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Z. VAN GELDER
3,546,521
LOW-PRESSURE GAS DISCHARGE LAMP FOR PRODUCING RESONANCE RADIATION
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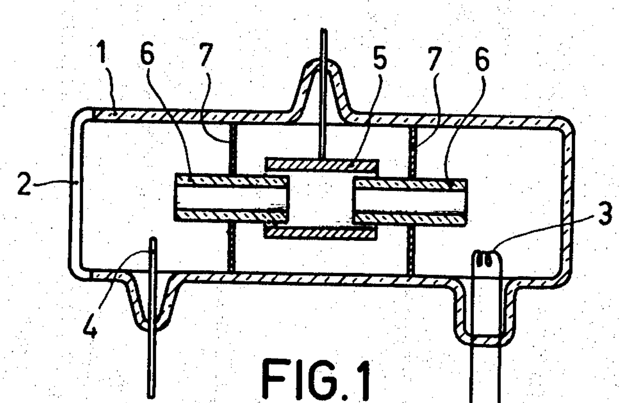

FIG.1

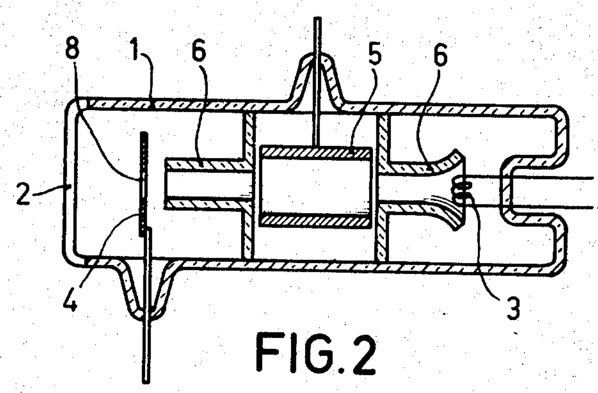

FIG.2

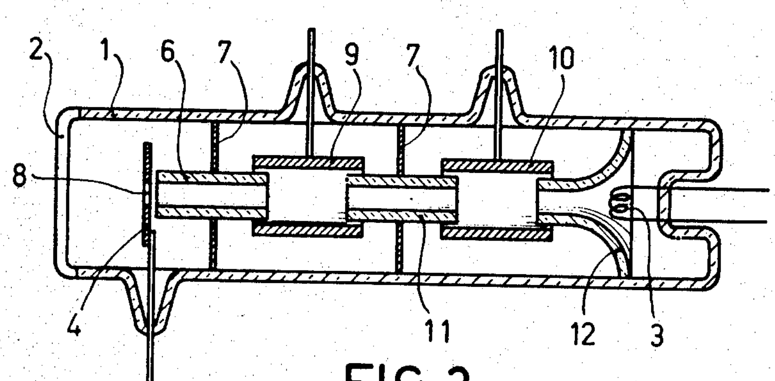

FIG.3

INVENTOR
ZEGER VAN GELDER
BY Frank R. Trifari
AGENT

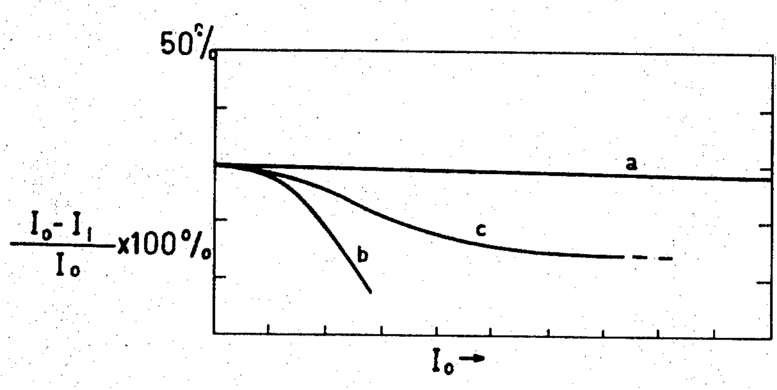

FIG. 4a

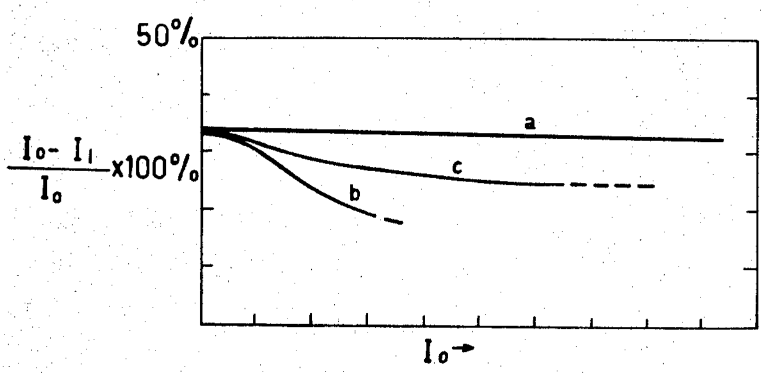

FIG. 4b

INVENTOR

ZEGER VAN GELDER

BY Frank R. Trifari

AGENT

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LOW-PRESSURE GAS DISCHARGE LAMP FOR PRODUCING RESONANCE RADIATION

Zeger van Gelder, Emmasingel, Eindhoven, Netherlands, assignor, by mesne assignments, to U.S. Philips Corporation, New York, N.Y., a corporation of Delaware

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Int. Cl. H01j *61/10*
U.S. Cl. 313—192 6 Claims

ABSTRACT OF THE DISCLOSURE

A low-pressure gas discharge lamp for producing resonance radiation employing a pair of electrodes with an envelope containing a rare gas. A positive column is maintained between the electrodes during operation of the lamp, the column having an axis which intersects a window in the envelope for transmitting the radiation. An atom source containing an element the resonance radiation of which is desired surrounds the positive column while a ring around the discharge path between the atom source and the window is provided which is spaced from the atom source a distance which is smaller than the length of the atom source and the inner surface of which has a perpendicular section which is smaller than that of the inner surface of the atom source. The length of this ring is at least equal to the largest dimension of the perpendicular section of the inner surface.

The invention relates to low-pressure gas discharge lamps for producing resonance radiation. Such lamps are frequently used in spectroscopy and particularly in resonance-absorption spectroscopy.

It is known to use gas discharge lamps for producing resonance radiation which have an anode and a hollow cylindrical cathode which consists wholly or partly of the material the resonance radiation of which is desired. Cathode material is sputtered by bombardment of ions and as a result the concentration of the atoms of the above-mentioned material in the hollow cathode will strongly increase. These atoms may be excited by the electrons from the discharge and subsequently