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(54) High intensity discharge lamp.

(57) A high intensity discharge lamp comprising an arc tube (11) disposed within an outer sealed glass envelope (13), said arc tube containing a fill material for supporting an electrical discharge and said envelope having a coating of phosphor particles (3) on the inner surface thereof wherein the individual phosphor particles (5) each have a substantially continuous coating of alumina.

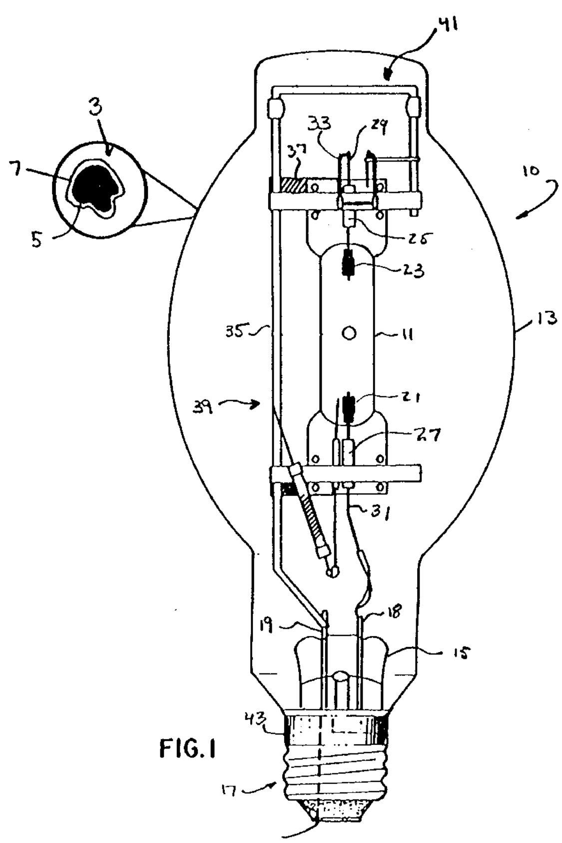

FIG. 1

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This invention relates to high intensity discharge lamp. More particularly this invention relates to such lamps having a coating of phosphor on the interior surface of an outer envelope.

A High Pressure Mercury Vapour (HPMV) lamp known as the Safeline^R (Sylvania Trademark) lamp family employs a safety filament to provide a self-extinguishing feature. In the Safeline^R lamp, a leakage of oxidizing atmospheric gases into the outer jacket causes a safety fuse filament within the arc tube circuit to oxidize, open the circuit, and, thus, extinguishing the bulb. To preserve the safety filament a getter is incorporated into the components contained within the outer jacket to provide the required reducing atmosphere to prevent oxidation of this filament.

The lamp produces a narrow, elongated column of radiation in a 266 kPa (2000 torr) Hg vapour discharge contained in a quartz arc tube which is, in turn, contained in a outer glass jacket. The central part of the arc tube typically reaches temperatures of 700-800°C. The outer bulb is filled with nitrogen to protect the arc tube and related metal parts from damage and atmospheric corrosion. It also regulates the arc tube operating temperature and acts as a filter to absorb ultraviolet radiation. The outer jacket becomes hot when the lamp is operating, reaching a temperature in excess of 350°C depending on fixture design and lamp wattage.

The visible radiation from the HPMV lamp consists almost entirely of the line spectrum from mercury vapour having intense lines at 405, 436, 541, and 578 nanometers and as such can be used as a stand-alone light source. This is in contrast with the low-pressure mercury fluorescent lamp whose emission is from predominantly visible-emitting phosphors used to convert the invisible ultraviolet energy to light emission.

The colour rendition of an HPMV lamp is fairly satisfactory for deep blue, green, and yellow objects, but extremely poor for red objects which appear brown in hue. This deficiency may be overcome by coating the inner surface of the outer jacket with a europium-activated yttrium vanadate (YVO_4:Eu) phosphor which improves the colour by converting some of the ultraviolet emitted energy in the arc into visible light predominantly in the red region of the spectrum.

Alumina-coated phosphors have been used to improve the maintenance (i.e., the drop off of light output with time) of low-pressure fluorescent lamps where the phosphor is in direct contact with the mercury plasma discharge, eg. US-A-14,710,674 discloses an alumina coating within a conventional fluorescent lamp. The phosphor particles are deposited onto the glass and then an alumina coating is deposited onto the phosphor layer using an electron beam source. Since this type of deposition is line-of-sight, it can be expected that at best even the top particles of the layer are only partially covered.

