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Hammer et al.

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[54] **FLUORESCENT LAMP WITH PROTECTIVE COATING**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 188,096, Oct. 10, 1971, abandoned.

[52] **U.S. Cl.** **313/486**; 313/113; 313/488; 313/489

[51] **Int. Cl.** **H01j 61/42**

[58] **Field of Search** ..... 313/109, 113, 220, 221, 313/489, 488, 486; 117/33.5 L

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[57] **ABSTRACT**

In a fluorescent lamp which is coated internally with a phosphor, a protective coating of fine alumina particles of sub-micron size is applied over the phosphor layer as a porous discontinuous coat. The protective postcoating improves maintenance and reduces end discoloration of the oxide ring type. It is most beneficial in lamps having relatively poor maintenance such as green zinc silicate aperture lamps and very highly loaded calcium halophosphate lamps.

5 Claims, 2 Drawing Figures

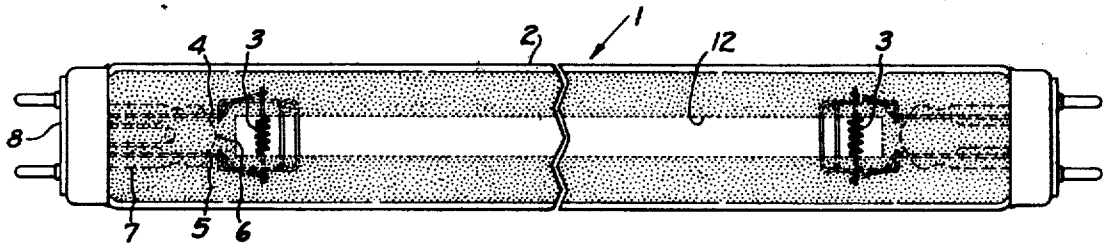


Fig. 1.

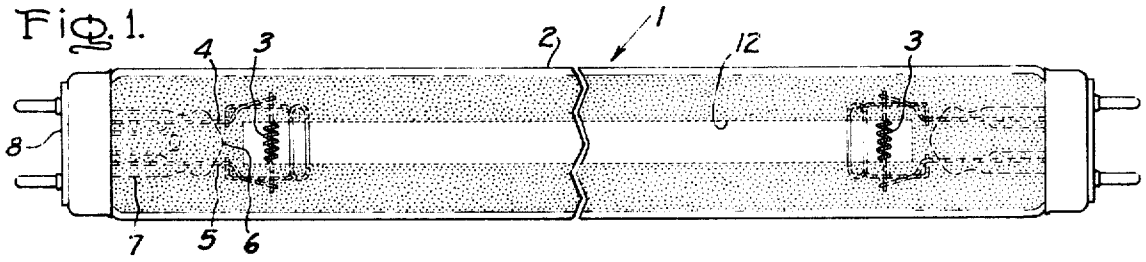
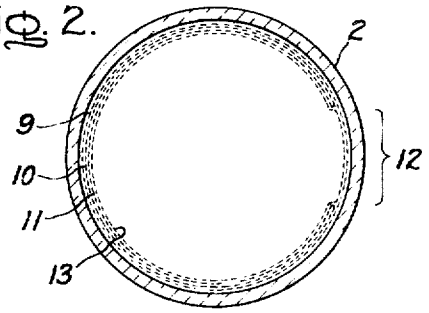


Fig. 2.



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FLUORESCENT LAMP WITH PROTECTIVE COATING

This application is a continuation-in-part of our earlier copending application Ser. No. 188,096 filed Oct. 10, 1971, similarly titled and assigned and now abandoned.

BACKGROUND OF THE INVENTION

The invention relates to fluorescent lamps wherein a low pressure discharge through mercury vapor produces ultraviolet radiation which excites a phosphor coated internally on the envelope walls to produce light.

It is well-known that the light output of the usual fluorescent lamp decreases during the course of its life. Various factors contribute to the drop-off in light output during operation. Some contributing causes are deposits of impurities from the cathode and formation of oxides of mercury, changes in the phosphor itself, and changes in the glass particularly where it is subject to ultraviolet radiation causing a decrease in transmission. The ability of a fluorescent lamp to resist drop-off in light output during life is generally termed maintenance, and it is measured as the ratio of light output at a given life span compared to initial light output and expressed as a percentage.