emit, inter alia, their resonance radiation. The radiation is used for absorption spectroscopy, the sample to be examined being arranged in alignment with the axis of the hollow cathode. The line shape of the resonance radiation of these known lamps is determined in the first instance by the so-called Doppler broadening. The Doppler broadening, dependent on the temperature of the atomic vapour, may be slight in these lamps and gives rise to the Doppler profile associated with this temperature.

Due to absorption of resonance radiation by unexcited atoms, the narrow Doppler profile is, however, considerably broadened and truncated. Since this absorption takes place in the lamp itself, the term self-absorption is often used. Two regions in the lamp where the said self-absorption occurs can be distinguished:

(a) The region where the discharge takes place and where consequently also excitation is possible. In the said known lamps this relates principally to the space within the hollow cathode. Since preferably radiation is absorbed having the resonance frequency the profile of the radiation originating from a certain point within the hollow cathode will be more or less truncated upon emerging dependent on the distance to be covered within the hollow cathode. Since the radiation at frequencies beside the central frequency of the Doppler profile is less absorbed, the edges of the profile of the total emerging radiation are relatively strengthened giving rise to a considerable broadening. This phenomenon is called absorption broadening.

(b) The region outside the discharge where only absorption is possible. Here the profile is truncated and possibly even hollowed so that in addition to the absorption broadening a relative minimum of intensity at the resonance frequency is obtained.

The absorption broadening is a function of the product of the length of the hollow cathode and the absorption coefficient which latter is proportional to the atom concentration. The intensity of the radiation is proportional to the product of the electron concentration and the atom concentration. In absorption spectroscopy it is desired to have radiation of high intensity and narrow line profile. To obtain such a radiation it is therefore necessary to achieve a high electron concentration and a low atom concentration. In the case of the hollow cathode these concentrations cannot be controlled independent of each other since both are determined by the discharge between hollow cathode and anode.