The utilization of phosphors in low pressure fluorescent lamps is distinguished from phosphor utilization in high pressure mercury lamps. Since the conditions of performance are substantially different, a teaching in one area does not apply to the other area. For example, Thomas et al. The article, "Phosphors for High Pressure Mercury Lamps", Illuminating Engineer 52, 279 (1957) by J. B. Thomas, K.H. Butler, and J.M. Harris, states: "While there have been major improvements in phosphors for conventional fluorescent lamps, they have been developed to meet specifically the demands placed upon them by the low-pressure discharge and the construction of the lamp". "Specifically,

1. They must respond efficiently to 254nm radiation".
2. "They must be stable to the effects of 185 and 254nm radiation and to the effects of mercury ion bombardment". (These phosphors are in direct contact with the plasma where they can undergo degradation.)
3. "They must be insensitive to the formation of UV absorbing Hg films onto the phosphor". (Again they are in direct contact with the discharge, in contrast with HPMV where the phosphor is separated from direct contact with the mercury plasma.)

"By their very nature these phosphors cannot be effectively used in HPMV lamps where the requirements are quite different".

Viewed from one aspect the present invention provides a high intensity discharge lamp comprising an arc tube disposed within an outer sealed glass envelope, said arc tube containing a fill material for supporting an electrical discharge and said envelope having a coating of phosphor particles on the inner surface thereof wherein the individual phosphor particles each have a substantially continuous coating of alumina.

In accordance with a preferred embodiment of the present invention, there is provided a high intensity discharge lamp comprising an outer sealed glass envelope having a phosphor coating on an interior surface and in which a pair of electrical conductors extend into the interior of the glass envelope and are electrically connected to a pair of spaced electrodes within an arc tube which contains a chemical fill. In at least preferred embodiments an oxidizable electrically conductive element is present in the gaseous atmosphere for interrupting the electrical connection with the arc tube when exposed to air upon breakage of said outer envelope. In at least preferred embodiments the outer sealed glass envelope contains a gas and a getter material for removing oxygen from the gas and the phosphor coating comprises alumina coated phosphor particles.

More specifically, a preferred self-extinguishing high intensity discharge light source employs an alumina-coated europium-activated yttrium vanadate phosphor particle as coating on the interior of the outer envelope.

The self-extinguishing feature is provided by a safety filament in the reducing atmosphere of the outer envelope. The lamp utilizing an alumina coated yttrium vanadate phosphor of a large particle size has a higher initial brightness, as measured after 100 hours of lamp burning, than a comparable lamp which employs the conventional uncoated smaller sized phosphor.

An embodiment of the present invention will now be discussed by way of example only, and with reference to the accompanying drawings, in which:

FIG. 1 shows a cross-sectional elevation of a high intensity discharge lamp showing an exploded view of a particle of phosphor coating.

Referring to FIG. 1, there is shown the structural features of a high intensity lamp discharge lamp 10. The lamp 10 includes a discharge tube or arc tube 11 disposed within an outer glass envelope 13. The outer envelope 13 is sealed to an affixed glass stem member 15 which has an external base member 17. The outer envelope 13 contains a non-oxidizing inert gas, preferably nitrogen. A getter 37 is desirably present to remove oxygen from the atmosphere so as to maintain its reducing characteristics.

As illustrated in the exploded section of FIG. 1, a coated phosphor particle 3 comprises a phosphor particle 5 with a continuous conformal coating 7 of alumina on the exterior surface. The coated phosphor particles 3 which form a coating on the interior surface of the outer envelope 13 are exposed to the reducing atmosphere of the outer envelope 13. Preferably the phosphor is selected so as to convert some of the ultraviolet emitted energy into visible light predominantly in the red region of the spectrum. A preferred phosphor is a europium-activated yttrium vanadate (YVO_4:Eu) phosphor. A preferred particle size for the phosphor is a Fisher Sub-Sieve Size of from about 7 to about 8.

