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E. L. MAGER

2,848,637

ELECTROLUMINESCENT LAMP

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Fig. 1

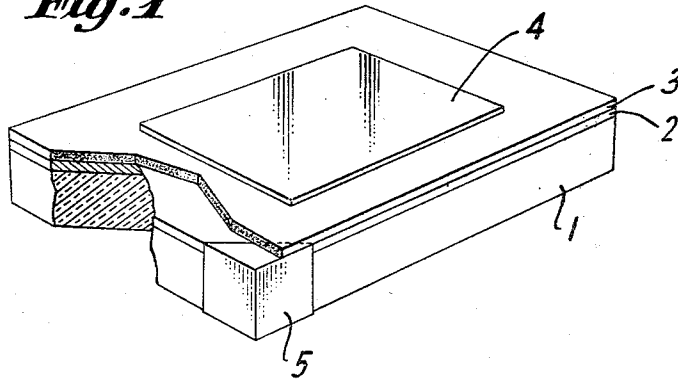


Fig. 2

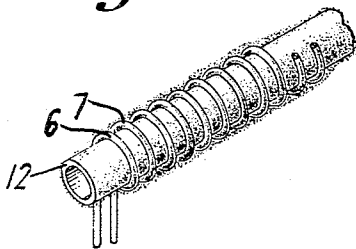


Fig. 3

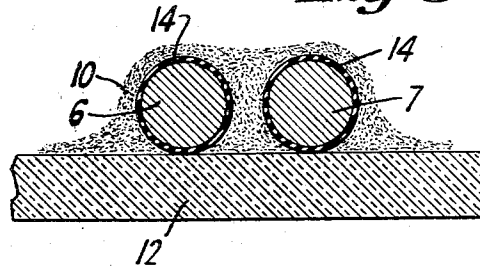


Fig. 4

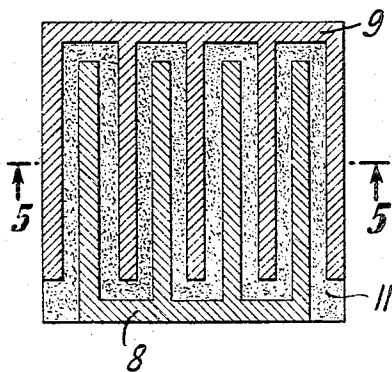
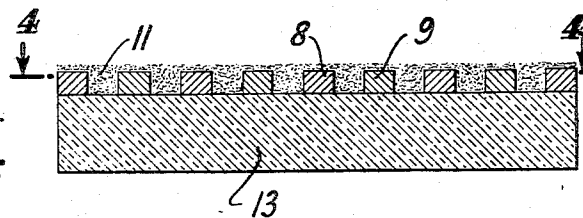


Fig. 5



INVENTOR.

ERIC LOWELL MAGER

BY

Laurence Burns,

ATTORNEY.

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2,848,637

ELECTROLUMINESCENT LAMP

Eric L. Mager, Peabody, Mass., assignor to Sylvania Electric Products Inc., Salem, Mass., a corporation of Massachusetts

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2 Claims. (Cl. 313—108)

This invention relates to electric lamps of the type in which light is produced by the application of a varying electric field to a dielectric material containing a phosphor. The phosphor is embedded in the dielectric material and placed in the field between two conductors.

I have found that the use of an embedding material of dielectric constant high with respect to that of the phosphor decreases the voltage necessary for exciting the device to a desired brightness, provided that the resistivity of the dielectric material is also high with respect to that of the phosphor. A high dielectric constant is not sufficient of itself, as shown by the ineffectiveness of glycerin, which has a dielectric constant of about 56 but a resistivity of only about 10^4 ohm-centimeters, a value high enough for many purposes but not high enough for use in the devices described herein.

Moreover, I have found that while high dielectric constant and high resistivity are necessary in the embedding medium for good brightness, the further feature of low acidity is essential to long life of the devices. For example, the life of one of my devices with plasticized nitro cellulose as the embedding dielectric was increased from about 50 hours to more than a thousand hours by the addition to the nitro cellulose of a small percentage of sodium bicarbonate as a neutralizing agent. Dielectrics, having acid numbers less than 3, such as hydrogenated castor oil, a wax, are sufficiently low in acidity to give good life without the addition of neutralizing material. The exact reason for the effect of the acidity on life is not known. The effect may be due to a reaction of the acid with the phosphor or with the conductive plates, or to some entirely different phenomena.