To obviate this drawback it is known to effect a positive column discharge perpendicularly to the axis of the hollow cathode between two additional electrodes at an area within the lamp where there are atoms of the material the radiation of which is desired. The electron concentration in the column discharge can be controlled with the aid of the column discharge current and the atom concentration with the aid of the hollow cathode current. The effective radiation emerging from the lamp along the axis of the hollow cathode comprises the sum of the radiation obtained by excitation of atoms in the positive column and the radiation produced in the hollow cathode. The first-mentioned part adds a narrow peak to the profile at the resonance frequency which reduces the dip of the radiation profile originating from the hollow cathode and increases the total intensity. The profile width of the total radiation remains as unfavourable as in the case of the hollow cathode. Also this known lamp has the additional drawback of self-absorption outside the region of discharge, inter alia, between the discharge and the window in the envelope.

It is the object of the invention to provide a low-pressure gas discharge lamp in which the above-mentioned drawbacks occur to a considerably reduced extent and which emits resonance radiation at a high intensity and a very narrow line profile.

A low-pressure gas discharge lamp for producing resonance radiation according to the invention comprises a discharge space filled with a rare gas and having an envelope provided with a window which passes the radiation produced and further comprises two electrodes between which a positive column discharge is maintained during operation of the lamp, and an atom source containing an element the resonance radiation of which is desired, and is characterized in that the axis of the positive column discharge intersects the window, that the atom source surrounds the positive column and that a ring is provided around the discharge path between atom source and window, which ring extends up to the vicinity of the atom source and the inner surface of which has a perpendicular section which is smaller than that of the inner surface of the atom source, the length of said ring being at least equal to the largest dimension of the perpendicular section of its inner surface.

The envelope of the discharge space consists, for example, of glass or quartz glass. The space is filled with a rare gas, for example, argon or neon or a mixture of these gases. The pressure of the rare gas is preferably not higher than 5 mm. Hg, because at higher pressures the spectral profile is broadened unfavourably as a result of Lorentz broadening. The electrodes between which the column discharge takes place are an anode and a cathode, preferably a filament cathode. The atom source comprises at least partially the element or elements the resonance radiation of which is desired and is mostly a sputtering electrode which, during operation of the lamp, is brought to a potential which is negative relative to the plasma potential of the positive column. The sputtering electrode is preferably cylindrically shaped by bending of a plate or a gauze wire, but it is alternatively possible to construct a cylindrical cage having bars of the desired material.

Elements having a high vapour pressure at temperatures lower than the operating temperature of the lamp, or having a softening point in the vicinity of that temperature may be used to manufacture compounds having a much lower vapour pressure and/or a higher softening point than that of the relevant element. The sputtering electrode may then contain these compounds. The sputtering electrode may, for example, comprise a porous, high-melting-point and electrically conducting material such as sintered nickel, tungsten or molybdenum, incorporating the elements having a high vapour pressure or a low melting point, or compounds of these elements. In certain cases it is then desirable to surround the sputtering electrode by a casing which is impermeable to those elements. The sputtering electrode may alternatively be designed in a manner known for storage cathodes. It is alternatively possible for the atom source to supply the desired vapour by heating a carrier containing the relevant material. In that case the atom source may, for example, be constructed as a coil having one or more turns about the discharge path and being heated by an electric current.

The ring is mostly cylindrical, but it may alternatively assume the shape of a composition of diaphragms. In any case the conditions must be fulfilled that the internal diameter of the ring is smaller than that of the atom source, and that the length of the ring is at least equal to the internal diameter. The expression "the ring extends up to the vicinity of the atom source" is understood to mean that the distance between ring and atom source is smaller than the length of the atom source. Part of the ring may, however, be located within the atom source. The ring preferably makes no mechanical contact with the atom source. If the atom source is designed as a sputtering electrode such a contact is undesirable because in that case not only the atoms adsorbed at the ring may contribute, through bombardment of ions, to sputtering but also material of the ring may be brought in the discharge.

An important advantage of a lamp according to the invention is that the radiation emerges along the axis of the positive column discharge. As a result the radiation produced does not pass any region in the lamp where strong absorption may occur without excitation by electrons also taking place, as is indeed the case in the known lamps.