The arc tube 11 has a pair of electrodes 21 and 23 at respective ends which project into the interior of the arc tube 11 to energize a chemical fill for emitting radiation. A portion of emitted ultraviolet portion is absorbed by the inert atmosphere present in the outer jacket while another portion is converted to visible light by the coating of coated phosphor particles 3. Arc tube 11 is generally made of quartz although other types of material may be used such as alumina, yttria or silica.

Each electrode 21 and 23 of the arc tube 11 comprises a core portion surrounded by molybdenum or tungsten wire helixes and is connected to respective metal foils 25 and 27, preferably formed of molybdenum which are sealed in the ends of the arc tube 11, preferably by pinch sealing.

Electrical energy is supplied to the arc tube 11 by an external source (not shown) during operation. An electrically conductive oxidizable element 33 which is present in the atmosphere of the outer envelope 13 is electrically connected in series with the arc tube 11. The element or filament 33 is sufficiently oxidizable to a nonconductive state so that the electrical path with the arc tube 11 is interrupted upon contact with air. This can occur upon breakage of the outer envelope 3. During normal operation, the reducing atmosphere present in the outer envelope 13 helps to maintain the integrity of the element 33.

The electrical connection of the arc tube 11 with the external source of electricity through the oxidizable element 33 is described in more detail as follows. The oxidizable element 33 is preferably formed from a tungsten coil. A pair of electrical conductors 18 and 19 are sealed into and pass through the stem member 15. Electrical conductors 29 and 31 which are electrically connected to respective foils, 25 and 27, extend outwardly of the respective press seals of the arc tube 11. Conductors 29 and 31 are in turn connected to the respective conductors 19 and 18 projecting from the glass stem member 15.

As illustrated in the drawing, the connection between conductor 29 and conductor 19 is through frame member 35 and the electrically conductive oxidizable element 33. The oxidizable element or filament 33 is constructed of a material that will burn through in the event the outer envelope breaks and admits air, for example tungsten. Thus, the electrical path from a source of electricity exterior to the lamp and to the electrodes 21 and 23 of the arc tube 11 is broken and the lamp is self-extinguished. Getter material 37 is mounted to the frame member 35 to maintain a reducing atmosphere to preserve the electrical conductive nature of the oxidizable element 33 during normal lamp operation.

Within the outer envelope 11, the arc tube 11 is supported by a frame generally indicated at 39. At one end, the frame 39 is secured to the glass stem member 15, At the other end, the frame 39 includes a envelope attachment generally indicated at 41. The frame 39 extends substantially parallel to the longitudinal axis of the lamp. The envelope attachment 41 mates with a dimpled upper partition of the envelope 13 so as to maintain the attached arc tube 11 proper alignment and resist deformation caused by external shock.

The drawing illustrates a mogul type base 43, e.g., such as an E27 screw base but it is contemplated that the lamp may have other forms of base such as a bayonet fitting or even a double-ended configuration with a recessed single-contact base.

The lamp may include other structural features commonly found in high intensity lamps such as an auxiliary starting probe or electrode, generally made of tantalum or tungsten which may be provided at the base end of the arc tube adjacent the main electrode 21.

The discharge tube 11 contains a chemical fill of inert starting gas and mercury when the lamp is a mercury vapour lamp. Other high intensity discharge lamps may contain, additional ingredients such as alkali metal iodides, and scandium iodide. Typically mercury is dispensed into the unsealed arc tube 11 as an amalgam containing mercury prior to introduction of the starting gas. A charge of mercury is present-in a sufficient amount so when fully vapourized an arc may be sustained. Such an amount should provide an operating mercury-vapour pressure of about 266 kPa (2000 torr) as calculated on the basis of an average gas temperature of about 2000K.

Sylvania has developed a series of mercury and Metalarc lamps known as "Safeline^R" type. In a conventional mercury lamp if the outer glass bulb leaks and ruptures, there is a possibility the arc tube will continue to burn, emitting unshielded ultraviolet radiation. During normal operation, the outer jacket is designed to filter out this harmful radiation. The design of the Safeline^R lamp is such that if there is leakage of oxidizing atmospheric gases into the outer jacket, a safety fuse filament within the arc tube circuit will oxidize, opening the circuit, and thus extinguishing the bulb.