The more common fluorescent lamps have excellent maintenance. For instance, white 40-watt fluorescent lamps for ordinary lighting have maintenance as high as 85 percent at 20,000 hours of life. However, other fluorescent lamps are not nearly as good. A green zinc silicate aperture lamp used for xerographic reprography may have lumen maintenance no better than 65 percent at 100 hours. In these lamps the fluorescent coating is applied over a reflector coating and the coatings extend only part way around the circumference of the envelope leaving a longitudinally extending clear strip or aperture through which the light is emitted. Other fluorescent lamps having poorer maintenance are extremely highly loaded lamps of both circular and noncircular cross section in which the power input ranges up to 50 watts per foot length.

SUMMARY OF THE INVENTION

The objects of the invention are to improve the lumen maintenance in fluorescent lamps where the maintenance tends to be low, and to reduce end discoloration.

In accordance with our invention, we have found that lumen maintenance in such lamps may be improved by postcoating with aluminum oxide wherein a thin layer of fine alumina is applied over the phosphor layer, suitably as a suspension in a binder. Both the phosphor layer and the Al_2O_3 postcoat may be lehred in a single operation in the same way as the phosphor layer alone would be lehred.

The aluminum oxide postcoat in accordance with our invention is beneficial in two ways. In lamps wherein lumen maintenance tends to be very low, as in green zinc silicate aperture lamps for reprographic applications, the postcoat achieves a remarkable improvement in maintenance, as much as sixfold. In other lamps wherein lumen maintenance is not so low but which are subject to end discoloration, the postcoat achieves an improvement in end discoloration and a substantial reduction in oxide ring darkening.

DESCRIPTION OF DRAWING

FIG. 1 shows an aperture fluorescent lamp having an Al_2O_3 postcoat according to the invention.

FIG. 2 is a cross section through the lamp to an enlarged scale showing the various layers internally deposited on the glass.

DESCRIPTION OF PREFERRED EMBODIMENT

Referring to FIG. 1, there is shown a fluorescent lamp 1 comprising an elongated soda lime silica glass tube 2 of circular cross section. It has the usual electrode 3 at each end supported on inlead wires 4,5 which extend through a glass press 6 in a mount stem 7 to the contacts of a base 8 affixed to the end of the lamp. The sealed tube is filled with an inert gas such as argon or a mixture of argon and neon at a lower pressure, for example 2 torr, and a small quantity of mercury, at least enough to provide a low vapor pressure of about six microns during operation.

As best seen in FIG. 2 showing a section through the tube wall, the inner surface of the glass tube is protectively coated with a thin clear film 9 consisting of titanium dioxide. To form this clear layer, a metallo-organic compound of titanium such as tetrabutyl titanate or tetraisopropyl titanate dissolved in an appropriate solvent such as butyl alcohol or butyl acetate, is applied to the glass. The solvent evaporates almost upon application and the titanate is left deposited upon the inner surface of the glass tube. Moisture from the air hydrolizes the titanate almost as fast as the solvent evaporates forming titanium dioxide which remains as a very thin clear continuous film in a thickness from 0.002 to 0.02 microns.

The illustrated lamp is provided with a reflector coating 10 and thereover a coextensive phosphor coating 11, both coatings extending around the major portion of the glass tube's circumferential surface. This leaves a narrow uncoated strip or aperture 12 extending lengthwise of the lamp. The coatings 10 and 11 may be applied at first over the entire glass tube internal surface and then scraped or brushed off to form the aperture 12 in the desired width, for instance over a 45° portion of the circumference of the tube. A preferred material for the reflective layer is a particulate coating of titanium dioxide having a particle size less than 1 micron, for instance centering on about 0.3 micron which is about half the median wavelength of the visible spectrum. The TiO_2 may be applied as a suspension in a solution of ethyl cellulose in an organic solvent to serve as a binder, the suspension being drawn up into the tube supported vertically and then allowed to drain out. Thereafter the tube is lehred in order to decompose and drive out the organic binder. Alternatively the reflector coat may consist of magnesium oxide MgO.

The phosphor consisting of zinc orthosilicate Zn_2SiO_4 is next applied as a suspension in a solution of nitrocellulose in butyl acetate which is drawn up into the tube and allowed to drain out. At this stage the clear area or aperture 12 is scraped out in the desired width. The scraping removes the relatively thick powdery reflective layer of TiO_2 and phosphor layer of Zn_2SiO_4, but the clear protective layer of TiO_2 which resulted from the hydrolysis of tetrabutyl titanate is very adherent and is not affected. Instead of applying the coating over the entire periphery and then scraping, an alternative method is to introduce a pool of suspension of the de-

sired coating in a horizontally supported tube which is then rocked back and forth to achieve the desired angular width of reflective coating, followed by drying and lehring, as taught in U.S. Pat. No. 2,892,440 - Fulton et al.