Although an improvement relative to the known lamps is also obtained without a ring, it is mostly advantageous to place a ring on either side of the atom source. In the first instance it is then achieved that the atom concentration outside the atom source and more particularly the atom concentration along the column discharge rapidly decreases. The region where absorption broadening occurs is consequently substantially limited to the space within the atom source and absorption in regions where no excitation by electrons is possible is substantially entirely excluded. The second ring on the cathode side of the column discharge further serves to prevent poisoning of the cathode by the atom vapour.

The rings provide the further advantage that they concentrate the positive column discharge in a narrow beam having a high concentration of electrons. The highest concentration of electrons in the atom source is found along the axis, whereas the concentration of atoms is lowest in that area. The latter fact is the result of the ionization of the vapour atoms which is strongest on the axis due to the high density of electrons in that area. Since the ambipolar diffusion coefficient of the vapour ions travelling towards the wall is much higher than the diffusion coefficient of the neutral vapour atoms moving towards the axis to eliminate the shortage occurring in that area, the decrease in the density of the neutral vapour atoms on the axis will be much greater than the increase in the density of the ions on the axis.

While the whole atom source is filled with radiation the conditions for radiation at a high intensity and a narrow profile are best fulfilled in the vicinity of the axis. The rings have the further advantage that they pass the radiation from the vicinity of the axis and that they do not pass the radiation coming from areas along the wall of the atom source. The spectral distribution of the emerging radiation then hardly deviates from the Doppler profile.

The ring or rings are preferably manufactured of an electrically insulating material, for example, glass or ceramic material. In some embodiments the rings are supported by disc-like plates adjoining the envelope of the discharge space and preferably of an electrically insulating material, for example, glass, ceramic material or mica. A very advantageous embodiment is the one in which a plurality of atom sources is present each of which may form the vapour of a different element and which are separated from one another by rings. Without the necessity of exchanging a lamp the resonance radiation of various elements can be produced separately by activating the relevant atom source either by applying a negative potential or by connecting a heating current. The rings prevent the possibility of deposition of atoms of one atom source into another atom source.

The invention will now be described in detail with reference to the accompanying drawing, in which:

FIG. 1 is a sectional view of an embodiment of a lamp according to the invention,

FIG. 2 shows a further embodiment, while

FIG. 3 shows an embodiment having a plurality of atom sources.

FIG. 4 is a graph showing the absorption sensitivity of a lamp according to the invention and of a few known lamps, plotted as a function of the intensity.

Corresponding components in the figures have the same reference numerals.

The lamp of FIG. 1 includes a glass envelope **1** having a quartz-glass window **2** and is filled with argon up to a pressure of 3 mm. Hg. A cathode **3** is a filament cathode covered with an emitting material; an anode **4** is a rod of tungsten. In this example the atom source **5** is a sputtering electrode in the form of a copper cylinder having an internal diameter of 1 cm. and a length of 2 cm. The argon ions from the positive column discharge between the electrodes **3** and **4** will cause copper atoms to be sputtered from the sputtering electrode **5** if this electrode is supplied with a negative potential. Cylindrical rings **6** of glass are placed on either side of the sputtering electrode **5**. These rings have an internal diameter of 4 mm. and an external diameter of 8 mm. They extend over a distance of approximately 3 mm. within the sputtering electrode, but do not make contact therewith. The length of the rings is 2 cm. The rings **6** are held in place by ceramic plates **7** which extend up to the lamp envelope. The rings **6** limit the copper vapour to within the space of the sputtering electrode **5**.

The embodiment of FIG. 2 deviates from that of FIG. 1 in that the three electrodes **3**, **4** and **5** are placed in one line and that the anode **4** is provided with a hole **8** which passes the radiation. The rings **6** have in this case the shape of a diaphragm provided with a cylindrical portion.

FIG. 3 shows an embodiment in which two sputtering electrodes are used, namely one for calcium **9** and one for magnesium **10**. The two electrodes enclose a glass ring **11** which prevents magnesium vapour from depositing on the inner side of the sputtering electrode containing calcium, and conversely. In the lamp of FIG. 3 the cathode side of the ring **12** has a widening which adjoins the envelope **1** of the lamp so that the column discharge bypassing the atom source is prevented.

