

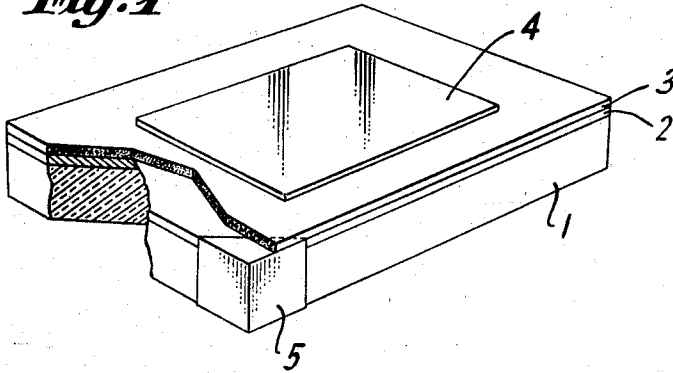
June 10, 1958

E. C. PAYNE  
ELECTROLUMINESCENT LAMP

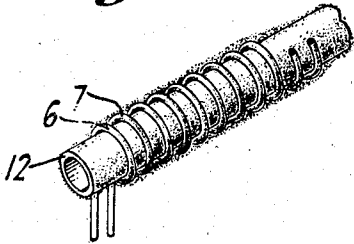
2,838,715

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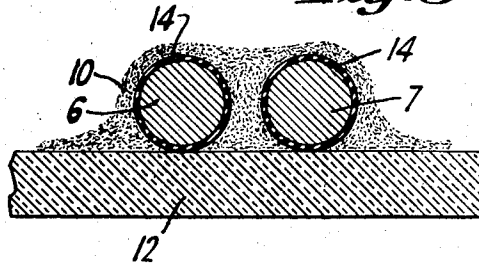
*Fig. 1*



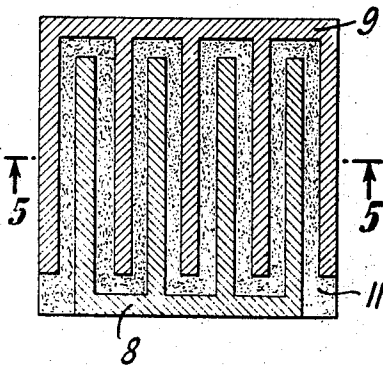
*Fig. 2*



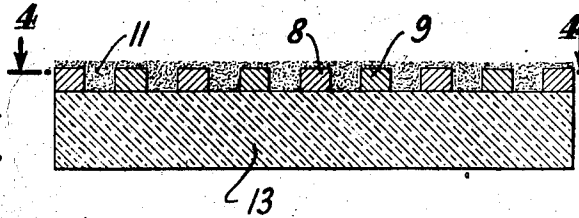
*Fig. 3*



*Fig. 4*



*Fig. 5*



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2,838,715

## ELECTROLUMINESCENT LAMP

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10 Claims. (Cl. 315-108)

This invention relates to lamps in which light is produced by the application of an electric field to a region including a phosphor. The invention relates also to phosphors particularly suited for such use, and to methods of preparing them.

Electric lamps utilizing phosphors have been previously known. In one commercial type, the electric field is applied to a gas and the resultant ultra-violet radiation used to excite the phosphor. In another, the field is applied to a space in which electrons are accelerated and the resultant cathode ray beam used to excite the phosphor. But in neither of these devices is the light produced by the direct application of a sufficiently intense field to the immediate region of the phosphor.

Moreover, both of these devices, like the well-known incandescent lamp, require an enclosing bulb or tube hermetically sealed, with consequent difficulties in manufacture and limitations in geometry. The devices of my invention are far less limited in such respects, requiring no sealed bulb or tube for their operation, and can be made in practically any convenient size and shape, thus making possible for the first time such new lighting applications as the illumination of a room by a complete ceiling of electrically-luminous plaques.

