electrodeless discharge lamp as claimed in claim 1, 2, or 3, wherein said rare gas is present in said space enclosed by said envelope at a pressure not less than 1333 pa (10 torr) and not more than 26660 pa (200 torr).

5. An electrodeless discharge lamp as claimed in claim 1, 2, or 3, wherein the rare gas is present in said space enclosed by said envelope at a pressure not less than 2666 pa (20 torr) and not more than 19890 pa (150 torr).

6. An electrodeless discharge lamp as claimed in claim 1, 2, or 3, wherein said rare gas is present in said space enclosed by said envelope at a pressure not less than 400 pa (30 torr) and not more than 17330 pa (130 torr).

7. An electrodeless discharge lamp as claimed in claim 1, wherein the amount of halogen atoms measured in terms of micromoles per cubic centimeter is not less than two times the amount of said metal measured in terms of micromoles per cubic centimeter.

8. An electrodeless discharge lamp as claimed in claim 7, wherein the amount of halogen atoms measured in terms of micromoles per cubic centimeter exceeds two times of said metal measured in terms of micromoles per cubic centimeter, by an amount not less



than 0.02 micromoles per cubic centimeter and not more than 2.0 micromoles per cubic centimeter.

9. An electrodeless discharge lamp for use in a high frequency electromagnetic field for emitting light rich in near-ultraviolet range, comprising an envelope formed of a light-transmitting material, and a fill material sealed in said envelope including a rare gas, mercury, a halogen, and a metal, characterised in that the metal is selected from the group consisting of dysprosium, holmium, thulium, scandium, and mixtures thereof, the amount of mercury per cubic centimeter of the space enclosed by the envelope is not less than 5 micromoles and not more than 55 micromoles, the amount of halogen in terms of atoms per cubic centimeter of said space enclosed by said envelope is not less than 0.15 micromoles and not more than 6.2 micromoles, and the total amount of said metal per cubic centimeter of said space enclosed by said envelope is not less than 0.05 micromoles and not more than 0.6 micromoles.

10. An electrodeless discharge lamp as claimed in claim 9, wherein the amount of mercury per cubic centimeter of said space enclosed by the envelope is not less than 17.6 micromoles and not more than 53 micromoles, and the total amount of said metal per cubic centimeter of said space enclosed by said envelope is not less than 0.13 micromoles and not more than 0.39 micromoles.

11. An electrodeless discharge lamp as claimed in claim 9, wherein the amount of mercury per cubic centimeter of said space enclosed by the envelope is not less than 17.6 micromoles and not more than 53 micromoles, and the total amount of said metal per cubic centimeter of said space enclosed by said envelope is substantially 0.25 micromoles.

12. An electrodeless discharge lamp as claimed in claim 11, wherein the amount of halogen atoms measured in terms of micromoles per cubic centimeter is not less than three times the amount of said metal measured in terms of micromoles per cubic centimeter.

13. An electrodeless discharge lamp as claimed in claim 11, wherein the amount of halogen atoms measured in terms of micromoles per cubic centimeter exceeds the amount of said metal measured in terms of micromoles per cubic centimeter.

14. An electrodeless discharge lamp as claimed in any preceding claim, wherein halogen is iodine.

15. An electrodeless discharge lamp as claimed in any preceding claim, wherein said rare gas is argon.

16. An electrodeless discharge lamp as claimed in any preceding claim, wherein said envelope is formed of light-transmitting quartz.

#### Patentansprüche

1. Elektrodenlose Entladungslampe (7) zur

Verwendung in einem elektromagnetischen Hochfrequenzfeld zur Emission von Licht mit hohem Anteil nahe im Ultraviolettbereich, mit einer Hülle oder einem Mantel (7a) aus einem lichtdurchlässigen Material, und einem Füllmaterial, das in der Hülle oder dem Mantel eingesiegelt ist und ein Edelgas, Quecksilber, Halogen und ein Metall aufweist, dadurch gekennzeichnet, daß das Metall aus der Gruppe ausgewählt ist, die aus Eisen, Nickel, Kobalt, Palladium und deren Mischungen besteht, daß die Quecksilbermenge pro  $\text{cm}^3$  des Raumes, der von der Hülle oder dem Mantel eingeschlossen ist, nicht weniger als 7 Mikromol und nicht mehr als 55 Mikromol beträgt, daß die Menge des Halogens in Atomen pro  $\text{cm}^3$  des von der Hülle oder dem Mantel eingeschlossenen Raumes nicht weniger als 0,2 Mikromol und nicht mehr als 6,2 Mikromol beträgt, und daß die Gesamtsumme des Metalls pro  $\text{cm}^3$  des von der Hülle oder dem Mantel eingeschlossenen Raumes nicht weniger als 0,1 Mikromol und nicht mehr als 2,3 Mikromol beträgt.