Absorption tests have been carried out with a lamp according to the invention and with a few known lamps in which the resonance radiation of the element copper is produced, and the results of the various lamps are compared in the graphs of FIG. 4*a*. The radiation produced by a lamp was directed through a small furnace containing copper vapour at a constant vapour pressure and argon at a pressure of 3 mm. Hg. This absorptive medium has an absorption profile which does not deviate much from the Doppler profile at the temperature of the furnace (approximately 500° C.). The intensity I_1 of the radiation passed through the furnace was measured and the absorption sensitivity of the lamps in said medium is plotted in the graphs

$$\frac{I_0-I_1}{I_0}$$

as a function of the intensity I_0 of the radiation produced by the lamp, said absorption sensitivity being defined by

$$\frac{I_0-I_1}{I_0}$$

The resonance radiation of the element copper is produced in a lamp according to the invention as described hereinbefore with reference to FIG. 2, and the intensity I_0 of the radiation is varied with the aid of the sputtering-electrode current. The curve (*a*) shows the variation of the absorption sensitivity of the lamp according to the invention as a function of I_0 and it is found that said sensitivity remains substantially constant up to very high values of I_0.

The curve (*b*) gives

$$\frac{I_0-I_1}{I_0}$$

as a function of I_0 for a lamp having a hollow cathode of copper. The same small furnace has been used as an absorptive medium. In this case I_0 is varied with the aid of the hollow cathode current. Here the absorption sensitivity is found to be quickly decreasing with I_0 increasing.

For a lamp having a hollow cathode of copper and a positive column discharge perpendicularly towards the axis of the hollow cathode,

$$\frac{I_0-I_1}{I_0}$$

is given in curve (*c*) as a function of I_0. The copper-containing furnace has again been used as absorptive medium and I_0 has been varied with the aid of the hollow cathode current. Here, too, the absorption sensitivity is found to be dependent on I_0, although to a lesser degree.

In FIG. 4*b* the absorption sensitivities of the said lamps are compared with one another in a different medium, namely an atmospheric flame, which is much used in absorption measurements. The temperature of this flame is approximately 2500° C. and the absorption profile is consequently much broader than that of the copper-containing furnace. This has the result that the differences in absorption sensitivity of the lamps are smaller in this case.

At low intensities all sources (*a*), (*b*) and (*c*) give the same absorption in the same medium. Since self-absorption is negligible at a low intensity, all sources will show a Doppler profile for I_0 tending to zero. The graphs of FIGS. 1*a* and *b* show that the line profile of the lamp according to the invention substantially retains the Doppler profile, whereas the profile of the known lamps already considerably deviates from the Doppler profile, even at a low I_0.

What is claimed is:

1. A low-pressure gas discharge lamp for producing resonance radiation comprising a discharge space filled with a rare gas and having an envelope provided with a window which passes the radiation produced, two spaced electrodes between which a positive column discharge having a given axis which intersects the window is maintained during operation of the lamp, a cylindrical atom source having a given length surrounding the positive column and containing an element the resonance radiation of which is desired and defining a discharge path with the window, and an annular ring around the discharge path between said atom source and said window, said ring being spaced from the atom source a distance which is smaller than the length of the atom source and the inner surface of which has a perpendicular section which is smaller than that of the inner surface of the atom source, the length of said ring being at least equal to the largest dimension of the perpendicular section of its inner surface.

2. A low-pressure gas discharge lamp for producing resonance radiation as claimed in claim **1**, wherein at least one of said electrodes intersects the axis of the positive column discharge and passes the radiation.

3. A low-pressure gas discharge lamp for producing resonance radiation as claimed in claim **1** wherein a ring is provided around the discharge path also on the side of the atom source remote from the window.

4. A low-pressure gas discharge lamp for producing resonance radiation as claimed in claim **3**, wherein said rings consist of an electrically insulating material.

5. A low-pressure gas discharge lamp for producing resonance radiation as claimed in claim **4**, wherein the rings are supported by disc-like carriers of an insulating material, said carriers adjoining the envelope of the discharge space.

6. A low-pressure gas discharge lamp for producing resonance radiation as claimed in claim **1**, wherein more than one atom source is provided in the lamp and all atom sources lie on the same axis and are separated by rings spaced from the adjacent respective atom sources a distance which is smaller than the length of the atom source.

References Cited

UNITED STATES PATENTS

2,050,341	8/1936	Knowles	313—185X
2,763,806	9/1956	Anderson	313—185

RAYMOND F. HOSSFELD, Primary Examiner

U.S. Cl. X.R.

313—204, 220, 225