As in certain specific embodiments of the invention described below, such plaques advantageously have a plate of conductive glass in contact with one side of a thin layer of phosphor embedded in a light-transmitting dielectric material, and a conducting layer in contact with the other side of said phosphor layer.

The device has a positive volt-ampere characteristic and hence requires no ballast. It can be operated directly from the usual 110 volt, 60-cycle per second power line, although in some cases a transformer may be desirable for higher voltage operation.

The device is in effect a luminous capacitor, and the light produced appears to be due to the action of the electric field on the phosphor, or on the phosphor and the embedding material.

The appearance of a faint glow upon the application of an electric field to a phosphor film appears to have been observed heretofore, but only as an obscure scientific phenomenon. Attempts by earlier scientists to produce light of practical illuminating intensities by such means appear to have been unsuccessful, as pointed out by Leverenz in his recently-published book, "An Introduction to the Luminescence of Solids" (McMillan, New York, 1950, page 392). Leverenz found that excitation of allegedly field-excited phosphor films produced only a feeble blue glow, barely perceptible to a partially dark-adapted eye, and he attributed the glow to excitation of aerospheres of atmospheric nitrogen trapped in the embedding medium, rather than to excitation of the phosphor itself by the field.

In contrast to this, the light produced by the present invention is not at all the blue glow of atmospheric nitrogen, and can be made blue, green, yellow, red or other color depending on the choice of phosphor. And instead

of the faintly perceptible glow of the films examined by Leverenz, my lamps can have brightness as high as 20 foot-lamberts or more. This brightness can be maintained over large areas to yield a very large total light output.

These unexpected results appear to be due to direct excitation of the phosphor by the field, although the exact reasons for the action are not easily explainable from a theoretical standpoint. The field may alter the quantization of the energy levels in the atom, as in the Stark effect, and the return of the levels to the original state may cause the emission of light. However, a mathematical analysis of this possibility indicates that the required field would need to be tremendously greater than that available. The emission may also be due to shifting some electrons into the conduction band of the phosphor, but here again the field available seems much too small. Leverenz, for example, at page 290 in the book previously mentioned, says that fields short of insulator breakdown are too small for electronic excitation in insulator crystals.

For even if we have 250 volts across a thousandth of a centimeter layer of phosphor, the two-volt drop necessary for emission in the visible range will require a distance of about  $10^{-5}$  centimeter, or about 1000 times the radius of the type of atom present. The mean free path through which an electron would have to be accelerated to be capable of exciting an atom to emit visible light would thus seem to be far greater than that available in the crystal.

The foregoing is on the assumption that the field is uniform. Actually, the field will be non-uniform, at least in the crystal, and also outside the crystal if the latter is in a dielectric medium of a different dielectric constant. If the crystal is a thin flat disc, perpendicular to the general external field, the field in the crystal itself may be greater than the applied field by a factor equal to the ratio between the dielectric constant of the embedding medium and that of the crystal itself. And inside the crystal, the same sort of field multiplication may occur where there is a small region of low dielectric constant.

In the specific embodiments of the invention described below, the phosphor is placed between two conductors across which a voltage can be applied. In a preferred embodiment, a thin layer of a dielectric material having fine crystalline phosphor particles embedded therein fills the space between two electrically conducting layers, at least one of which is light-transmitting such as a conducting glass or plastic. In the absence of the embedding material, the crystals appear to glow at most only at their points of contact with a conductor. The presence of the embedding medium greatly enhances the glow, which can be seen under the microscope to spread out over the entire crystal. The phosphor in its embedding dielectric appears to be excited directly by the field.

The response of a particular phosphor to this method of excitation cannot be predicted from its response to other forms of excitation. Some of the best fluorescent lamp phosphors do not respond to the electric field, but the zinc sulphide type phosphor can be made very effective for such purposes. The crystals of an effective zinc sulphide type phosphor are roughly flat hexagons of zinc sulphide that appear to have small bumps on their flat surfaces, and those bumps may be smaller crystals of zinc oxide affixed to the main zinc sulphide crystals, or they may be due to some other distorting influence. If the bumps or projections are zinc oxide crystals, then there may be a very high field at the interface between these and the main zinc sulphide crystal. And if they are not zinc oxide, the bumps may still increase the field because of their distortion of the crystal shape. In any event, the oxide, the activators and other "impurities" added to the crystal would seem to insure sufficient irre-

gularity inside the crystal to afford the possibility of localized build-up of the field at some point in the crystal.