In a specific embodiment of the invention described below, a plate of transparent conductive glass or plastic is coated with a layer of phosphor and dielectric, over which a metal layer is placed. The metal layer may be coated onto the phosphor-impregnated layer by various methods, but I prefer to apply the metal by vacuum-deposition, which gives superior results. Depositing the conductive metal film on the phosphor suspension in vacuum has the effect of insuring intimate contact of the film and the suspension and of excluding occluded gas that might otherwise be trapped between the film and the phosphor suspension. The light output during the life of the resultant lamp can often be improved by heating the phosphor coating in vacuum for a short period before deposition.

The metal coating can be replaced by an additional plate of conductive glass or conductive plastic if desired, and other geometrical configurations can be used.

Where a metal backing layer or plate is used, aluminum, chromium, or even stainless steel can be used. These are good reflectors and have given satisfactory life.

If the phosphor is used without any embedding material, the glow appears to be at best rather dim, and to occur only at scattered points of metallic contact with the phosphor. The addition of the embedding material can be seen microscopically to spread the glow out over the

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crystal and increase the brightness. But too much embedding material will reduce the brightness below its maximum, and I have found that with hydrogenated castor oil for example, the maximum brightness ordinarily occurs with the amount of the plasticized wax present by weight equal to about twice the weight of phosphor used.

The light output from my devices increases with the voltage applied until the breakdown point is reached, so the embedding medium should have a high breakdown voltage, often called its dielectric strength.

Other features and advantages of the invention will be apparent from the following detailed description of specific embodiments thereof.

In the accompanying drawings, three devices embodying aspects of the invention are shown, Fig. 1 being a perspective view partly in section of one such device; Fig. 2 being a perspective view of a second device; Fig. 3 being an enlarged cross-sectional view of the device in Fig. 2; Fig. 4 being a plan cross-sectional view of a third device along the line 4—4 in Fig. 5; and Fig. 5 being an enlarged cross-sectional view of the device in Fig. 4, along the line 5—5.

The device shown in Fig. 1 has a glass plate 1, having a transparent conductive surface 2, over which is a thin layer 3 of phosphor-impregnated dielectric material, with a metal backing layer 4 over that and in intimate contact therewith. This completes an illumination source, suitable for use as a luminous plaque for walls and ceilings, for example. One terminal of a proper source of varying or alternating voltage can be connected to a metal backing layer 4, the other to a metal tab 5 which is connected to the conducting surface 2.

In a modification of this device the layer 4 can also be of a conductive glass, instead of being of metal, thus providing a plaque which emits light from both sides, and when not energized is translucent. Such a device can be used in various ways, for example in table lamps and other lighting fixtures or even as a window pane which transmits sunlight by day and emits its own light at night.

A conducting surface 2 of good transparency or translucency is difficult to obtain, because good electric conductors are generally good reflectors of light, rather than transmitters of it. However, although other coatings may be used, I find that a particularly effective conductive surface can be provided by heating the glass and exposing it while hot to vapors of the chlorides of silicon, tin, or titanium, and afterward placing the treated glass in a slightly reducing atmosphere. Where the application in the vapor state is not convenient, good results may be obtained by mixing stannic chloride with absolute alcohol and glacial acetic acid and dipping the glass plate into the mixture.

However applied, the resultant conductive surface appears to contain stannic (or silicic or titanic) oxide, probably to some extent at least reduced to a form lower than the dioxide, although the exact composition is difficult to determine.

The conductive surface 2 so applied will have a resistance of about 100 ohms per square, that is a resistance of 100 ohms taken between the entire opposite sides of any square on the surface 2.