To preserve the safety filament, a getter is incorporated into the components contained within the outer jacket. Preferably this getter is an ST101 getter of zirconiumaluminum alloy developed and marketed by SAES Getters, Hamburg, N.Y. This getter provides the required reducing atmosphere to prevent oxidation of this filament. A more complete description of the ST101 getter is provided in a handbook entitled Getters for Lamps by E. Rabusin, prepared by SAES Getters. Milan, Italy, p.18-21.

An illustration of a specific Safeline^R mount assembly which uses an oxidizable element or safety fuse 33 and a ST101 getter 37 in the form of a strip is shown in FIG. 1. Other lamps set forth in Table 1 are in the Safeline^R family of lamps.

Safeline^R mercury vapour lamps with improved initial brightness, as measured after 100 hours of lamp operation, are made by the use of an alumina coated yttrium vanadate phosphor (YVO_4:Eu) as the coating on the outer glass jacket of the HPMV lamp. In addition, the initial brightness is further improved by the use of a larger particle sized coated phosphor than the particle size of the uncoated phosphor which is currently used for this application.

In the case of HID lamps, "initial brightness" refers to the brightness of the lamp measured after 100 hours of lamp operation. This point in the burning lifetime curve is the industry standard reference point and is selected because at shorter burn time, wide unreliable variations in measured light output occur in HID lamps. This can be attributed to the presence of impurities, incomplete volatilization of condensable components in the lamp, and a variety of other factors.

TABLE 1

Safeline^R Lamps, i.e. safety fuse and ST10l Getter.		
Mercury	Lamp Rating	Outer Glass Jacket
	100 Watt	R-40
	175 Watt	BT28
	250 Watt	BT2S
	400 Watt	BT37
	1000 Watt	BT56
Metalarc^R	400 Watt	B37
	1000 Watt	BT56

What now follows are specific examples of how the phosphor is coated, how it is applied to the lamp, and test results in 175-watt DX (Deluxe) high pressure mercury vapour lamps.

Phosphor Coating

Europium-activated yttrium vanadate phosphor was obtained from the Chemical and Metallurgical Division of GTE, Towanda, PA. The particle physical properties of this powder is given in Table II along with the specification for the Type 2391 phosphor which is conventionally used in HPMV lamps.

TABLE II

Particle Size Characterization of YVO_4:Eu Phosphors

	Phosphor Particle Size Distribution			Fisher Sub-Sieve Size
Type	25%	50%	75%	
2391 (standard size)	2	3	4	2-3
2390 (large size)	6	8	10	7-8

* Particle size distributions are based on Coulter counter analysis using ultrasonic dispersion techniques. Sizes listed are in micrometers at listed percentages.

Approximately 1800 grams of the large particle yttrium vanadate phosphor (Sylvania Type 2390) with approximately 0.1% by weight of phosphor of Aluminum Oxide C, available from Degussa, Inc., as a fluidization aid was loaded into a fluid bed column comprising an 80 millimeter ID quartz tube having a quartz frit fused to the bottom acting as a distributor plate. A 65 millimeter stainless agitator disc was positioned inside the quartz tube. The agitator disc was attached to a vibromixer agitator. Approximately 50 millimeters from the base of the agitator a two-micron stainless steel filter element was welded in line and functioned as the diffuser of the oxygen mixture. The agitator disc itself was located approximately 25 millimeters above the quartz distributor. The fluidization column was placed inside a three-zone Lindberg furnace with furnace zone lengths of 6 inches, 12 inches, and 6 inches, respectively. The fluid bed temperature located at the mid-bed height of the column located between the distributor plate and the top of the expanded bed was maintained at approximately 420°C by adjusting the top two furnace zones. Typical zone temperatures as measured by spike thermocouples penetrating through the furnace elements to the outside of the quartz tube were between 460-470°C with the bottom zone turned off.