The effect of the field on the emission of light may, however, be due to entirely different reasons, and I do not wish to be limited to any particular theory.

However, the thin, flat, hexagonal crystals of the sulphide type, with projections or "bumps" extending from their flat surfaces in an embedding medium, appear to be particularly suitable for the emission of light on application of an electric field.

A certain amount of zinc oxide is helpful in the zinc sulphide mixture while the latter is fired presumably because it aids in formation of the proper type and constitution of crystals. Nonetheless washing the phosphor with a suitable solvent for zinc oxide, such as a solution of acetic acid or of ammonium acetate, improves and multiplies the brightness of such phosphors. Such solvents may also have the effect of removing surface impurities from the surfaces of the active crystals, and the latter may actually be the determining factor, but in any case the solvents do remove the excess zinc oxide which is of low resistivity. This has the effect of increasing the resistivity of the phosphor about 100 times in some cases and the resultant high resistivity improves the phosphor.

The emission from the sulphide phosphors may be a surface effect, or due to a surface layer between the dielectric medium and the main portion of the crystal, but the great brightness of these high resistivity phosphors may indicate that the field penetrates well into them and excites a larger portion of the crystal material than would be the case with phosphors of lower resistivity.

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 the 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 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 electrical 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 may 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.

For example, about 20 grams of nitrocellulose with a suitable plasticizer such as chlorinated diphenyl can be dissolved in about 80 cc. of a suitable solvent such as butyl acetate, and about 10 grams of finely-divided phosphor suspended therein. The plasticizer in the above example is included in the weight of the nitrocellulose, which can be of quarter-second viscosity, although any convenient viscosity can be used, the proportions and constituents of the above mixture being capable of considerable variation. A large number of plasticizers are well known, but for best results those with high resistivity and high dielectric constant should be chosen. The plasticizer may be used in considerable quantity, if desired, and may even comprise the major portion of the combined weight of nitrocellulose and plasticizer, as shown in the application of Eric-L. Mager, filed concurrently herewith, and a non-acid dielectric medium, or one of low acidity or acid number may be used as shown in that application.

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 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.

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

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.

A highly effective phosphor can be prepared by intimately mixing as fine powders about 75 parts by weight of zinc sulphide and 25% parts zinc oxide, with about 1.0 part zinc chloride, about .075 part copper, added as copper sulphate, and about 1 part lead sulphate.

These are the preferred values for best results, but the copper, calculated as metallic copper, can be varied over a range of about 0.03% to 0.3%, and the amount of chloride, calculated as zinc chloride, should be between 0.4% to 2.0%, although if a fluoride is used the amount added should not ordinarily be greater than about 0.1%. The amount of lead, calculated as the sulphate, should be between ¼% and 5%, the higher amounts being used only when there is a considerable flow of nitrogen or other inert gas during the firing, to carry away the excess lead.

The components should be thoroughly mixed in the form of fine powders, and heated to between 900° C. to 1250° C. in an inert atmosphere, for example in a gas-tight electric furnace filled with nitrogen, and having a chamber of nitrogen connected thereto to pass a slow stream of the gas therethrough. A batch of 200 grams has been fired in an electric furnace at about 1000° C. in a small silica boat in a silica tube 3 inches in diameter and 30 inches long sealed at both ends, with a quarter inch silica tube feeding nitrogen into one end of the tube and a quarter inch tube for exhausting the nitrogen at the other end. The rate of flow of nitrogen was about 0.1 liter per minute.