In the case of a very highly loaded fluorescent lamp for general illumination, the reflective layer is omitted and the phosphor layer is applied directly over the clear protective film of titanium dioxide. A phosphor commonly used for white fluorescent lamps is calcium halophosphate activated with manganese and antimony and it is commonly applied as a suspension in a water soluble binder.

In accordance with our invention, a postcoat **13** consisting of Al_2O_3 particles in a size less than 1 micron is applied over the phosphor coat. The Al_2O_3 particles may be applied as a suspension in a solution of ethyl cellulose in an organic solvent serving as a binder. The suspension is brought up into the tube while vertically supported and then allowed to drain out and dry. The tube is then lehred at a temperature from about 550°C to 600°C for 3 to 5 minutes to decompose and drive out the binder of both the phosphor layer and the alumina postcoat layer thereover. The lehring procedure is the same as is conventionally used in regular fluorescent lamp production without postcoat, so that no additional burden is imposed thereby on the manufacture of the lamp.

By way of example of postcoating technique, a relatively thick suspension may be prepared by dispersing 200 grams of Al_2O_3 powder of 0.02 micron average particle diameter pre-fired at 1100°C, in 5.6 liters of binder comprising 100 grams of ethyl cellulose dissolved in thinner consisting of equal parts by volume butyl acetate and naphtha. A ball mill or a suitable high speed dispersion mill (Kady mill) may be used. Before application, the foregoing thick suspension is thinned down by diluting 100 cc thereof with binder comprising 2.5 grams of ethyl cellulose in 740 cc of the same thinner. This thinned suspension contains about 4.24 mg Al_2O_3 per cc and about 3.25 cc are retained in the 18 inch **T8** aperture fluorescent lamp previously described, corresponding to 14 Mg Al_2O_3 per bulb or 40 micrograms per cm^2 of bulb surface. We prefer to have the postcoat extend over the clear aperture, as shown in FIG. **2** of the drawing.

Table 1 below compares the light output of 18 inch **T8** green zinc silicate aperture lamps, some postcoated with Al_2O_3 as previously described, and others similar in all respects except not postcoated, serving as control.

The marked improvement in maintenance of the postcoated lamps is apparent. Lumen maintenance calculated as the ratio of light output at 300 hours relative to light output at ½ hour, is 71 percent for the postcoated lamp, as against 51 percent for a control lamp similar in all respects except for the absence of the postcoat. The comparison has been made on the basis of the ½ hour rather than the zero hour figure to avoid the very rapid drop-off during the first minutes of operation which distorts the maintenance figures and has no practical significance.

Tests on very highly loaded fluorescent lamps wherein the power input ranges up to 50 watts per foot length show similar improvements in maintenance as a result of postcoating. In one series of lamps wherein maintenance was 70 percent at 3000 hours life, postcoating raised the maintenance to 75 percent.

The improvement in end discoloration due to oxide rings made possible by the use of a postcoat according to the invention is apparent in the following Table 2 comparing end discoloration in cool white fluorescent lamps operated with frequent starts at a loading of 10 watts per foot. The comparison is made in demerit points wherein **1** represents barely noticeable graying, and **10** represents heavy blackening all around.

TABLE 2

Test	End Discoloration			
	0 hr.	100 hr.	1000 hr.	3000 hr.
Postcoat	0	0	0	1
Control	0	0	3	10

It is apparent from the table that barely noticeable graying, whose onset occurs before 1000 hours in the control lamps, is delayed to 3000 hours by postcoating.

The thickness of coating applied over the phosphor is very difficult to measure because both phosphor particles penetrate into the voids throughout the phosphor. The coating thickness for a particular suspension of Al_2O_3 depends on phosphor particle size and coating texture or laydown characteristics, and the weight of Al_2O_3 per unit area is more easily measured. The effect of weight of postcoat on window brightness and lumen maintenance in 18 inch **T8** green zinc silicate aperture lamps is given in Table 3 below.

TABLE 3

Coating Weight Mg/Bulb	Coating Weight G/cm²	Light Output 0.5 hr.	100 hr.	300 hr.	500 hr.	Maintenance 500/1/2
None-control	0	691	517	422	380	55.0%
10	30	667	569	503	481	72.1%
20	60	652	505	460	471	72.2%
30	90	601	318	225		

TABLE 1

Test	Light Output 0 hr.	½ hr.	100 hr.	300 hr.	Maintenance 300/1/2
Postcoat	130.5	127.1	98.4	90	71%
Control	133.6	127.7	84.5	65	51%

As may be expected, an excessive weight of Al_2O_3 is not good, due in part to the greater difficulty of properly lehring the underlying layers. The optimum weight of Al_2O_3 postcoating will vary with the phosphor and lamp combination. We have found the desirable range to extend from 10 to 160 micrograms per cm^2 of bulb surface, and prefer approximately 40 micrograms/cm^2 for the 18 inch T8 green zinc silicate aperture lamp previously described.