A fluidized bed is formed by passing nitrogen through the distributor plate at the bottom of the quartz column and up through the phosphor particles. In addition to fluidizing the particles, the nitrogen gas functions as a carrier gas for the vapourized trimethyl distributor: first, a nitrogen flow of 2 liters per minute is passed through the bubbler containing liquid trimethyl aluminum at approximately 30°C thus vapourizing trimethyl aluminum into the gas flow, second, a flow of 1 litre per minute of nitrogen gas acts as the carrier for the first flow. An alumina coating is formed on the surface of the individual phosphor particles when the vapourized trimethyl aluminum is exposed to oxygen in the bed. The oxygen is introduced through the two-micron filter element located on the shaft of the vibrating mixer above the vibrating disc at a flow of 2.5 litres per minute. With phosphor surface area of 0.52 m^2/g, the coating process was carried out for a time of 5.33 hours to deposit alumina coating. X-ray Photoelectron Spectroscopy (XPS) was carried out to establish the surface chemical composition of the coated phosphor. As shown in Table III, the alumina-coated phosphor is fully coated as indicated by the complete attenuation of the vanadium, yttrium, and europium XPS signals and the presence of only the oxygen and aluminum signals. The carbon is residual surface contamination common to XPS analysis. Scanning Electron Microscopy (SEM) was used to determine that the coating is conformal.

Electrostatic Lamp Coating and Lifetesting

175-Watt/DX lamps containing the ST101 getter were fabricated at the HID lamp plant, Manchester, N.H..

using the various europium-doped yttrium vanadate phosphors to be described below. In order to facilitate good adhesion of the phosphor coating to the outer bulb jacket, the phosphor was mixed with 5 weight % Aluminum Oxide C.

The outer jacket to be coated is supported and rotated during the coating process. Burner manifolds shaped to the configuration of the glass envelopes flank the bulbs as they rotate on a turntable. Gas burners are used to preheat the glass envelopes and make them conductive.

TABLE III

X-Ray Photoelectron Spectroscopic (SPS) Surface Elemental Analysis of Alumina-coated Large-Particle Europium-doped Yttrium Vanadate (Mole Percent)

	Al	O	C	V	Y	Eu
virgin-uncoated	nd*	68	3.7	15.5	12.0	0.8
Al_2O_3-coated	39.7	58.2	2.1	nd	nd	nd

*nd = not detected

Phosphor particles are charged negatively. The charging mechanism is a corona, produced by applying a high negative potential to four tungsten wires which protrude into the annular path of the two-phase flow of powder and carrier gas. The carrier gas is nitrogen. A diffusing non-conducting nozzle attached to a central plastic rod located in the annulus controls the angular distribution of the exiting charged powder stream. The phosphor thus charged is attracted to the glass envelope due to the electric field between the charging electrode and the grounding brush, forming the adherent electrostatic coating. The powder which is not deposited on the glass makes its way out through to an exhaust.

Three sets of lamps were fabricated each containing a different phosphor material. They were the uncoated standard size yttrium vanadate (Type 2391) the phosphor typically used in production, uncoated large-particle size yttrium vanadate (Type 2390), and alumina-coated large-particle size yttrium vanadate.

Lifetest data were accumulated for the three sets concurrently from 100 hours through 1000 hours of lamp operation. Brightness levels were not recorded before 100 hours because wide variations in light output are normally observed at shorter time in HID lamps. This is generally attributed to instabilities in the arc due to impurities, incomplete volatilization of condensable components in the lamp, and a variety of other factors.

The recorded lifetest data are listed in Table IV. Also tabulated are the percent gains in brightness achieved between the lamps which employ standard yttrium vanadate, the uncoated large particle size yttrium vanadate, and the large size alumina-coated yttrium vanadate as the outer jacket luminescent coating. The data show that after 100 hours of burning, the lamp containing the uncoated large-particle yttrium vanadate achieves a 7% gain over the lamp containing the standard yttrium vanadate. Further, the lamp containing the large-particle alumina coated yttrium vanadate has a brightness gain of almost 11% over the standard size phosphor lamp. After 1,000 hours of burning, the lamp containing the large size alumina-coated yttrium vanadate still maintains its performance gain over the lamp containing the standard uncoated phosphor. The lamp containing uncoated large-particle yttrium vanadate loses its brightness gain so that its brightness is only 5% over the aged lamp containing the standard uncoated phosphor. Although some variation may be attributed to variation in lifetest photometric measurement precision, this variation is not believed to effect the above results.

In conclusion, lamps made from Al_2O_3-coated large particle size YVO_4:Eu phosphor give superior initial brightness to uncoated small- and large-particle size phosphor in a reducing atmosphere. In Safeline[R] lamps which employ the ST101 getter, as part of the mercury/Metalarc[R] mount assembly, lamps which use the Al_2O_3-coated phosphor as a coating on the outer glass jacket achieve a 10 percent brightness advantage in initial brightness over the standard lamp which contains the conventional particle size uncoated YVO_4:Eu phosphor on the outer jacket.