In firing the phosphor, there are three distinct stages. In the first stage, the mixture emits fumes of the halide and the lead compound used, and turns a yellow color, which deepens with heating. If removed from the furnace at this stage, the material will not have any appreciable electroluminescence. In the second stage, the evolution of fumes decreases greatly and the color of the phosphor darkens somewhat to a greenish-gray. If removed from the furnace during this stage the phosphor will luminesce. Finally there is a third stage, where the phosphor darkens further and becomes gritty, gradually losing its electroluminescent capability. The phosphor should be removed from the firing furnace toward the end of the second stage or the beginning of the third. The soft, fluffy mass can then be crumbled or shaken to separate the powder particles.

After firing of the phosphor, a treatment with acetic acid or ammonium acetate improves the luminescence of the phosphor. The brightness is usually increased several times, and in many cases the treatment makes the difference between a good brightness and no brightness at all.

In treating the fired phosphor powder with acetic acid, a solution of about 5% of the acid in water is heated to between 60° C. and 100° C., preferably nearer to 60° C., and poured over the phosphor while the latter is subjected to a gentle grinding action until thoroughly treated, for example, about 2 minutes, and the suspension is then filtered, washed with water, and dried. The temperature of the solution is kept at about 60° C. to 100° C. during the entire treatment, even during the filtering.

While the foregoing treatment improves the phosphor, an ammonium acetate treatment may be preferred because it is less critical in use and is more effective in increasing the brightness. In some cases, the acetate has given a 50% brighter phosphor than the acetic acid. In using this treatment, enough of a saturated solution of ammonium acetate in water is added to the phosphor to give a slurry, which is stirred in a mortar and thoroughly ground until all the large aggregates are broken up into their component particles. Then a quantity of half-saturated acetate solution is added, in proportions of say 200 cc. for every 100 grams of phosphor, enough to give a thinner slurry and the supernatant suspension poured off. A similar amount of half-saturated acetate

solution is then added to the phosphor and poured off or filtered off. The process is repeated with successive dilutions, two treatments with one-eighth saturated solution, then two with one-twelfth saturation, two with one-sixteenth and several with pure water. The treatment could, if desired, be continuous with two streams of liquid, one being of water and one of acetate solution, pouring onto the phosphor, the stream of acetate solution being gradually reduced in flow. If the acetate concentration on the phosphor is not diluted gradually, the dissolved zinc oxide will precipitate out again over the phosphor.

The effectiveness of the treatment is apparently in removing the excess zinc oxide, leaving the sulphide and presumably leaving also any small particles of zinc oxide which may have attached themselves to the sulphide, or any zinc oxide distributed throughout the sulphide crystals.

If the acetic acid solution is used, it should be weak enough to remove the oxide without also removing the sulphide. With the acetate solution, the sulphide is unaffected, and the pH of the solution may be varied from 4 to 9, by varying the proportions of the ammonium and acetate radicals, and still be effective. This is a helpful circumstance, for commercial ammonium acetates generally vary in composition, differing considerably from stoichiometric. The acetate solution may possibly remove also any surface film on the sulphide crystals and perhaps some of the copper, although the latter seems less likely.

Other ammonium salts, such as the chloride, are also effective, but ammonia itself is not satisfactory. The reason appears to be that in a reaction between zinc oxide and ammonium acetate a complex zinc diammine acetate is formed, plus water. Ammonia itself lacks a negative radical to form such a complex for removing both the oxide and zinc portion of the zinc oxide. But ammonium chloride and many other ammonium salts would work like the acetate.

The effects of the treatments described on a ZnS—ZnO phosphor, suitably activated, are indicated in the following table:

Percent ZnS In Starting Mixture	Relative Brightness	
	Untreated	Treated
100	1	1
99	1	10
80	0	50
70	0	60
50	0	5

The treatment in the above tests was with acetic acid. The ammonium acetate treatment generally gives about 50% more brightness near the maximum point.