The phosphor-impregnated layer 3 placed over the transparent conductive layer 2 is a phosphor of copper-activated zinc sulphide as described below, in the form of fine particles embedded in plasticized nitro-cellulose, and the backing layer 4 is of metal, preferably a good reflecting metal such as aluminum or chromium, which will not react appreciably with the phosphor or embedding material used. The metal layer or conductive surface 4 is preferably of low resistance and can be applied in any convenient manner, taking care not to damage the cellulose-phosphor layer. However, best results have

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been obtained by vacuum-deposition of the metal. The glass plate 1, with its conductive surface 2, is coated with the embedded phosphor layer 3, placed in a bell jar and the latter evacuated. The coating 3 is then heated for a moment, for example by passing a current through the conductive surface 2. The heating is preferably of the order of that used for drying, and should not, of course, be sufficient to char the embedding material in phosphor layer 3. The heating is not essential to producing a plaque of good initial brightness, but aids in maintaining the brightness throughout the life of the lamp.

The aluminum or other metal is then deposited on the phosphor layer in a vacuum, for example by being placed on a tungsten filament and the latter heated by the passage of an electric current therethrough, as shown for example in U. S. Patent 2,123,706, issued July 12, 1938, to O. H. Biggs.

The phosphor is prepared for application as a suspension for example including the following materials:

Phosphor	g	10
Sodium bicarbonate	g	2
Nitrocellulose (quarter-second viscosity)	g	8
Castor oil	g	1
Orthonitrodiphenyl	g	3
Di-octyl sebacate	g	1
Chlorinated diphenyl	g	2
Di-octyl phthalate	g	1
Benzophenone	g	2
Methyl acetyl ricinoleate	g	2
Cellosolve ricinoleate	g	2
Glyceryl tri-aceto ricinoleate	g	3
Butyl acetate	cc	85

The substances appearing between nitro-cellulose and butyl acetate in the above list are plasticizers for the nitro-cellulose. This particular combination of plasticizers gives a more vitreous mixture, with less tendency toward crystallization. Other plasticizers can be used, however, and a single one will often suffice. The butyl acetate is a solvent for the nitro-cellulose and plasticizers. Other solvents or mixtures thereof can be used.

The plasticizer will generally be a large proportion of the embedding material, because the electroluminescence of the phosphor appears to be best when the embedding material is soft.

The plasticizer should have high resistivity, high dielectric constant and high dielectric strength, in order not to greatly diminish the values of these factors in the main cellulosic component. Chlorinated-di-phenyl, for example, has a dielectric constant of about 6. Nitro-cellulose itself has a constant of 7.5.

The proportions of dielectric material to phosphor in the above example (after drying) are seen to be about 2.5 to 1 by weight. Proportions between 2 and 3 are generally satisfactory for best results, although the ratio can be varied considerably.

The sodium bicarbonate prolongs the life of the lamp, presumably by reducing or neutralizing the acidity of the embedding material.

In making the above suspension, the nitro-cellulose is dissolved in about 35 cc. of the butyl acetate and this lacquer is then added to the rest of the mixture. The suspension is sprayed onto the conducting surface 2 of glass plate 1 with a spray gun of a type usual in the art.

The coating is air-dried, or oven-dried, and on its exposed surface a thin layer of metal, for example, aluminum is deposited by the usual evaporation methods or by some other method, as previously explained.

Various other plastics can be used instead of nitro-cellulose. Glass and various enamels may be used, particularly glass of low enough melting point to insure that the phosphor crystals remain unmelted.

The voltage at which the layer 3 has a given brightness can be reduced by using hydrogenated castor oil, or

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castor wax, as the embedding medium. This wax has an acid number of 2 and a dielectric constant of about 12. A suitable embedding medium and phosphor combination with this type of wax is as follows:

	Grams
Phosphor	20
Castor wax	24
Beef fat	12
Castor oil	4

A suspension is formed by dissolving the last three components in a solvent of 200 cc. of benzene and 50 cc. of tetrahydrofuran, and working the phosphor into suspension with a mortar and pestle. The resultant suspension can then be sprayed over the conductive coating 2 on glass plate 1.

The benzene and tetrahydrofuran will evaporate on drying, leaving the phosphor and the embedding medium.

The coating tends to be somewhat flaky at this stage. A quick or flash heating with a flame smooths out the coating. This flash heating gets the phosphor particles into suspension for a moment, and then freezes them while suspended. A longer heating may allow the particles to settle out of suspension.