While the example cited in this disclosure has been for 175-watt HPMV lamps, there are a variety of other

HID lamp types of similar construction to the HPMV/Metalarc[R] family products line which use the YVO_4:Eu phosphor for colour correction and which should offer enhanced brightness performance. Further, preferred embodiments of the present invention may be used to enhance the brightness performance of HID lamps that do not use an oxidizable element and could even be applied to lamps of an electrodeless design.

Furthermore, in at least preferred embodiments the phosphors comply with the following unique requirements, different to those for conventional fluorescent lamps, which are needed for full utilization of the potential value of phosphors in a HPMV lamp, namely

1. They should respond efficiently to a wide range of ultraviolet wavelengths, with response to 313 and 365 being most important". (This is the predominant UV emission in HPMV).
2. "They should retain high fluorescent efficiency at the high temperatures used in HPMV lamps due to thermal quenching of their luminescence".
3. "They should be stable at high temperatures to chemically active gases in the lamp envelope". (These gases are formed during the sealing and lamp-finishing operations as well as outgassing from the quartz and metal parts as the lamp is in operation.)

These statements clearly indicate that completely different sets of operating criteria apply to phosphors used in fluorescent and high-pressure mercury vapour lamps and that if a phosphor is found satisfactory for low-pressure fluorescent lamp applications, the configurations and operating conditions are sufficiently different so that it does not follow that the phosphor will be found satisfactory for HID lamp applications.

A preferred embodiment of the present invention may provide improved brightness and maintenance for a high intensity discharge lamp of the type having a reducing atmosphere in the outer envelope.

Claims

1. A high intensity discharge lamp comprising an arc tube (11) disposed within an outer sealed glass envelope (13), said arc tube containing a fill material for supporting an electrical discharge and said envelope having a coating of phosphor particles (3) on the inner surface thereof wherein the individual phosphor particles (5) each have a substantially continuous coating of alumina (7).

2. A lamp as claimed in claim 1 characterised in that said phosphor particles (3) are selected for converting ultraviolet emitted energy from said arc tube into visible light predominantly in the red region of the spectrum.

3. A lamp as claimed in claim 2 characterised in that said phosphor particles (3) comprise a europium-activated yttrium vanadate phosphor.

4. A lamp as claimed in any of claims 1, 2 or 3 characterised in that said phosphor particles (3) have a Fisher Sub Sieve Size of from about 7 to about 8.

5. A lamp as claimed in any of the preceding claims characterised in that said arc tube (11) has a fill material comprising mercury and an inert gas.

6. A lamp as claimed in any of the preceding claims characterised in that said envelope (13) contains a gaseous non-oxidizing or reducing atmosphere and includes a piece of material (37) adapted to remove oxygen from said atmosphere.

7. A lamp as claimed in claim 6 characterised in that said piece of material (37) comprises a zirconiumaluminum alloy.

8. A lamp as claimed in any of the preceding claims characterised in that an oxidizable element (37) disposed within said envelope (13).

9. A lamp as claimed in claim 8 characterised in that said oxidizable element (37) is adapted to disconnect power to said are tube (11) in the presence of oxygen.

10. A method for producing a high intensity discharge lamp according to any preceding claim characterised in that said individual phosphor particles (5) are coated by a method comprising the steps of fluidizing a bed of phosphor particles with nitrogen, heating the fluidized bed to approximately 420°C, and introducing a supply of oxygen, and supply of vaporized trimethyl aluminum carried in the stream of nitrogen, whereby to form a substantially continuous coating of alumina about the individual phosphor particles (5).