It is seen from the table that the treatment had no effect on the 100% zinc sulphide sample, presumably because there was in that case no zinc oxide to be removed, but in the other cases the treatment had a remarkable effect in increasing the brightness. The untreated samples appeared to have no appreciable luminosity before treatment and this may have been due to the screening effect of the zinc oxide, which has an electrical conductivity high with respect to that of the sulphide.

The test device actually passed 100 times as much current with untreated phosphors as with treated ones. With a sinusoidal 100 volts at 60 cycles per second on a test device using a cell 0.01 inch thick and 5 sq. in. in area, between a metal plate at the bottom and a piece of conductive glass at its top, using 1.5 grams of phosphor in 1.2 cc. of castor oil, the current passed was 5 milliamperes before treatment and 0.05 milliamperes after treatment. Thus a high-resistivity phosphor is defined for the purposes of this specification as one which passes of the order

of 0.05 milliamperes when tested in the above apparatus under the conditions specified, that is one which does not pass more than 0.5 milliamperes.

The resistivity of the treated phosphor is even greater than the current passed through the cell might at first seem to indicate, because a large part of the current through the cell is due to capacitance. The current of 0.05 milliamperes when the cell is filled with the castor oil and treated phosphor in the above example is about double that passed when the cell is filled with castor oil alone.

Since the phase angle between voltage and current is only about five or ten degrees, only a small part of the increase in current is due to the conductivity of the treated phosphor. The greater increase appears to be due to the increased dielectric constant of the mixture with the treated phosphor added. Since the dielectric constant of the phosphor-oil mixture appears to be double that of the oil alone, the constant of the treated phosphor appears to be quite high, say greater than ten, because the phosphor makes up only about a third of the volume of the mixture in the cell.

But when the phosphor is untreated, there is a considerable amount of zinc oxide present, and since the dielectric constant for the oxide appears to be only about 2.5, the great increase in current with the untreated phosphor is due to its high conductivity.

A further example of a phosphor useful in electroluminescent devices has been prepared by intimately mixing the following ingredients as finely-divided powders, in the proportions indicated:

	Grams
Zinc sulphide (ZnS)-----	74.60
Zinc oxide (ZnO)-----	24.42
Lead carbonate (PbCO <sub>3</sub> )-----	1.87
Cuprous oxide (CuO)-----	0.0637

The sulphide used contained 5 grams of water and 1% zinc chloride. The water was removed by drying the mixture at 160° C. The batch was then placed in a quart mill and milled with acetone for half an hour, after which it was again dried and then fired at 1000° C. in an open silica tray, for half an hour in a furnace. Pre-purified nitrogen was flowed over the mixture in the furnace at a rate of 0.06 liter per minute, during the firing. After this heating, the phosphor was ground lightly in a mortar to break up the resultant fluffy cake into its component particles or into its smaller aggregates of particles.

The powder was then treated with a boiling solution of 5% acetic acid in water, then with a ½% solution of the same and then washed with water. In each case the phosphor was placed in the acetic acid solution and the whole raised to boiling temperature in about ten minutes, continuing the boiling for five minutes.

In phosphors using about 25% oxide in the starting mixture, the percentage has been found to be still substantially 25% after firing. But after treatment with the solutions as above described, the amount of oxide present has been reduced to 5% or less, so that the final phosphor is about 95% sulphide or more.

Phosphors made without any oxide in the starting materials have luminesced but were only about 20% as bright as those made with oxide. The copper content for even the 20% brightness should be much greater than the optimum values for the phosphors using oxides. A small amount of oxide may possibly be formed in this phosphor during firing, since it is difficult to insure that every trace of oxygen is absent from the nitrogen atmosphere used during firing.

The sulphide phosphor prepared as in the preceding examples fluoresces a greenish-yellow under excitation at 60 cycles per second and fluoresces blue under excitation of about 2000 cycles.