The colloidal aluminum oxide postcoat in accordance with the invention is discontinuous, that is porous and pervious, rather than continuous, nonporous and impervious. This result follows necessarily from the weight or quantity of Al_2O_3 applied as previously described herein, and its method of application by deposition out of a liquid suspension. It is well-known that a phosphor coating is not a smooth uniform dense coating but consists of protuberances and cavities, or hills and valleys. According to published data, phosphor particles as used in lamps vary in size from a few to several microns, and 4 microns may be taken as typical for a zinc silicate phosphor. In order to have a phosphor film without bare spots, the phosphor layer must be several particles thick and the top layer of particles will project at least 4 microns above the mass. If a projection of 5 microns is assumed, this determines the thickness or depth of Al_2O_3 coating that must be applied in order to have a continuous coat or impervious barrier.

Suppliers of colloidal Al_2O_3 powder having 0.02 micron average particle diameter (v.g. Cabot Corp.) give the density of the material as 3.6 grams per cc. Thus for instance where **40** micrograms of colloidal alumina are applied per square centimeter, the volume of this quantity will be 40×10^{-6} gm/3.6 gm/cm^3 $= 1.1 \times 10^{-5}$ cm^3. Assuming that the upper 5 micron layer of phosphor is half filled with phosphor particles, then the volume of Alon needed for complete filling of the empty spaces to assure complete coverage of the phosphor particles will be $5 \times 10^{-4}/2$ cm^3 $= 2.5 \times 10^{-4}$ cm^3. Comparing the volume of Alon supplied to the volume required for complete coverage, the ratio is seen to be $1.1 \times 10^{-5}/2.5 \times 10^{-4} = 4.4 \times 10^{-2}$. In other words when 40 micrograms of colloidal alumina are provided per square centimeter of phosphor coated surface, there is 4.4 percent of the quantity needed to provide complete coverage of the phosphor particles.

In fact, there is not even that much coverage because the hill and valley effect of the phosphor particles is appreciably greater than the 5 micron thickness that has been assumed. For instance, W. Elenbaas in Light Sources says that the phosphor film has to be 3 mean particle diameters thick in order to have no bare spots on the glass not covered by phosphor. Thus, a hill and valley depth of 12 microns is needed to avoid bare spots and on that basis the percentage of phosphor surface coated by Alon is less than 2 percent. In the case of a cool white phosphor wherein the average phosphor particle size is 10 microns, the thickness required would be 30 microns and the percentage coating effected by Al_2O_3 would be even less. Clumping of the colloidal alumina further reduces the proportion of the phosphor particles coated or covered. It is apparent from the foregoing data that the quantity of aluminum oxide in the postcoat according to our invention is only a minor fraction of the quantity required to provide complete coverage of the phosphor particles.

The discontinuous, that is porous and pervious nature of the colloidal alumina postcoat applied over the phosphor layer in accordance with the invention has been confirmed by photo-micrographs taken by scanning electron microscope.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A fluorescent lamp comprising an elongated vitreous tube containing an ionizable medium including mercury vapor and having electrodes sealed into its ends, a coating of phosphor on a major portion of the inside surface of said tube, and a postcoat of finely divided aluminum oxide of submicron size forming a porous discontinuous coating on the particles of said phosphor layer to improve maintenance and reduce end discloration, the quantity of aluminum oxide in said postcoat being but a small fraction of the quantity required to achieve complete coverage of the phosphor particles, the weight of said aluminum oxide postcoat being in the range of 10 to 160 micrograms per square centimeter.

2. A lamp as in claim **1** wherein a particulate reflector layer underlies the phosphor layer.

3. A lamp as in claim **1** wherein a particulate reflector lamp underlies the phosphor layer and an aperture is provided therein extending over a minor portion of the tube periphery.

4. A lamp as in claim **1** wherein a particulate reflector layer of TiO_2 underlies the phosphor layer and an aperture is provided therein extending over a minor portion of the tube periphery.

5. A lamp as in claim **1** of the aperture type comprising a reflector layer of TiO_2 underlying a Zn_2SiO_4 phosphor layer, an aperture therein extending over a minor portion of the tube periphery, and a postcoat of Al_2O_3 of about 40 micrograms/cm^2 over the phosphor layer.

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