2. Elektrodenlose Entladungslampe nach Anspruch 1, dadurch gekennzeichnet, daß die Menge des Quecksilbers pro  $\text{cm}^3$  des von der Hülle oder dem Mantel eingeschlossenen Raumes nicht weniger als 17,6 Mikromol und nicht mehr als 41,3 Mikromol und die Gesamtmenge des Metalls pro  $\text{cm}^3$  des von der Hülle oder dem Mantel eingeschlossenen Raumes nicht weniger als 0,38 Mikromol und nicht mehr als 1,91 Mikromol beträgt.

3. Elektrodenlose Entladungslampe nach Anspruch 1, dadurch gekennzeichnet, daß die Menge des Quecksilbers pro  $\text{cm}^3$  des von der Hülle oder dem Mantel eingeschlossenen Raumes im wesentlichen 25 Mikromol beträgt, daß die Menge des Halogens in Form von Atomen pro  $\text{cm}^3$  des von der Hülle oder dem Mantel eingeschlossenen Raumes nicht weniger als 0,2 Mikromol und nicht mehr als 6,2 Mikromol beträgt, und daß die Gesamtmenge des Metalls pro  $\text{cm}^3$  des von der Hülle oder dem Mantel eingeschlossenen Raumes nicht weniger als 0,5 Mikromol und nicht mehr als 1 Mikromol beträgt.

4. Elektrodenlose Entladungslampe nach Anspruch 1, 2 oder 3, dadurch gekennzeichnet, daß das Edelgas in dem von der Hülle oder dem Mantel eingeschlossenen Raum einen Druck von nicht weniger als 1333 Pa (10 Torr) und nicht mehr als 26660 Pa (200 Torr) aufweist.

5. Elektrodenlose Entladungslampe nach Anspruch 1, 2 oder 3, dadurch gekennzeichnet, daß das Edelgas in dem von der Hülle oder dem Mantel eingeschlossenen Raum einen Druck von nicht weniger als 2666 Pa (20 Torr) und nicht mehr als 19890 Pa (150 Torr) aufweist.

6. Elektrodenlose Entladungslampe nach Anspruch 1, 2 oder 3, dadurch gekennzeichnet, daß das Edelgas in dem von der Hülle oder dem Mantel eingeschlossenen Raum einen Druck von nicht weniger als 4000 Pa (30 Torr) und nicht mehr als 17330 Pa (130 Torr) aufweist.



7. Elektrodenlose Entladungslampe nach Anspruch 1, dadurch gekennzeichnet, daß die Menge der Halogenatome gemessen in der Größe von Mikromol pro  $\text{cm}^3$  nicht weniger als zweimal die Menge des Metalls gemessen in der Größe von Mikromol pro  $\text{cm}^3$  beträgt.

8. Elektrodenlose Entladungslampe nach Anspruch 7, dadurch gekennzeichnet, daß die Menge der Halogenatome gemessen in der Größe von Mikromol pro  $\text{cm}^3$  zweimal das Metall gemessen in der Größe von Mikromol pro  $\text{cm}^3$  übersteigt in einer Menge von nicht weniger als 0,02 Mikromol pro  $\text{cm}^3$  und nicht mehr als 2,0 Mikromol pro  $\text{cm}^3$ .

9. Elektrodenlose Entladungslampe zur Verwendung in einem elektromagnetischen Hochfrequenzfeld zur Emission von Licht mit einem hohen Anteil nahe des Ultraviolettbereiches, mit einer Hülle oder einem Mantel aus einem lichtdurchlässigen Material und einem Füllmaterial, das in der Hülle oder dem Mantel eingesiegelt ist und ein Edelgas, Quecksilber, ein Halogen und ein Metall aufweist, dadurch gekennzeichnet, daß das Metall ausgewählt ist aus der Gruppe, die Dysprosium, Holmium, Thulium, Scandium und deren Mischungen aufweist, daß die Menge des Quecksilbers pro  $\text{cm}^3$  des von der Hülle oder dem Mantel eingeschlossenen Raumes nicht weniger als 5 Mikromol und nicht mehr als 55 Mikromol beträgt, daß die Menge des Halogens in Form von Atomen pro  $\text{cm}^3$  des von der Hülle oder dem Mantel eingeschlossenen Raumes nicht weniger als 0,15 Mikromol und nicht mehr als 6,2 Mikromol beträgt, und daß die Gesamtmenge des Metalls pro  $\text{cm}^3$  des von der Hülle oder dem Mantel eingeschlossenen Raumes nicht weniger als 0,05 Mikromol und nicht mehr als 0,6 Mikromol beträgt.