A phosphor fluorescing orange-yellow may be prepared by using manganese in activating amounts with the sulphide. In an example, such a phosphor is produced by

mixing 87 parts by weight of zinc sulphide and 13 parts zinc oxide as finely divided powders, together with about 2.1% manganous sulfate and 0.8% zinc chloride and 1% lead sulfate. The constituents are blended as dry powders, preferably finely-divided, or they may be blended wet, for example, in a water slurry and dried. Some of the compounds will remain as powders and some will dissolve in the water.

In any case, after the components are thoroughly mixed together, the resultant mixture should be fired, preferably in an inert atmosphere, as with the previously-described phosphor, at a temperature of about 900° C. to 1200° C., preferably about 1000° C. After firing, the resultant mass is crumbled or milled to a desired particle size, although the less the milling, the better will be the phosphor.

The phosphor should then be given a treatment such as the acetic acid or ammonium acetate treatment previously described, to improve its brightness. Such a treatment appears to be less marked in its effect on the manganese phosphor, probably on account of the smaller quantity of oxide in the starting mixture.

Among the other manganese-activated phosphors which exhibit electroluminescence are the cadmium silicate and zinc fluoride phosphors. Electroluminescent sulphide phosphors can also be made in which the zinc is replaced partly or entirely by calcium or strontium.

Figs. 2 to 5 show forms of the invention in which paired long spaced narrow conductors 6 and 7, 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 pointed 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 application is in part a continuation of my co-pending applications Serial Nos. 105,803, 119,021, and 119,022 filed respectively July 20, 1949, September 30, 1949, and September 30, 1949, all of which are now abandoned.

What I claim is:

1. An electroluminescent lamp comprising a first electrode, a second electrode in proximity thereto, and a solid layer therebetween including an electroluminescent phosphor, at least one of said electrodes being a light-transmitting conductive solid material in close contact with said layer.

2. An electroluminescent lamp comprising a first electrode, a second electrode in proximity thereto, and a solid layer therebetween including an electroluminescent phosphor, at least one of said electrodes being a glass plate having a transparent conductive coating thereon of partly reduced stannic chloride, said coating being directly in

contact with one surface of the layer which includes the electroluminescent phosphor.

3. An electroluminescent lamp comprising a first electrode, a second electrode in proximity thereto, and a solid layer therebetween including an electroluminescent phosphor consisting essentially of activated crystals of combined zinc oxide and sulphide and substantially free from any uncombined zinc oxide.

4. An electroluminescent lamp comprising a first electrode, a second electrode in proximity thereto and a solid layer therebetween including an electroluminescent phosphor substantially free from any uncombined low-resistivity crystals.

5. An electroluminescent lamp comprising two electrodes of conductive glass and a solid layer therebetween including an electroluminescent phosphor.

6. The method of making an electroluminescent zinc sulphide phosphor which includes the steps of washing a fired and activated zinc sulfide-oxide phosphor with a solution capable of removing zinc oxide and leaving the sulphide, filtering, and rinsing the remaining undissolved solids with water.

7. The method of making an electroluminescent zinc sulfide phosphor, which method comprises: washing a fired and activated zinc sulfide-oxide phosphor in a solution of a compound capable of reacting with zinc oxide to form a soluble complex oxide-bearing compound of zinc, filtering off said solution with its dissolved zinc oxide complex, and rinsing the remaining undissolved solids with water.

8. The method of making an electroluminescent zinc sulfide phosphor, which method comprises: washing the fired and activated zinc sulphide-oxide phosphor in a solution of ammonium acetate, filtering, and rinsing the remaining undissolved solids with water.

9. The method of making an electroluminescent zinc sulfide phosphor, which method comprises: mixing the fired and activated zinc sulphide-oxide phosphor with a substantially saturated solution of ammonium acetate to form a slurry and diluting the acetate solution until it is substantially pure water.

10. The method of making an electroluminescent phosphor, which method comprises the steps of mixing together with suitable activating compounds approximately 3 parts of zinc sulphide, approximately one part of zinc oxide in order to insure the formation of suitable crystals on firing, firing the mixture, and then immersing the fired mixture in a solvent for zinc oxide to remove uncombined oxide crystals.

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