The beef fat and castor oil are plasticizers, and although other plasticizers can be used, the combination of these two is particularly satisfactory, presumably because of their dielectric properties.

The thickness of the various layers can be altered to suit various voltage conditions and the like. The voltage necessarily will depend on the phosphor used, the thickness of the phosphor layer 3, and the brightness desired, but voltages between 25 volts and 2500 volts and even higher have been used. A lamp operable from a 110-volt alternating current power line can be made with the conducting surface 2 of a thickness of about a wavelength of light, producing an iridescent effect when viewed at an angle, the phosphor layer 3 of about 2 one-thousandths of an inch, and the metal layer 4 of a fraction of a thousandth of an inch. The plate 1 can have any convenient thickness and should be transparent or translucent.

The phosphor used can be made, for example, by intimately mixing as fine powders about 75 parts of zinc sulphide and 25 parts zinc oxide, with about 1 part zinc chloride, 1 part lead sulphate and about 0.075 part copper sulphate.

The mixture is then heated at between 900° C. and 1250° C. in an inert atmosphere, for example in a gas tight furnace through which nitrogen is flowed, and removed from the furnace after the evolution of fumes has decreased but before the phosphor darkens too much and becomes gritty. The phosphor will generally be a light-greenish-gray in color.

It should then be treated with an aqueous solution of 5% acetic acid at between 60° C. and 100° C., then washed with water. An aqueous solution of half-saturated ammonium acetate can be used instead of the acetic acid, if desired, and gradually reduced in concentration until the final washing with pure water.

The preparation of this phosphor, and of other electroluminescent phosphors useful in my lamp, is described in detail in an application filed by Elmer C. Payne concurrently herewith for an Electroluminescent Lamp. Other phosphors will be effective in my device however, and my device is not restricted to the use of those described.

The voltage at which the layer 3 has a given brightness may be reduced by using castor wax (hydrogenated castor oil) as the embedding medium. Castor wax has an acid number of 2 and a dielectric constant of about 12.

The voltage necessarily will depend on the phosphor used, the thickness of the phosphor layer 3, and the brightness desired, but voltages between 25 volts and 2500 volts and even higher have been used. Lamps, according to my invention, operating directly from the usual 110 volt

line, with no transformers or auxiliary equipment necessary, have been made.

The device can also be used in the forms shown in Figs. 2 to 5, in which paired long spaced narrow conductors 6 and 7, and 8 and 9, are placed side by side, the conductors and the space between them being occupied by a coating or layer 10, 11 consisting of an electroluminescent phosphor embedded in a dielectric material. The conductors and the layer are carried by insulating supports 12 and 13. In Fig. 2 the conductors 6, 7 are wires, having an enamel insulating layer 14, wound side by side and close together but spaced apart a distance of a few thousandths of an inch or less. In Fig. 4, the conductors 8 and 9 have intermeshed lengths which can be metal painted or suitably adhered to an insulating support such as the glass plate 13. The opposite sets 8, 9 of conductors, while intermeshed, are not in contact with each other, being spaced apart a few thousandths of an inch or less.

A lamp is defined for the purposes of this specification as a device which produces light of practical illuminating intensities. Intensities below a foot-lambert are practical for some application, although the lamps herein described have given several foot-lamberts on 60 cycles per second alternating voltage supply, and 15 to 20 foot-lamberts on a supply of several thousand cycles per second.

Such lamps are therefore useful for general illumination purposes including use as luminous panels for ceilings, as lighting sources for table lamps, as luminous signs and clock faces, as luminous face plates for household electrical switches, for street lighting and for many other applications.

This is in part a continuation of my copending applications Serial Nos. 120,398 and 141,050, filed October 8, 1949, and January 28, 1950, respectively, now Patent No. 2,624,857 and Patent No. 2,566,349, respectively.

What I claim is:

1. An electroluminescent lamp comprising two spaced conductors in close proximity to each other and a coating therebetween of phosphor embedded in a wax of hydrogenated castor oil.
2. An electroluminescent lamp comprising two spaced conductors in close proximity to each other and a coating therebetween of phosphor embedded in an insulating material the dielectric constant and resistivity of the embedding material being high compared to that of the phosphor.

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