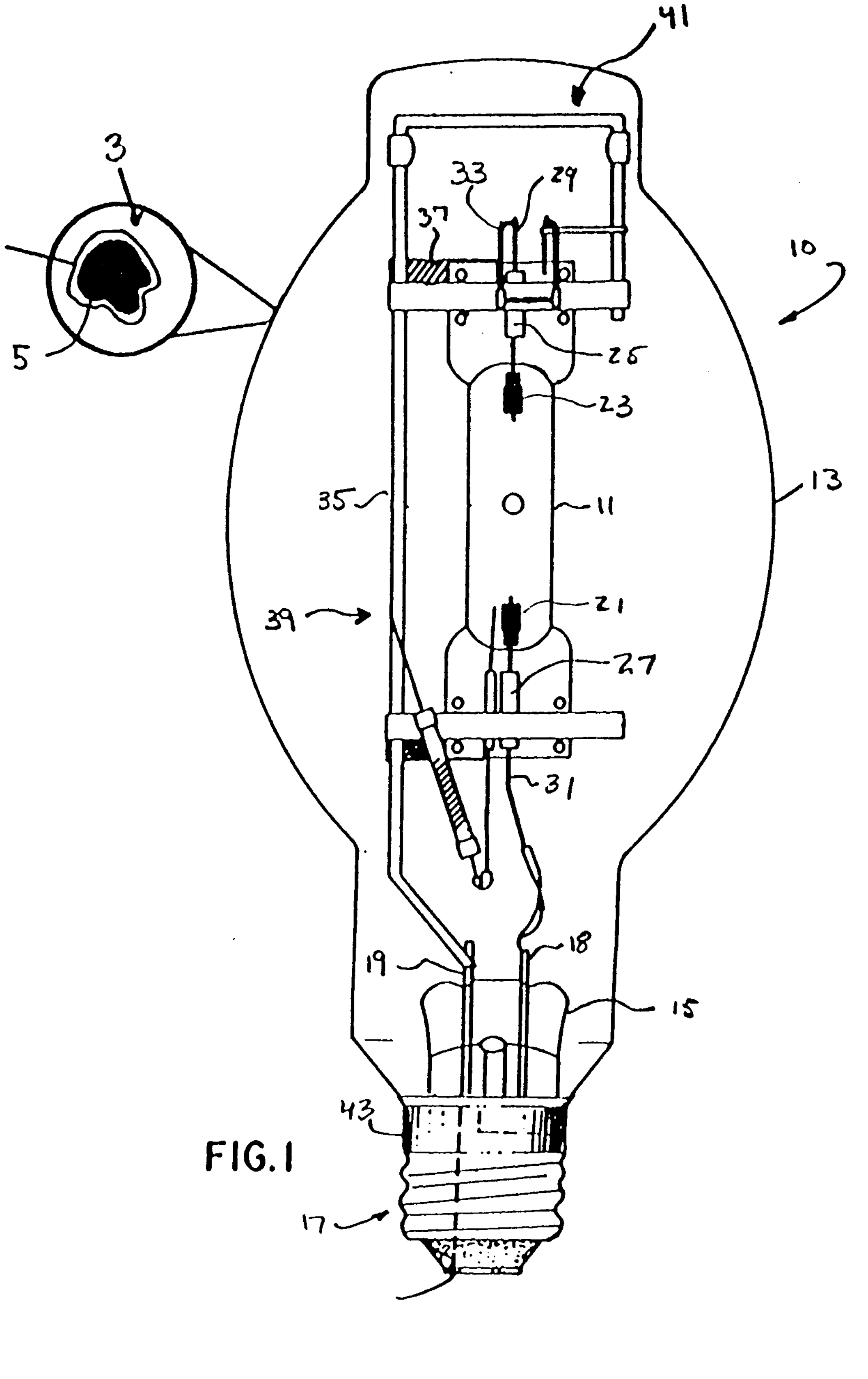

FIG.1

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 30 0312

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
A	EP-A-0 335 203 (AGFA-GEVAERT AG) * page 2, paragraph 1 * * page 3, line 52 - page 4, line 42 * * page 5, line 44 - page 6, line 33; figure 5 * ---	1-3,5	H01J61/44
A	US-A-4 629 939 (JAWOROWICZ ET AL.) * abstract * * column 2, line 15 - line 59; figure 1 * ---	5,6,8,9	
A	US-A-4 241 276 (WYNER ET AL.) *whole document* ---	1-3	
D,A	E. RABUSIN 'Getters for Lamps' 1980 , SAES GETTERS , MILAN (ITALY) * page 18, paragraph 1 - page 21, last paragraph * ---	6,7	
A	US-A-4 979 893 (PAPPALARDO ET AL.) * column 1, paragraph 1 -paragraph 5 * * column 4, line 51 - column 5, line 33 * -----	10	TECHNICAL FIELDS SEARCHED (Int.Cl.5) H01J

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	25 April 1994	Greiser, N

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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