10. Elektrodenlose Entladungslampe nach Anspruch 9, dadurch gekennzeichnet, daß die Menge des Quecksilbers pro  $\text{cm}^3$  des von der Hülle oder dem Mantel eingeschlossenen Raumes nicht weniger als 17,6 Mikromol und nicht mehr als 53 Mikromol und die Gesamtmenge des Metalls pro  $\text{cm}^3$  des von der Hülle oder dem Mantel eingeschlossenen Raumes nicht weniger als 0,13 Mikromol und nicht mehr als 0,39 Mikromol beträgt.

11. Elektrodenlose Entladungslampe nach Anspruch 9, dadurch gekennzeichnet, daß die Menge des Quecksilbers pro  $\text{cm}^3$  des von der Hülle oder dem Mantel eingeschlossenen Raumes nicht weniger als 17,6 Mikromol und nicht mehr als 53 Mikromol und die Gesamtmenge des Metalls pro  $\text{cm}^3$  des von der Hülle oder dem Mantel eingeschlossenen Raumes im wesentlichen 0,25 Mikromol beträgt.

12. Elektrodenlose Entladungslampe nach Anspruch 11, dadurch gekennzeichnet, daß die Menge der Halogenatome gemessen in Form von Mikromol pro  $\text{cm}^3$  nicht weniger als dreimal der Menge des Metalls gemessen in Form von Mikromol pro  $\text{cm}^3$  beträgt.

13. Elektrodenlose Entladungslampe nach

Anspruch 11, dadurch gekennzeichnet, daß die Menge der Halogenatome gemessen in Form von Mikromol pro  $\text{cm}^3$  die Menge des Metalls gemessen in Form von Mikromol pro  $\text{cm}^3$  übersteigt.

14. Elektrodenlose Entladungslampe nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß das Halogen Jod ist.

15. Elektrodenlose Entladungslampe nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß das Edelgas Argon ist.

16. Elektrodenlose Entladungslampe nach einem der vorhergehenden Ansprüche, dadurch gekennzeichnet, daß die Hülle oder der Mantel aus lichtdurchlässigem Quarz besteht.

## Revendications

1. Lampe (7) à décharge sans électrode destinée à être utilisée dans un champ électromagnétique à haute fréquence en vue d'émettre de la lumière riche dans l'ultraviolet proche, ladite lampe comprenant une enveloppe (7a) formée dans un matériau transmettant cette lumière et un matériau de remplissage scellé dans ladite enveloppe comprenant un gaz rare, du mercure, un halogène et un métal, caractérisée en ce que le métal est choisi dans le groupe constitué du fer, du nickel, du cobalt, du palladium ou d'un mélange de ces métaux, la quantité de mercure par centimètre cube de l'espace contenu dans l'enveloppe n'est pas moindre que 7 micromoles et pas plus grande que 55 micromoles, la quantité d'halogène donnée en terme d'atomes par centimètre cube dudit espace contenu dans l'enveloppe n'est pas moindre que 0,2 micromole et pas plus grande que 6,2 micromoles et que la quantité totale du métal par centimètre cube dudit espace contenu dans l'enveloppe n'est pas moindre que 0,1 micromole et pas plus grande que 2,3 micromoles.

2. Lampe à décharge sans électrode conforme à la revendication 1, caractérisée en ce que la quantité de mercure par centimètre cube de l'espace contenu dans l'enveloppe n'est pas moindre que 17,6 micromoles et pas plus grande que 41,3 micromoles et que la quantité totale du métal par centimètre cube de l'espace contenu dans l'enveloppe n'est pas moindre que 0,38 micromole et pas plus grande que 1,91 micromole.

3. Lampe à décharge sans électrode conforme à la revendication 1, caractérisée en ce que la quantité de mercure par centimètre cube de l'espace contenu dans l'enveloppe est de substantiellement 25 micromoles, la quantité d'halogène en termes d'atomes par centimètre cube dudit espace contenu dans l'enveloppe n'est pas moindre que 0,2 micromole et pas plus grande que 6,2 micromoles et que la quantité totale du métal par centimètre cube dudit espace contenu dans l'enveloppe n'est pas moindre que 0,5 micromole et pas plus grande que 1 micromole.



4. Lampe à décharge sans électrode conforme à l'une des revendications 1, 2 ou 3 dans laquelle ledit gaz rare est présent dans ledit espace contenu dans l'enveloppe à une pression pas moindre que 1333 Pa (10 torr) et pas plus grande que 26660 Pa (200 torr).

5. Lampe à décharge sans électrode conforme à l'une quelconque des revendications 1, 2 ou 3 dans laquelle le gaz rare est présent dans ledit espace contenu dans l'enveloppe à une pression pas moindre que 2666 Pa (20 torr) et pas plus grande que 19890 Pa (150 torr).

6. Lampe à décharge sans électrode conforme à l'une quelconque des revendications 1, 2 ou 3 dans laquelle le gaz rare est présent dans ledit espace contenu dans l'enveloppe à une pression pas moindre que 400 Pa (30 torr) et pas plus grande que 17330 Pa (130 torr).

7. Lampe à décharge sans électrode conforme à la revendication 1 dans laquelle la quantité d'atomes d'halogène mesurée en termes de micromoles par centimètre cube n'est pas moindre que deux fois la quantité du métal mesurée en termes de micromoles par centimètre cube.

8. Lampe à décharge sans électrode conforme à la revendication 7 dans laquelle la quantité d'atomes d'halogène mesurée en termes de micromoles par centimètre cube excède deux fois la quantité du métal mesurée en termes de micromoles par centimètre cube par une quantité pas moindre que 0,02 micromole par centimètre cube et pas plus grande que 2,0 micromoles par centimètre cube.

9. Lampe à décharge sans électrode destinée à être utilisée dans un champ électromagnétique à haute fréquence en vue d'émettre de la lumière riche dans l'ultraviolet proche, ladite lampe comprenant une enveloppe formée dans un matériau transmettant cette lumière et un matériau de remplissage, scellé dans ladite enveloppe comprenant un gaz rare, du mercure, un halogène et un métal, caractérisée en ce que le métal est choisi dans le groupe constitué du dysprosium, du holmium, du thulium, du scandium ou d'un mélange de ces métaux, la quantité de mercure par centimètre cube de l'espace contenu dans l'enveloppe n'est pas moindre que 5 micromoles et pas plus grande que 55 micromoles, la quantité d'halogène donnée en termes d'atomes par centimètre

cube dudit espace contenu dans l'enveloppe n'est pas moindre que 0,15 micromole et pas plus grande que 6,2 micromoles et que la quantité totale du métal par centimètre cube dudit espace contenu dans l'enveloppe n'est pas moindre que 0,05 micromole et pas plus grande que 0,6 micromole.

10. Lampe à décharge sans électrode conforme à la revendication 9, caractérisée en ce que la quantité de mercure par centimètre cube de l'espace contenu dans l'enveloppe n'est pas moindre que 17,6 micromoles et pas plus grande que 53 micromoles et que la quantité totale du métal par centimètre cube de l'espace contenant dans l'enveloppe n'est pas moindre que 0,13 micromole et pas plus grande que 0,39 micromole.

11. Lampe à décharge sans électrode conforme à la revendication 9, caractérisée en ce que la quantité de mercure par centimètre cube de l'espace contenu dans l'enveloppe n'est pas moindre que 17,6 micromoles et pas plus grande que 53 micromoles et que la quantité totale du métal par centimètre cube de l'espace contenu dans l'enveloppe est de substantiellement 0,25 micromole.

12. Lampe à décharge sans électrode conforme à la revendication 11 dans laquelle la quantité d'atomes d'halogène mesurée en termes de micromoles par centimètre cube n'est pas moindre que trois fois la quantité du métal mesurée en termes de micromoles par centimètre cube.

13. Lampe à décharge sans électrode conforme à la revendication 11 dans laquelle la quantité d'atomes d'halogène mesurée en termes de micromoles par centimètre cube excède la quantité du métal mesurée en termes de micromoles par centimètre cube.

14. Lampe à décharge sans électrode conforme à l'une quelconque des revendications précédentes dans laquelle l'halogène est l'iode.

15. Lampe à décharge sans électrode conforme à l'une quelconque des revendications précédentes dans laquelle ledit gaz rare est l'argon.

16. Lampe à décharge sans électrode conforme à l'une quelconque des revendications précédentes dans laquelle l'enveloppe est constituée de quartz transparent à la lumière.



\* C L M S \*